DOMESTIC ECONOMY

AND

HOUSEHOLD SCIENCE.

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FOR HOME EDUCATION; AND FOR SCHOOL MISTRESSES
AND PUPIL TEACHERS.

BY

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LATE SUPERINTENDENT OF EDUCATION IN NATAL.

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PREFACE.

THE object of this book is to explain the broad principles of the Science of Domestic Economy; a subject which is wisely in process of introduction into the routine of general education.

In all cases in which matters of this practical character are used in the routine work of instruction, it is leading principles, rather than subordinate details, that should be dwelt upon. A manual of Domestic Economy, for purposes of teaching, should be a scientific guide, rather than a modified form of cookery book, or a volume of rules and receipts. At any rate, at the present time, there is more want of the scientific guide than of any addition to the already long roll of books of an opposite kind. The position is, therefore, from the first assumed in this manual that **Domestic Economy** and **Household Science** are connected together by inseparable ties, and that they must go hand in hand.

For the sake of convenience, the text has been cast into separate Lessons, which may be taken each one by itself. This will probably be found of some practical consequence whenever it is thought desirable to employ the volume as a Reading Book in the classes of schools. The work is, however, intended for home-use, as much as for schools; and it is conceived to be especially adapted for pupils who have pretty well finished their course of formal instruction, as well as for the higher grade of teachers. It is addressed especially to women and girls, because these are the arch-administrators of orderly rule in all households; but there is, in reality, scarcely anything in its pages that does not need to be intelligently understood by men, as well as by women.

The entire range sketched out in the Domestic Economy requirements of the Regulations of the Education Department,* is covered by these Lessons; but their subject and sequence have been determined by the necessities of the case rather than by external suggestion. It will hence be found that the Domestic Economy which is dealt with in these pages is an organized and methodical system, inherently connected from beginning to end.

The introductory lesson of the section which is devoted to the Alphabet of the Subject, sufficiently indicates the extent and character of the design.

* Fourth Schedule. New Code of Regulations of the Education Department of the Government.

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DOMESTIC ECONOMY

AND

HOUSEHOLD SCIENCE.

SECTION 1.—INTRODUCTION, AND ALPHABET OF THE SUBJECT.

LESSON I.

DOMESTIC ECONOMY AND HOUSEHOLD SCIENCE.

In treating, for teaching purposes, of that branch of practical knowledge which is called **Domestic Economy**, it is desirable to consider carefully, in the first place, what is implied in those words, and what the various subjects are that may properly be held to fall within the range they cover.

The word **economy** was first used by the intelligent race of men, who lived in the country called Greece, more than two thousand years ago. The term, as they employed it, meant the regulation and management of the household. The word consists of two parts: the **eco** is derived from the Greek word **oikos**, a house, and the **nomy** is also taken from the Greek **nomos**, law, or management. Eco-nomy is, thus, properly house-regulation, or management.

The Romans, who followed the Greeks as the leaders of European enlightenment and civilization, were marked above all things by their reverence for order and law. They, therefore, soon adopted the good Greek word into their own language. But, before very long, being essentially an organizing as well as a law-loving people, the word took a wider meaning in their hands, and implied the orderly regulation of affairs, in the broader relations of the community, and the State; as well as in the narrower ones of the family, and house. Englishmen of modern days have followed the example of the Romans in adopting the word, but, in their turn, have also in some measure changed the sense in which it is employed. In the English language, and by English-speaking people, economy is generally understood to signify both a judicious and careful expenditure of money, and a prudent and unwasteful use of such things as are purchased by it. Economy is thus now held to mean the wise and prudent employment of money, upon an orderly and well-considered plan; and the right and careful use of the various things that are bought with it. In the best English dictionaries, the word is defined to mean, the management and conduct of the general affairs of life, with prudence, thrift, and frugality.

But it is, nevertheless, convenient, that there should be a branch of this science of general good management, which is considered to apply to the family or household in particular; and accordingly, one department of it is distinguished as **Domestic Economy.** The word domestic is derived from **domus**, the old Roman word for a house or home. There is the somewhat awkward circumstance in connection with this designation that the house or home appears, first, as the Latin domus, in the limiting adjective, and then again as the Greek oikos, in the noun combined with it. The whole expression, therefore, amounts to domestic house-management. As, however, the expression has now taken a strong hold upon the public understanding, there is no help for this; and domestic economy must be accepted as the designation of the science which teaches the prudent, frugal, and good ordering of a household; or, as it has been well expressed in some recently published little books, **home-management.**

The first matter which domestic economy must deal with, in this acceptation, is the condition and needs of the living bodies that have to be cared for in human dwellings, or homes. There are certain prime necessaries, as they are called, of life, which are quite indispensable to living beings, and which, indeed, are in some sense provided for them by nature, but which have to be further arranged for when households are formed in accordance with the plans of civilized existence. These prime necessaries of life are **food, water, air, warmth,** and, in all but the most barbarous communities, **clothing.** As human beings advance from the rude to the more civilized and better ordered social state, the providing of these necessaries has to be more and more made a matter of forethought and plan; and when they reach the most advanced condition, of living together in crowded societies, such as are seen in cities and towns, this forethought and plan become of the highest importance. The well-being, indeed, of each member of the family and household depends upon the good ordering of the supply of such necessaries, and the judicious application of their influences. Hence, these are all the proper objects both of the study and the practice of domestic economy, and will have to be fully dealt with, as such, in these pages.

When, however, the household or home is not well managed and well cared for in respect to these prime necessaries of life; the result sooner or later is, that some one member of the family falls into sickness. Indeed, just because homes are ignorantly managed, and ill-cared for, sickness is very commonly met with in them. When sickness comes from this cause, or,—as it sometimes, although much less frequently does, from other causes, which cannot be as easily understood and controlled,—it has to be removed by remedial treatment and nursing, and this must be for the most part accomplished in the home. Good and bad health, sickness and nursing, are also, therefore, matters that have to be dealt with by this particular branch of economy.

When all that relates to the direct necessaries of life, to the maintenance of health, and to the removal of sickness has been attended to, there still remains a large class of other things that have also to be considered in ordering the home. These, although *not prime necessaries of life, are prime necessaries of comfort*, and therefore not to be overlooked in a plan which avowedly regards good order, as well as absolute need.

The furniture and utensils that are employed in the house, the warm bedding and beds, the tables and chairs, the curtains and carpets, and above all, the means and appliances for cooking and cleaning, are prime necessaries of comfort.

Again, in most households it is found necessary to divide the work which has to be done amongst various people, and to have some of these especially trained for certain parts of it; such as cooking the food, cleaning the house, and waiting upon the inmates. The arranging of all this work has to be thought of and planned by the master and mistress, who are the responsible controllers and heads of the house. Thus the duties of servants, their relations to their employers, and their good management or handling, are also matters with which domestic economy has to deal.

Since prudent and frugal, as well as judicious and well-directed, expenditure is involved in the very idea of economy, in the broad English acceptation of the term, **money**, which is the common medium of exchange, and the artificial representative of value, unavoidably presents itself in connection with the subject. Since money has to be earned before it is spent, and should always be turned to good account, and well managed, when it is not spent as well as when it is, there are some points and considerations relating to earning and saving, that require to be especially glanced at by themselves. A distinct section of the book is, therefore, devoted to the spending, earning, and saving of money.

Brief reflection will lead any intelligent person to see that the well-ordering of all these various matters, or, in other words, a good and sound system of domestic economy, can be secured only when there is a competent knowledge of the materials and conditions that have to be dealt with. To mean well is not enough, unless correct and sufficient knowledge goes with the good purpose. Hence, the science which bears upon each branch of the subject requires to be explained; and, in this way, **Household Science**, or the knowledge of the properties, conditions, and relations of the objects that have to be considered and managed, becomes the inseparable companion of Domestic Economy, and runs hand in hand with it.

The lessons which are contained in the following pages will, therefore, not only tell what things are to be done in the good management of a household; but will also explain why they are to be done; and why, in very many instances, they *must* be done, if such management is to be good.

One great point, indeed, which has to be aimed at from first to last, is to get clearly to feel, that a satisfactory scheme of practice in this matter can be arrived at only when the great natural facts, upon which operations are based, are clearly known and apprehended.

It is one important advantage of this method of treating the subject, that it enables a vast and almost unmanageable array of merely dry details, which would be sufficient to fill a large book by themselves, and which are too often unnecessarily and disadvantageously introduced into the routine of teaching, to be omitted altogether. An adequate knowledge of the leading principles, or, in other words, an acquaintance with the science, of domestic economy, at once serves as a trustworthy guide through the innumerable details of practical action; and also enables the whole to be efficiently and intelligently dealt with, upon a general plan.

LESSON II.

ATOMS AND MOLECULES.

The first and, perhaps, most important necessary of living existence is **food.** This food is, however, prepared for the use of animals in a particular way; and is made out of particular things; both of which must be known to a certain extent, before much that has afterwards to be studied, can be properly understood.

But, before considering the *nature of food*, there are certain introductory facts which must be glanced at;

just as it is always found well, that young children should be taught the alphabet, before they are set to read. The alphabet, in this case, relates to the construction of the bodies of living women and men, and to the nature of the several substances out of which those bodies are formed. Some things must therefore be learned concerning these, before the action of food upon those bodies can be satisfactorily considered.

All the material substances of nature, whether living, or dead, are made of little pieces, or parts, just as the walls of a house are built of bricks. But these little bricks, which are used in the construction of the materials of the earth and of living bodies, are very small indeed. They are in reality so small, that it is not at first easy to form any clear notion of their minuteness. Still, there are some ways of looking at the matter which enable this to be done; and it is well that it should be done in the beginning of this work, since it is by such little pigmies of existences, as have now to be described, that so many of the beautiful operations of nature, afterwards to be spoken of, are worked out.

Gold, which is used for the making of sovereigns, is a material substance. Now, when a small lump of such gold is beaten down into thin leaf, like that which is employed in the process of gilding, it is at last beaten so thin that not less than 300,000 leaves can be piled upon each other within the depth of a single inch. Let it be considered what this condition of thinness involves. The little particles, or bricks, of which the gold leaf is built, cannot be larger than the thickness of the leaf. So much is at any rate clear. They must be so small, that 300,000 of them could be laid side by side in a row, within the length of an inch. If it be conceived that those particles are as long as they are broad, then there would be 300,000 times 300,000, or 90,000,000,000 (ninety thousand millions) of them in a square inch of the leaf; that is to say, it would take as many of them as that, laid down side by side, after the fashion of the pavement of a brick or tiled floor, to make up the square inch of the leaf.

A small particle of gold which is as small as this—that is, which is only the 300,000th part of an inch across,—can be quite readily seen by the help of the powerful microscopes that are now employed by scientific men. Gold particles, indeed, can be made so small that they are not much more than half that breadth, or the 500,000th part of an inch across, before they cease to be visible on account of their smallness, with the most powerful microscopes. So small, then, it can actually be *seen* that the little particles are, of which a substance like gold is built up.

But the gold can be broken up by particular means, that men who understand chemistry know how to employ, until each particle, or part, is very much smaller than the least one that can be seen by the microscope; and this, which is true of gold, is true also of every other substance in nature. All can be broken up into particles that are far too small to be seen even by microscopes. Every substance in nature can therefore be made to disappear to the eye, if it be broken up into the minute fragments of which it has been primarily made; and if these several minute fragments be so scattered apart, that no two of them can be looked at, clinging together as one. There are indeed good reasons for the belief, that the smallest particles, of which material nature is built, are at least a quarter of a million times smaller than the smallest speck of shining gold, that can be seen by the help of the microscope.

The several particles, of which all material substances are made, are therefore so small, that none of them can be seen, until a great number are crowded together. But the smallest particle into which matter of any kind can be broken up, although it cannot be seen, can be detected and observed by other contrivances of science. These smallest particles which may, in a sense, be looked upon as the little bricks employed in the construction of material bodies, have indeed a name of their own. They are called **atoms.** That word simply means things which cannot be cut into halves, or divided again. An atom is thus merely a particle of matter so small, that it cannot be again further broken into pieces by any contrivance that is known to man. The atoms of matter are all fragments, or particles, which are *very much too small* to be seen even by means of microscopes. They are things which can be reasoned about, but not individually shown.

There is another word which is constantly used when the construction of the material bodies of nature is spoken of, and which needs also to be well understood. When hard bodies are broken down into very small fragments, and the fragments are again broken down until they are as small as they can be made by grinding, pounding, and other mechanical operations of a like kind, those finely divided parts are then termed **molecules.** Now the word molecule merely means a little mass. A molecule, indeed, is a little mass, or grouping together, of atoms. There may be many atoms, or few, in the mass; and the mass, after it has been formed of this group of atoms, may still possibly be so small that it cannot be seen, and in fact almost always is so. It is only when many molecules are put together into a lump, that the lump becomes visible even with microscopic help. Thus, in the building up of material bodies, atoms are first grouped together into molecules, and these molecules are united together into continuous **substance**, or **mass**. In this way, then, molecules may be looked upon as being the bricks out of which material bodies are made; whilst atoms, in their turn, serve as the bricks for the construction of molecules. Atoms are the smallest and indivisible parts of material bodies; and molecules are groups, or clusters of atoms.

LESSON III.

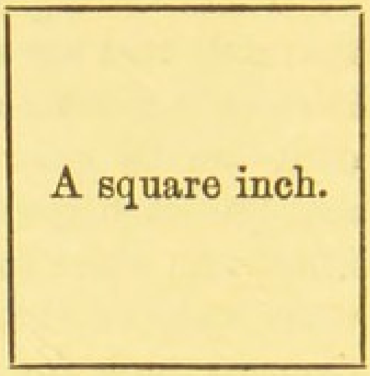
THE NATURE OF AIR.

As men move about on the ground and upon the sea, they are surrounded everywhere by material substance although it cannot be seen. This invisible substance is felt pushing against the face, when the wind blows; it can be weighed in a pair of scales even whilst it eludes the eye; and in reality is rolled quite round the earth as a soft, thick garment, which is familiarly known to the people who live in it and breathe it, under the name of **air**.

Now this invisible air, which is heavy in its way, and substantial, although it eludes the eye, is a ready illustration of the fact already explained, that matter is made up of little particles or atoms, which are too small to be seen when they are scattered loosely asunder. The air is composed of little atoms in just this separated, and widely spread state. The atoms of the air are so widely spread apart that each one of them floats at least many times its own breadth away from its nearest companions or neighbours. In other words, there are comparatively broad intervals, or empty spaces, between them. On this account air is thin and light compared with all other substances on the earth, that are as common and as abundant as itself. It is so light and thin that only a trifle more than five grains of it can be got into a half-pint bottle, although there are 480 such grains in an ounce. If that bottle were filled with water instead of air, it would be found that the water weighed 4280 grains, because it is 800 times heavier than air, bulk for bulk. The same bulk of quicksilver would weigh nearly 52,000 grains; and the same bulk of gold, which is one of the heaviest bodies known, 75,000 grains. Air is nearly fifteen thousand times lighter than gold.

The air which is scattered around living creatures that move upon the face of the earth, extends up from the ground to a very long distance. It rises up into the sky high above the clouds. It is not known exactly how far it goes up, because men have never been high enough to find where it ends. They have, however, climbed up lofty mountains five miles high, and found air there; and they have floated up seven miles in balloons, and found it there also. It is probable, indeed, that the air extends at least forty-five, or fifty miles away from the surface of the earth.

Although, therefore, the air is so thin and so light in itself, it becomes heavy enough when the great height to which it extends is taken into account. If a small square of card, one inch long and one broad, that is, as large as the sketch on the next page, be held in the hand or be laid flat upon the ground, that small piece of card has a weight of fifteen pounds of the thin light air resting upon it. Upon every square yard of ground there lies something more than five tons of air—that is, as much air, by weight, as fifty sacks of coals. Upon every acre of grass land, or of ploughed field, there is pressing down something more than 22,000 tons of this invisible substance. The air, therefore, has a heavy as well as a light side to be taken into consideration.



There is one way, and one way only, in which a bare glimpse of this otherwise invisible substance can be caught by the eye. If the very great depth of it, for the entire fifty miles, be looked into on a clear bright day, when there are no clouds floating in the way, the light, which glances off from the vast array of little particles that crowd on and on behind each other in that upward direction, may be seen, although the particles themselves are not.

The blue sky is, in reality, this glancing light reflected from the deep and not entirely transparent air, just as the greenness of the sea is an appearance caused by looking into the substance of water downwards instead of upwards. When men climb up high mountains, the sky over their heads gets constantly darker and less blue, with each successive stage of their ascent, because there is then less and less of the blue aerial substance to be looked through, and seen by means of the glancing light.

LESSON IV.

THE GASEOUS STATE.

When the molecules of matter float in this aeriform, or air-like, way, a considerable distance apart, so that the intervals or blank spaces between are larger than the spaces that are occupied by the air-molecules themselves, each separate atom is free to roll over and over amongst the rest; and not only so, but is also free to leap farther away from its neighbours, unless it is pressed in upon them by an outer force, that is as strong as its own tendency to move away. In the case of the air, an outside controlling force of this kind is provided in the attraction of the earth. The earth holds its soft outer garment of air pressed closely round its surface of land and sea, by what is termed the **attraction of gravitation.**

The obedience of the air to the pull which the solid earth exerts upon its substance, is its weight, and it is the pressure of this weight that keeps the entire mass of little air-particles from flying away into space. The outer layers of the thin substance press down upon the lower or inner ones, and hold them in their place, although not touching them, just as an outer shell might do. Both the repulsion of the several little particles from each other which strives to make them leap asunder, and the controlling attraction of the earth which prevents them from doing so beyond a certain limited distance, act, however, through an intervening blank space, just as the attraction and repulsion of magnets are seen to do. Magnets attract needles, and repel other magnets like to themselves, when there are considerable blank spaces intervening between. The molecules of air in this particular of repulsion and attraction are like magnets.

When the substance of a body is spread out, by the loosening and scattering of its particles asunder in this thin and air-like way, it is termed, in the language of science, a **gas.** The air is in the gaseous state; but there are sundry other gases in nature, although not found so readily, nor so abundantly supplied, as the air. They all of them agree in the attributes that have been described as belonging to air. They all of them have their minute particles, or atoms, so small and floating so widely apart, that their substance cannot be seen; and in all of them the little invisible atoms that compose them repel one another, and are nevertheless drawn together by the attraction of the earth.

There are two properties, therefore, that at once serve to distinguish all bodies in the gaseous state. They are all *compressible*, and can be made to occupy a smaller space when their widely separated atoms are squeezed in more closely together; and they are all *elastic*, and leap back into their original bulk, as soon as the squeezing in force, or compression from without, is withdrawn. These properties, as they are called, of gaseous bodies, namely, **compressibility** and **elasticity**, are very strongly marked in air.

One immediate consequence of this condition of the particles of the air is, that its substance gets thinner and thinner as it is farther away from the level of the sea, which may be taken as the general position of the proper surface of the earth. When men climb to the top of a mountain, like Mont Blanc, which is a little more than three miles high, they find they have got up through half the substance of the air, that is, as far as its quantity, when estimated by weight, is concerned. One-half of the entire number of air-particles lies within three miles of the earth, and the other half is scattered in the forty-seven or more miles beyond. The extreme limit of the air would be found where the outward repulsive play of its particles is just balanced by the power with which the earth draws them together, in the opposite direction. Where that occurs, the particles form a definite surface of air, in some measure like that of the liquid surface of the sea; and at that surface the air-substance surges up and down, just as the waves or billows of the sea surge up and down on the outer surface of the water.

The loosened arrangement of the particles of the air, (scattered widely asunder as they are in the way which has been described), is a direct provision for one of the chief offices that this soft outer garment of the earth has to perform. The living creatures that dwell upon the surface of the earth, and that are there closely surrounded by the air, have their bodies made of various substances which are always in a state of what is termed decomposition, and of change; that is, they are always taking new particles in, and throwing old particles out. As will shortly be seen, all the operations of life are of this character of unceasing and never-ending change. It will be readily understood, therefore, how serviceable for these operations, involving incessant change, must be an abundant supply of a substance the molecules of which are already loosened asunder, and floating apart; and in consequence, ready to move in any direction in which they can best be turned to account.

The readiness with which the loosely floating molecules of the air rush about for the performance of this appointed task, is shown in the free and unceasing movements of the wind. The wind is always blowing, either in gentle streams or in violent gusts. The wind is, in reality, the rushing along of the molecules of the air, in currents or in eddying whirlpools. In all cases, the blowing of the wind is sustained by the readiness with which the loosely scattered molecules of the air can roll about amongst each other.

LESSON V.

VITAL AIR, OR OXYGEN GAS.

THE air-substance, which is rolled, as a loose soft garment about the earth, to enable the life of organized structures to be maintained and worked out, is formed of a number of exceedingly minute atoms which cannot be seen, but which nevertheless cannot escape examination in another way. By such an examination, indeed, it is found, that there are two quite different kinds of these invisible atoms associated together, to constitute the air.

That there must be these two altogether different substances in the air, can be easily proved by a very simple experiment. If a short piece of burning candle be placed in the middle of a flat dish of water, and a bell-shaped glass, or jar, be placed over it, so that the lower edge of the jar rests in the water; it will be found that the flame of the candle shut up under the jar, at first begins to burn dimly, and then after a little time goes out. When it does so, however, it will be seen that the water from the dish has risen up one-fifth of the way into the jar, to take the place of so much of the air as has been consumed, or got rid of, by the burning of the candle. The air was thus obviously made up, in the first instance, of two parts; of a small part, which enabled the flame of the candle to be sustained, and of a larger part which extinguished the flame.

That portion of the air, which is able to sustain the burning of a flame, is called "vital air," because it can sustain the life of an animated being, as well as the burning flame. A mouse, for instance, could live and breathe in that imprisoned air as long as the candle can burn, but would have its life quenched in the same way as the flame of the candle, when all the vital air was consumed. The word "vital" is derived from the Latin **vita**, which signifies "life." Vital air, simply means that kind of air which is able to sustain life through the operation of breathing.

But another name is also given to this vital air, which is so commonly used that it requires to be known. That name is **oxygen gas**. The word oxygen, which is derived from the Greek language, implies that under certain circumstances this gas is a maker, or generator, of sourness. The word was selected by the chemists who discovered this important peculiarity, and it has now become fixed by mere custom. Oxygen is a "gas," because all that has already been said about the atoms of air is also true of it. It is composed of a number of minute, quite invisible atoms, floating relatively far apart, and possessing the properties of compressibility and elasticity.

Oxygen is one of the most important bodies in nature, and a little pains must therefore be taken to make sure that its character and qualities are well understood. There are many different kinds of atoms in nature, as will presently have to be more fully shown; the oxygen atom is but one of these many: but it is by far the most abundant and, indeed, important of them all. It has been estimated that if the earth and the air could be together weighed in a huge pair of scales, one half the weight that was so found, would belong to oxygen alone; and the other half would have to be divided amongst the many other kinds of atoms.

Oxygen, partly on account of its abundance, and also partly on account of another peculiarity to be further examined almost immediately, is found, fixed in most of the solid substances of the earth that come under notice;

that is to say, the gas is compressed in amidst their solid parts, as one of the constituents of their structure. Thus, for instance, there is a white salt that can be bought at the chemists under the name of **chlorate of potash**, and that is made up of a number of little flat white crystals. About two-fifths, by weight, of the substance of these crystals, is oxygen; and if a quantity of them be placed in a glass tube, or flask, and heated over a flame, the oxygen pours off from them, in its proper state of gas. It can be so caught in abundant streams in another bottle, first filled with water to keep out the air, and then whelmed over the end of a tube so arranged as to lead the oxygen from the flask. Oxygen is procured, in this way, by heating chlorate of potash, when it is required by itself for the purpose of examination, or experiment.

The leading characteristic of this abundant substance is that it is one of the most active and energetic bodies in nature. Its little molecules leave hardly anything alone, they combine readily with all the other different kinds of atoms, save one, and make substances of an almost endless diversity by the union. Thus, for instance, if a piece of bright iron be placed in moist air, it soon becomes covered all over its surface with red rust. That red rust is formed by the mingling of the atoms of the oxygen contained in the air, with the atoms of the iron. If the grains of rust be scraped away, the pure oxygen can be got back out of them, just as it is from the white crystals of chlorate of potash. The iron is corroded, or consumed, by the oxygen and turned into rust. And just in the same way, almost every substance in nature is capable of being rusted, or consumed, by oxygen.

The activity of oxygen then, as an agent in the operations of nature, is primarily shown by the large range of different substances that it can meddle with in this corrosive way; in other words, by its power to take up from them their atoms, and to mingle those atoms in a close and intimate connection with its own. But the **energy**, or eagerness and strength, with which it does this, is otherwise manifested. Whenever it does join its own atoms with those of some other kind of body in a close union of this kind, it produces **heat**; and sometimes the union of the atoms goes on so fast, and the heat which is produced is so great, that the heated particles burst into shining incandescence, or flame. This really is what occurs in the fires that are burned in fire-places and grates, and in the lamps and gas flames that are employed in illuminating streets, shops, and houses. In all these instances, the burning is due to some of the oxygen contained in the air uniting with the molecules of the coal, the oil, or the coal-gas, with intense rapidity, and consuming them in the act. The more rapid the union of the different kinds of atoms, the greater is the heat, or the light. The production of heat and light, therefore, becomes a very good sign, or expression of this leading characteristic of oxygen, its energetic power of combining itself with other things. It will hereafter be seen that it does very much the same for the bodies of living animals that it does for coal. It consumes them by uniting its atoms with theirs, and produces heat by doing so; and this is the reason why the bodies of living animals are warmer than the air by which they are surrounded.

It should here, however, be understood that it is not only when oxygen unites its atoms with those of other bodies that heat is produced. Heat is set free whenever two different kinds of atoms, whatever they may be, are united together, or, as it is properly termed, **combined** to make up some new compound substance between them. But union of this kind is so much more frequent in the case of oxygen, on account of the great abundance of its free atoms in the air, and on account of the readiness and energetic force with which it enters upon the work, that it has come to be looked upon as the great promoter, or supporter of burning, for the production of heat and light. And, indeed, it is the great agent of the chief part of the restless changes that are going on in the various operations of nature, and especially of those which are connected with the maintenance of life. It is therefore that such a vast reservoir of it is kept in a free state always on hand, and ready for work, in the air.

The only other things that need be, at present, known about oxygen are, that it is nearly of the same weight as air, and that it is without taste or smell. It is a small trifle heavier than the air, which it helps to form; that is to say, a pint bottle would contain nearly a quarter of a grain's weight more of oxygen than it does of air. It will at once be perceived how necessary it is that oxygen should be without taste or smell, when it is remembered that living animals are plunged in it throughout their lives. It would be very tedious and unpleasant for women and men if they were always tasting one taste and smelling one smell, as they would of necessity be if the oxygen, which is so incessantly pouring into their mouths and noses, were different from what it is in this particular.

LESSON VI.

UNVITAL AIR, OR NITROGEN GAS.

It has been seen that the great bulk of the air, that which is left when the vital air or oxygen is taken away by the flame of a candle, both puts out the flame and extinguishes animal life. That larger portion of the air is, on this account, called "unvital air." A more learned name for the same thing is "Azote," and is the one by which it was designated in the first instance. The word is derived from the Greek language, and means properly the "depriver" or "destroyer" of life.

But another name, which was adopted by chemists for purposes of convenience, has become attached to this unvital, or suffocating portion of the air, and is now generally used. It is called **nitrogen**, and this name is also derived from the Greek. It only means a producer or generator of the salt termed "nitre."

The nitrogen contained in the air is also a gas made of little movable particles scattered widely asunder, and floating about easily with broad spaces between. But the atoms of nitrogen appear to be as unlike as possible to the atoms of oxygen. They are indifferent and unwilling to combine with other kinds of atoms, instead of being eager to do so, and if, by any particular influence, they are constrained to unite with other bodies, they escape again from the union as quickly as they can, and return to their free roving state. If bright iron be plunged into pure nitrogen gas instead of into oxygen, no red rust appears on it. Bright iron will remain unrusted and uncorroded in nitrogen, for any length of time.

The contrast between the natures of oxygen and nitrogen is very strikingly brought out by the fact, that whilst the list of the different kinds of substances which are made by the union of oxygen with other kinds of atoms is so long as to amount to many hundreds; there are only four natural compounds, unconnected with the operations of life, of which one is the salt called nitre, that are formed by the union of nitrogen with other simple bodies. Another consequence of this important difference is, that the great bulk of the oxygen contained upon the earth is in a state of close and fixed union with other bodies; and that the part of it which exists free and uncombined in the air, vast as that is, is only a small portion of it when compared with the rest. Whilst, on the other hand, the principal bulk of the nitrogen which is contained on the earth exists in a free and uncombined state in the air, and only a much smaller part of the whole is in combination with other bodies.

The air, then, consists of two distinct kinds of gases, oxygen and nitrogen, mixed up together in the proportion of about one part of the former to four parts of the latter; or, more exactly, in the proportion of twenty-one parts to seventy-nine parts by measure; or of eight parts to twenty-eight parts by weight. If a piece of phosphorus instead of a candle-flame be burned in a jar of air, all the oxygen is taken away by its burning, and the nitrogen is left alone and nearly pure. Nitrogen is commonly procured for the purposes of examination and experiment in this way.

But when oxygen gas and nitrogen gas are mixed together to form the air, the mingling is such that their atoms float loosely and freely about amongst each other. They are not united together, or combined. The atoms of the one kind of gas roll freely about in the intervals that lie between the atoms of the other kind. The spaces or intervals between the several atoms of either kind, are so spacious that there is abundance of room for both, without any need for their being forced into close neighbourhood or contact.

The result, however, of the mingling in of so large an amount of the lazy and indifferent atoms of nitrogen, with those of the lively oxygen, is, that they act as a kind of clog or damper upon the energies of the latter. In all such matters as the burning of fires and flames, the process is performed four times more gently and slowly in air, than it would be in oxygen which had no nitrogen mingled with it.

Nitrogen, therefore, may be looked upon as the indifferent, or inert, element of nature. But it must be understood that this applies only in the case of the part which it plays in its uncombined state, and whilst it contributes to form the air. The mistake is sometimes made of speaking of it as indifferent and inert in all its relations. This, however, is not absolutely true; in certain combinations which it is compelled to form it is very energetic indeed. Some of the most deadly and dangerous poisons, for instance, that are known, are constructed by its help, and so again some of the most violent explosions depend upon its presence.

This most noteworthy peculiarity of inertness, however, is manifested in most instances in which nitrogen is forced to combine. Various compounds of nitrogen are formed by the action of living structures upon its little atoms. Although only four compounds containing nitrogen are known in what may be called the dead or inorganic departments of nature, there are a great number of compounds formed by its help in the structures that belong to the living domain, and that are made through the operation of life. This inertness of nitrogen is constantly exhibited in the building-up processes of living bodies.

Nitrogen gas is quite as destitute of taste and smell as oxygen, and for the same reason. It exists, as has been seen, very abundantly in the air, and the air, which is composed of it and oxygen mingled together, is without taste or smell. The weight of pure nitrogen gas is almost exactly the same as that of air. A half-pint bottle can contain a little more than five grains' weight of it.

LESSON VII.

C LIGHT INFLAMMABLE AIR, OR HYDROGEN GAS.

If a small quantity of iron filings, or of broken pieces of iron wire, and a little oil of vitriol (sulphuric acid), be put into a bottle of water, bubbles almost immediately begin to rise, and to pour up through the water in continuous streams. These bubbles are caused by a gas which is set free in the water; and if a piece of lighted paper, or a burning match, be brought near to the neck of the bottle when the bubbles are rising rapidly, it will be found that the gas which is escaping out of the bottle in a stream will burst into a flame. The bubbles, therefore, which rise through the water, are bubbles of inflammable gas, and this inflammable gas is produced out of the water.

The fact simply is, that water is made of inflammable gas, mixed up with another kind of substance; and that that second ingredient of the water is neither more nor less than oxygen. As the inflammable gas is formed, the iron filings, or wire, first get rusted by the oxygen, which is also set free, and then the rust is dissolved away in the acid.

The inflammable gas, which can be procured out of water in this way, is called **hydrogen** gas. The word hydrogen, which, like the other names of this class, is derived from the Greek language, means, indeed, the producer, or generator of water. Hydrogen is mingled with oxygen in a certain definite proportion to form this familiar liquid. Water can, in fact, be actually manufactured by the close uniting together of hydrogen and oxygen. If hydrogen and oxygen gases be mingled together in a strong glass jar, in the proportion of two measures of hydrogen to one measure of oxygen, and the mixture be set light to, or an electric spark be passed through it, a loud explosion is heard, and, on the instant of the explosion, both the gases disappear, and only a few drops of water remain in their place. The water is formed by the union of the atoms of oxygen and hydrogen.

Hydrogen, which is in this way procured out of water, by the separation of that liquid into the constituents of which it is formed, is in the gaseous state like oxygen and nitrogen; that is, it is formed of very minute invisible particles floating loosely and widely asunder. But this hydrogen gas has a very much thinner substance than either oxygen, nitrogen, or air. It is indeed so thin and light, that the quantity of it which can be contained in a half-pint bottle weighs only a trifle more than a quarter of a grain, instead of the five grains which the same bulk of air would weigh. Hydrogen gas is fourteen times lighter than air, and nearly 12,000 times lighter than water, bulk for bulk.

The separate atom of hydrogen is, in fact, the lightest body that is known in nature. It has been very carefully weighed, although it cannot be seen, and on account of its surpassing lightness, it has been taken by chemists and men of science to represent the unit or standard of weight. Thus, it is said that each atom of oxygen weighs sixteen atoms of hydrogen, and each atom of nitrogen twenty-eight atoms of hydrogen.

On account of its great lightness, this hydrogen gas is used for filling balloons which are intended to float up into the higher regions of the air. It is not, however, the pure form of the gas which is employed, but an impure and mixed form which can be procured from ordinary gasworks at less cost, and which, although not so light as the pure gas, is still light enough to do what is required of it.

Hydrogen burns as a flame, because oxygen seizes upon it at a high temperature, and unites energetically with it When a jet of hydrogen gas is lit in a burner, the hydrogen which comes out of the opening is combined with the oxygen contained in the air around, and light and heat are produced in the well-known form of flame.

The characteristics which distinguish this third kind of gas are, therefore, its lightness, its power of burning, and its ability to produce water when, in burning, its atoms are intimately combined with those of oxygen. As, for purposes of familiar illustration, oxygen and nitrogen are commonly termed vital and unvital air; hydrogen may also be spoken of as light inflammable air.

It appears probable that when water is formed by the union of oxygen and hydrogen, one atom of oxygen seizes upon two atoms of hydrogen, and that these three atoms are grouped together in a very close embrace as a compound molecule, which, thenceforth, becomes the molecule, or ultimate particle of water. It is this kind of union of unlike atoms together in a close embrace to form compound atoms, or molecules, which is termed chemical union, or **chemical combination.** Chemical union is at once distinguished from a mechanical mixture by the fact that the new compound body, which is formed by the combining of the separate elements, ceases to be like either of them, and acquires a new and distinct character of its own. Thus, water will not support the burning of bodies and flame as oxygen does, and it will not burn as hydrogen will; yet it is made of those two gases, oxygen and hydrogen, and of nothing else. And so, again, the water is a comparatively heavy and visible liquid, whilst both the oxygen and hydrogen are light and invisible gases. This may be very instructively compared with the condition of things in air. In air, the two primary gases, the oxygen and the nitrogen, are loosely mingled and not chemically combined, and therefore the properties of both the oxygen and the nitrogen, the flame-and-life-sustaining power of the one, and the softening and sobering-down influence of the other, are still found in air.

Water, then, it will be understood, is simply a chemical combination of the two gaseous bodies oxygen and hydrogen, in the proportion of one part of oxygen and two parts of hydrogen, if estimated by measure; or of eight parts of oxygen and one part of hydrogen, if estimated by weight.

LESSON VIII.

THE NATURE OF WATER.

Water, which is formed by the union of the gases oxygen and hydrogen, is one of the most beautiful and useful of the products of nature, and, at the same time, one of the most abundant. Its leading characteristic is that it is liquid, or can flow. It can do this because the little molecules of which it is made are not bound tightly together, as the several molecules are in a lump of metal, or a piece of stone, or, indeed, in a fragment of ice. If a piece of ice be laid upon the ground, it remains where it is placed so long as it is very cold. But as soon as it is warmed, it is melted into water, and then the water runs down all round, and flows away upon the ground. This is merely because, when the ice is melted into water, the little molecules of which it is composed are so far loosened asunder that they can begin to slip and slide over each other. The molecules which are at the top are then dragged down to the ground over the lower ones, by their own weight.

Liquids, such as water, therefore, agree with gases and air in the circumstance that their little molecules, or particles, are not bound immovably together, but are free to roll about over each other. There is, however, this important difference in the two kinds of substance. In liquids the several molecules are not widely scattered apart, but are near together, although not so near as to be firmly bound to each other. It is because its little molecules are so much nearer together, that water is 800 times denser and heavier than air. There is 800 times as much material substance squeezed within a given space in water as in air. It is also for this reason that liquids can be seen. Although they are made of a vast number of exceedingly minute, and invisible, particles, or parts, a considerable number of these particles are grouped in such close neighbourhood, that the many form masses, or lumps, large enough to be seen.

Water, however, can exist in three distinct conditions, or states. It is a **liquid** at the ordinary temperatures of the air; but when very cold, it is turned into **ice**; and when very hot, it is converted into **steam**. The only difference in these three conditions, however, is that the molecules are closer together in one form, and farther apart in the others. In ice, the little particles are squeezed so closely together that they cling firmly to each other, and make a hard, solid, and immovable mass. In water, the little particles are just so much apart that they can slide about easily over each other without getting really asunder. In steam, they are so far apart that they float many times their own breadths away from each other, and cease to be visible; exactly as is the case, for the same reason, with the atoms of air. In steam the little molecules are so far apart that its substance is 1700 times thinner and lighter than that of water. Or, in other words, in steam the same weight of substance is expanded into 1700 times larger bulk. The water which can be contained in a half-pint bottle weighs half a pound, or 3840 grains. The steam which can be contained in the same bottle, weighs only a trifle more than two and a half grains. Ice really is solid water, and steam is water in the vaporous, or gaseous state. This change of state, from the mere application of heat, is well illustrated in water, because both the ice and the steam are so familiarly known. But the change is not peculiar to water. Nearly all the solid bodies of nature are capable of being first melted, and afterwards of being turned into vapour, if heat enough be used. Iron is melted by the heat of the furnace of the foundry, and even the stones of the earth are turned into molten lava by the heat of the volcano.

Another property which water possesses is of very great importance in the arrangements of nature. It is able to turn various other bodies, that are solids themselves, into a liquid state like its own, as soon as it comes into contact with them. Thus, if a lump of white sugar be placed in a glass of water, the sugar entirely disappears, its own particles being so loosened apart that they are all scattered and mingled in with the particles of the water. The sugar, however, is not destroyed, although it ceases to be seen. It can be still tasted in the water, and indeed can be got back from it unchanged, if the water be all steamed off by heat. There are very many other bodies which behave in exactly the same way; and with all of them, the same fact applies, namely, that they are not changed in their essential properties when they are dissolved in water. This indifference of water to the bodies which it dissolves, or this disinclination to alter them in any material way, even when it mingles itself with them so closely as to make them for the time liquid, and capable of flowing in streams like itself, is a very remarkable fact. This, indeed, is the peculiarity which so admirably fits water for some of the useful offices it has to perform, as will abundantly appear presently when those offices are described.

The inability of water to stand still, unless when it is confined in cavities or vessels; or, in other words, its tendency to run along in streams, and down sloping surfaces in the effort which its little loose molecules make to roll as low as they can get, is also another of its important characteristics. It is the chief reason why water is found almost everywhere over the earth. When the rain descends from the clouds upon the hill tops, it runs down the hill sides, gathers into rivulets in the valleys, and then courses along as rivers, until it reaches the basin of the sea. All this follows from the simple circumstance that water is liquid, and cannot stand upon the ground like solid masses, or stones.

Pure water, like air, is entirely destitute of taste and smell, and is, on that account, the better fitted to play its part of a neutral and indifferent carrier of other things. It is also transparent and clear, and, on account of its look of pure crystal, is one of the most beautiful of the more abundant products of nature. It does not occupy so vast a space as the air; but there is more of it than air, if its quantity be estimated by weight instead of by measure. Nearly three-quarters of the surface of the earth are covered by the basins of the liquid sea, and in many parts the water goes down in those basins to a depth of certainly more than five miles.

LESSON IX.

CARBON, AND CARBONIC ACID GAS.

NEARLY allied to the three gases thus described, on account of the important part it plays in helping to make the structures of organic bodies, is another substance, which is much more easy to understand, because it can be at once seen by the eye and felt by the hand. This is the solid black body which is familiarly known as **charcoal**, and which also bears the less common, and somewhat learned name of **carbon.** Both of these names, however, are very near to signifying the same thing. The word carbon is but a slightly changed form of the old Latin word for coal; and charcoal, it will be at once perceived, is simply coal which has been charred or half-burned.

This common black substance is visible to the eye, instead of being invisible as the air and gases are, because it is itself solid and not a gas at the ordinary temperatures which occur upon the earth. That is to say, in its natural state, the little atoms of which it is composed are so close together that they are able to cling to each other in a lump, instead of sliding or rolling about amongst each other, as the several molecules or atoms of water and air do. A great number of them also are so grouped together, that they are able to be seen as a connected mass.

But the lump of carbon, or charcoal, thus formed has this very remarkable peculiarity, which at once distinguishes it from the other solid substances met with upon the earth. It cannot be melted by heat into a liquid state, as most of those bodies can. Stones, it has been seen, are turned into soft paste or liquid lava, by the heat of the burning mountain. Lead, it is known, may be easily melted over the fire, until it can be poured out in streams like water. Iron is fused in the same way in the furnace of the iron foundry; and silver and gold are, in their turn, liquefied in the crucibles of the goldsmith. Charcoal, on the other hand, keeps solid under the same circumstances, and remains so in the fiercest furnaces in which it can be put. It turns red hot and shines with a bright glow, but it does not melt. It keeps its proper form of a solid lump, whatever the intensity of the heat. It therefore furnishes a very remarkable exception to the otherwise general law that all solid substances may be melted into the liquid state, if heat enough be used.

Now this obstinate black substance which is thus proof against the softening powers of heat, shows its stubborn resistance in yet another way. It is proof likewise, so long as it remains cold, against the energetic activity of that oxygen which is so ready to consume and corrode most of the solid substances it comes into contact with. If a piece of black charcoal be placed in a jar of pure oxygen gas, it will remain there unchanged for any length of time, just as it does when exposed to the air. It also remains unchanged if it be plunged into water. It neither corrodes in the water, as iron would do, nor dissolves in it after the fashion of a lump of sugar. As soon, however, as the piece of charcoal is made red hot in the midst of oxygen or air, a most important change occurs in its condition. It is then corroded away by the oxygen, very much more rapidly than iron when it is turned into rust. The red-hot charcoal is seized upon by the oxygen with such impetuosity as to be carried away bodily. Two little atoms of the oxygen lay hold of one of the atoms of the charcoal, and fly away with it; and more atoms of oxygen then come for more atoms of carbon, until the whole of the charcoal has been snatched entirely out of sight.

The charcoal, nevertheless, is not *destroyed;* and it is by no means a difficult task to ascertain what has become of it. If a small piece of charcoal be made red hot, and be then shut up within a glass jar, or bottle, of air, and burned in it, one-fifth part of the air, that is its oxygen, is taken up by the charcoal, exactly as in the case where phosphorus, or the flame of a candle is burned under a bell-glass receiver. But it is found that something else, which is equal in bulk to the oxygen taken away, is returned into its place; and that this new product is a gas, transparent and invisible, like the air, or the oxygen, but distinguishable from both by certain essential characters of its own, which may be easily marked.

The new gas, which is thus made when charcoal or carbon is burned in the air, is called **carbonic acid gas**; because, in the first place, it has a slightly acid taste, and in the second place, it is made out of the carbon. The gas can be collected pure by itself with proper management, and is then found to be possessed of remarkable properties. It is half as heavy again as air, and can on that account be poured through air, just in the same way as water may. In consequence of its weight, the half-pint bottle, which would hold five grains of air, will contain quite eight grains of this heavier substance. It extinguishes flame and animal life, after the manner of nitrogen, and, like nitrogen, will not itself burn. But it is soluble in water, which nitrogen is not; that is to say, large quantities of the gas can be dissolved away in water, as sugar may be, until it is only known to be still in the water by the slightly acid taste which it confers upon the liquid A half-pint of water will readily dissolve its own bulk of this gas, that is, as much as the eight grains which can be contained in a half-pint bottle. The gas, which escapes in bubbles when a bottle of aërated water, or, as it is sometimes called, soda water is opened, is carbonic acid gas.

Carbonic acid gas is heavier than oxygen, or air, for a very good reason. Notwithstanding its clear transparency and gaseous form, it actually has a considerable amount of the heavy black carbon hidden or stored away in it. This then is what has become of the carbon. When in its red-hot state, its particles are seized by the oxygen. They are changed by the touch into the gaseous form. Every little group of two atoms of oxygen with one atom of carbon in their fast embrace, forms a compound molecule; and several molecules of the same compound kind then float wide apart, in the elastic state which has been described as being the condition of a gas. Each of the little molecules, although made up of three atoms pressed closely together, is still very much too small to be seen, and is also many of its own breadths away from its nearest neighbours; and so the compound gas is transparent and invisible, just like the simple gases oxygen, nitrogen, and hydrogen, or like air. Carbonic acid gas is sometimes familiarly spoken of as **fixed air** on account of its weight and of its tendency to become fixed in various other kinds of solid substances, such as potash, and soda, and lime. It is also occasionally, and still more expressively, called **choke-damp,** because it is the heavy vapour which sometimes suffocates miners at their work in the coal-pits, when it is suddenly poured out from the coal seams in large quantities.

The great characteristic of the black substance called carbon is, therefore, that it is a *solid* body at the ordinary temperature of the surface of the earth, and that when exposed to great heat, instead of melting into a liquid, as most other solid bodies do, it keeps its form and turns red hot. When it is red hot, it is gradually converted into a transparent and invisible gas, not because its own particles are loosened and spread wide apart by the heat, as happens when water is turned into steam; but because they are seized upon by the atoms of oxygen surrounding them in the air, and so changed into the new state of gaseous expansion by the combination of the particles of the solid with the particles of the gas. The gaseous oxygen transforms the dense solid into its own transparent and invisible state by uniting with it.

But when atoms of red-hot carbon are united with atoms of oxygen, in this way, to form the compound gas, the further consequence is that so much heat is produced by the union as to enable more and more carbon to be turned red hot, and so brought into the state fit for continuing the same process. After the process has once been fairly started, the carbon goes on burning in consequence of the high temperature, necessary for the maintenance of the action, being in that way furnished.

LESSON X.

THE ELEMENTS OF LIVING STRUCTURES.

Carbonic acid gas is thus the first instance that has had to be noticed of a **compound body** existing as a gas at the ordinary temperatures of the earth's surface. The other three gaseous substances which have been separately described are all simple bodies, or, as may perhaps be still more expressively stated, **elementary**

bodies. An elementary body, in the correct and scientific meaning of the term, is one which is simple in itself, and not formed of different kinds of ingredients, or elements, put together.

The word element is derived from an old Latin term, which was first employed by the Romans to express the ultimate things, or original materials, out of which they conceived all nature to be made. They thought that four ultimate or elementary bodies of nature were employed in the fabrication of all other kinds of substances, and that these were **earth, air, fire,** and **water.** It is now known that none of those four things are elements in the sense which was intended. But the term is a very convenient one, and has been seized upon by scientific men of more recent times to express the various ultimate substances, or different kinds of bodies, which are now known to be used in the building up processes of nature.

Carbonic acid is not an elementary body, or an element, because it is built up of two separate and distinct ingredients, namely, oxygen and carbon. Water, again, is not an element, because it too is formed by the combination of two substances, oxygen and hydrogen. But oxygen, nitrogen, and hydrogen gases, and the black solid carbon, are each and all elements in their own right. They are all elementary bodies, which can by no means be further separated, or resolved into components different from, and simpler than, themselves. The final atoms of these four bodies, oxygen, nitrogen, hydrogen, and carbon, cannot be split up into smaller parts, as the separate molecules of water and carbonic acid are when they are loosened and resolved into the atoms of carbon, oxygen, and hydrogen, of which they were severally made.

The four bodies which have thus been enumerated and described, namely, the gases oxygen, nitrogen, and hydrogen, and the solid carbon, are all elements, which are employed in the construction of the material fabric of the earth. They are not, however, the whole of the elements that are used for this purpose. It is now known that there are in the materials of the earth something like **sixty-six** elementary bodies, or substances, that cannot be broken up into yet simpler ingredients, instead of only four. The four which have been especially dwelt upon are, however, upon the whole, of more importance than all the rest. They are the substances upon which chiefly fall the responsibility and work of enabling the earth to support its astonishing burthen of living creatures. They are the materials of which by far the larger part of the bodies of such living creatures is fashioned.

Thus, for instance, in the case of the body of a living man, which weighs about 154 lb., fifteen of those pounds would be taken up by the bony parts forming the skeleton. These are principally made of a hard earthy substance, containing a large quantity of lime, and which, in consequence, should scarcely be included amongst the actively living structures. The hard bones of the skeleton are merely the framework to which the more vital parts are attached, in order that they may be conveniently carried about. If, then, the weight of these bones be deducted, there remain about 139 lb. of living substance to be taken account of. But of these 139 lb., certainly as much as 136 are altogether composed of the four chief elements, carbon, nitrogen, hydrogen, and oxygen! The remaining three pounds, with as much as 10 lb. of the bones, are made up of other less important elements.

Of those secondary, and less important elements, also drawn upon for the construction of living creatures, seven are of the nature of metals, and four of an unmetallic nature, one of these last being a gas, and two the well-known substances phosphorus and sulphur. These secondary elements are all, however, employed in relatively small quantities, a little here and a little there, according to the work that has to be done, and are mingled in with the larger amounts of the more important elements. The four most abundant elements are the agents relied upon by Nature for the important processes that are connected with the operations of life. It is necessary to make a close acquaintance with them, therefore, if anything is to be accurately known either about our own bodies, the bodies of animals, or the structures of plants.

The names of the eleven subordinate elements used in the construction of vegetable and animal substances are: chlorine gas, phosphorus, sulphur, fluorine, potassium, sodium, lithium, calcium, magnesium, silicon, and iron. The last seven in this list are metals.

SECTION 2.—FOOD, COOKING, AND DRINK.

I.—Nature and Action of Food.

LESSON XI.

THE NATURE AND USE OF FOOD.

The most important of the prime necessaries of life to all animals, and therefore to human beings, is **food**. Everyone is practically aware of this. Everybody knows that the human being must be fed from day to day if it is to be kept alive, and that, if it be not fed from day to day, it dies of starvation. It is not everyone, however, who is aware of either the value or the extent of the service that is performed by food.

In the first place, the living human body is a machine; and a machine of the most elaborate and perfect construction, which accomplishes a large amount of work. It carries itself about, it moves, feels, and thinks, and over and above this, it accomplishes all the manifold tasks that are seen going on in the world, as efforts of human industry and skill. All these things are done by the moving machinery of the body, quite as much as the heavy train upon a railway is carried along by the machinery of its steam engine.

But in all cases of acting machinery, work can be accomplished only so long as the forces of the machine are sustained, or, as it were, fed by fuel. The engine that drags the carriages upon a railway, has a truck attached to it, which is loaded with black coal. That coal is shovelled from time to time into the furnace of the engine, and it is the consumption of that coal in the fire which makes the steam from the water in the boiler, and drives round the wheels resting upon the railroad. If no more coal were shovelled upon the fire, the movements of the machinery would very soon stop, and the rolling wheels come to a stand.

Exactly the same thing takes place in the living human body. The movements of its acting machinery are sustained by fuel, which has to be constantly supplied in fresh quantities at short intervals. The fuel of the living body is food.

But there is this notable peculiarity in the case of the living machine or engine which at once marks it out from the dead one. A considerable part of the fuel, or food, that has to be furnished for the support of its power, is, in the first instance, turned into the very substance of the body, and is afterwards used for the production of its various activities and movements. The engine itself is consumed by its own work, but is re-made, or renewed, as fast as it is consumed. By this contrivance the very admirable result is secured of keeping the machine in good order and perfect repair, so that it never fails, for an instant, to perform its proper work. When a steam engine gets wrong, it has to be stopped in order that the faulty parts may be taken away, and new ones put in their place; but in the living machinery, this could not possibly be done. To stop the movements of some of its parts would be to stop the living action of the whole, or, in other words, to stop life itself. Thus, the constant beating of the heart, which is one of the most important movements of the living machine, must go on without a pause from the beginning of life to its end. Each human heart has to beat before it is worn out, and its movements are stilled, seventy times every minute, 4200 times every hour, more than 100,000 times per day; and this 365 times over every year, for as many years as life may last. During all this time the wear caused by the heart's never-ceasing movements has to be made good, and that repair has to be carried on even whilst the movement is continued. All this is accomplished by repairing the heart as fast as it is worn. The heart is made new or renovated, from hour to hour, and from day to day, by the fresh food that is put into it; and so, with all other parts of the living machinery, which, like the heart, are kept in energetic and unceasing activity.

But there are some operations performed in the living machinery of a human body which are not maintained by the consumption of its substance. Those operations are carried on much more upon the plan of steam machinery, which is not alive, that is to say, in which fuel, or food, is directly consumed without having first been made a part of the living frame.

Food thus answers two distinct purposes in the living animal economy. It repairs the waste of the acting and moving parts, by continually renewing their substance, and so enables them to be unceasingly employed in their proper work; and it also serves as material which can be otherwise turned to account, very much as oil in a lamp is used for the production of light, or as coal in a steam engine is employed for driving the rods and wheels of which it has never and could never itself form any part.

A third use which has to be made of the food, for a period of several years at least in the case of human beings, is that it has to be employed for enlarging the size of the body. For nearly a third part of a human life the body grows larger from day to day. Each human being is first a small infant carried about in the nurse's arms, and weighing not many pounds. But after twenty years, it is a full-grown adult, five or six feet high, and weighing, perhaps, 150 or even 180 pounds. All this additional size is built up during the course of those years out of the supplies of new substance furnished in the food; and this is done whilst the renewal of the wear and tear of the growing body, and the support of its various activities and movements, are, at the same time, provided for.

But, since one of the purposes of food is to build up, and keep in a state of completeness and repair the various structures of the living body, it at once becomes apparent that, whatever the materials which are used in the building of those structures may be, each and all must also be contained in the food. The body gets its substance out of the food, therefore the food must contain the substance of the body. All the fifteen elements recently enumerated as being the materials which are drawn upon for the building purposes of life, must be contained in the food, that being the form in which successive supplies of them are conveyed to the body. Above all things, the food must contain an unstinted abundance of those four primary and most important elements, the carbon, nitrogen, hydrogen, and oxygen, which, it has been seen, make up so nearly the whole of the actively living textures.

Food-substances that are employed for the nourishment and support of living bodies, must therefore be themselves made *chiefly* of the four important elements, carbon, nitrogen, hydrogen, and oxygen, with an intermingling in less quantities of the other eleven simple bodies which are also used in constructive work.

LESSON XII.

THE FOOD-FORMING OPERATIONS OF PLANTS.

The various substances which, under the name of foods, are used for the nourishment and support of the bodies of living animals, are all prepared for the work of sustenance that they have to perform by the constructive or building-up operations of plants. Animals can feed only upon complex substances which have been made by plants; but plants feed upon the simple elements, that is they build up their own structures out of those elements. At the same time, by a similar process, they build up also other things, which are stored away in the midst of their own structures, and become food-substances for animals.

How this building up of nourishing food-substance for animals by the action of the plant is accomplished may be conveniently explained by describing what happens in one instance. Rice is one of the substances which are used for the nourishment of living animals. Now, the rice grain is made by a kind of grass which grows in moist and warm countries in the bright sunshine. When the rice plant makes rice, this is what occurs. It drinks in, partly from the ground by its roots, and partly from the air by the pores of its leaves, water and carbonic acid gas. Water and carbonic acid, it will be remembered, are formed of the three elements hydrogen, oxygen, and carbon. In each molecule of water there are two atoms of hydrogen and one atom of oxygen. In each molecule of carbonic acid two atoms of oxygen and one atom of carbon. When, however, twelve molecules of carbonic acid and ten molecules of water, which have been brought into the interior of the plant out of the moist soil and air, are operated upon, twelve atoms of carbon, twenty of hydrogen, and ten of oxygen are closely fitted together and combined, so as to be worked up into a new molecule of a higher and more complex character. Twenty-four atoms of pure oxygen are therefore set free, and dismissed as ingredients which are not required for this particular process of construction. The twelve molecules of carbonic acid and the ten of water have their atoms regrouped and rearranged in a new form, and the oxygen atoms, which are not wanted in the new combination, are expelled from the plant, and so got rid of. The new complex molecule that is formed is called **starch.** Rice, or the rice grain, is almost entirely made up of a mass of starch molecules adhering somewhat closely together.

The change which takes place when water and carbonic acid are transformed into starch by the constructive powers of the plant, may be represented to the eye in the following simple way:—

10 Molecules of water contain	10 atoms of Oxygen 20 atoms of Hydrogen	form one Molecule of Starch.
12 Molecules of Carbonic acid contain	12 atoms of Carbon	
	24 atoms of Oxygen	— dismissed free.

The essential part of the work performed by the plant is, therefore, the seizing and fixing a considerable quantity of the solid element, carbon, which has been brought to it in the thin condition of a gas, and mingling in with it a measured or fixed amount of hydrogen and oxygen. The starch which is so fabricated is a white, solid substance, perceptible to the touch and visible to the eye, on account of the large proportion of the dense element, carbon, used in its construction. There are various other kinds of food-substances besides starch which are made in an altogether similar way. Thus gum and sugar are both substances that are serviceable as food. In the construction of both exactly the same kind of process is gone through. Carbon is worked up with hydrogen and oxygen to form molecules of gum and of sugar; and the carbon, the hydrogen, and the oxygen which are used are all derived from water and carbonic acid. Carbon is, indeed, the great condensing or solidifying element of vegetable structures. Gum, sugar, starch, and sundry other substances of a similar character, are water made thick and dense by the mingling in of carbon amongst its elements.

When the simple elements are built into vegetable structure and food-substance in this way, it is the living plant which is the effective agent of the change. Without the agency of the plant no work of this kind can be accomplished. Such manufacturing is, indeed, the great office which the plant is appointed to fulfil. But the plant cannot get through its fabricating labour unless it is very energetically aided in its task—that is to say, unless it is placed in warm sunshine. The warm sunshine then becomes to it a quickening and vitalizing power. Plants perform no building up or constructive work in the cold of winter, or, indeed, in the darkness of night. But when, in bright warm days, the sunshine penetrates into the interior of their thin outstretched leaves, it sets the green living substance it finds there to work at transforming and remodelling the carbonic acid and water which have been already drawn in.

In all living plants carbon is in the process of being fixed into vegetable substance, and oxygen is in process of being discharged, so long as the influence of the sun's light is acting upon their leaves.

This process, indeed, may be watched actually going on if a suitable arrangement be made. If a few green leaves of any kind be put into a saucer of water which is well charged with carbonic acid, as is the case with common aërated water, and the saucer be placed in bright sunshine, it will soon be observed that bubbles of gas appear clinging all over the under surface of the leaves, where the pores for its escape are the most abundant.

All those bubbles are composed of pure oxygen, and they are, in reality, the superfluous quantity of that gaseous element which is thrown out from the leaf, as the carbon of the carbonic acid is taken from it to be built up into vegetable substance.

The sunshine is really *used* by the plant when it constructs complex material out of the simpler elements, and this is the reason why the process cannot go on in the dark. The sunshine is employed in keeping the several elementary ingredients held firmly together in the constrained state of combination in which they exist in the new complex molecules. Some power, or, as it is termed, *force*, is required to compel the several atoms contained in each molecule to remain in the new state of association into which they have been brought. That force is a peculiar energy which resides in the sun's light, and which remains fixed in the molecule in a changed form—in a kind of latent, or hidden-away state, as it is called—until the molecule is again resolved into its elements. Then the hidden force awakens once more into activity, and is set free.

This is the force which the animal extracts out of its food for its own purposes of life; and the reason why animals consume, or tear down and destroy, the complex fabrics which have been formed by the plant, is in order that they may get for their own uses and needs the forces and energies which were worked in with the material ingredients when those ingredients were elaborated and built up into complex molecules. It is in this marvellous way that plants make food for the use of animals and men.

LESSON XIII.

PLASTIC, OR NITROGEN-CONTAINING FOOD-SUBSTANCES.

The complex food-substances, which are formed by the action of living plants, all have the solid element, carbon, in them in considerable quantity. In all, carbon is the great source of their fixedness and coherence. But the food-substances prepared by plants are of two distinct kinds, some being of much higher complexity than the rest—that is to say, some have each one of their molecules made of a larger number of simple atoms, and of more kinds of them. Thus one class of the complex substances fabricated by plants are formed almost entirely of the three simple elements, carbon, hydrogen, and oxygen; whilst the other class have nitrogen also mingled up in their molecules. There is a very important reason for this difference. The vegetable substances which are formed of the four elements are all of a more **plastic** character than those which contain only three; that is, they are more fitted to be built in their turn into the structures of animal bodies. This distinction between the two classes of vegetable products may be instructively studied in one particular instance.

After the wheat-plant has been sown for the production of its grain, and after the grain has been ripened, harvested, and ground into flour, there are found, loosened out by the grinding into a powdered state, all the several ingredients which were put into the grain during the growth of the plant. If, after the mere husks of the grain have been removed, some of the fine flour be placed in a basin and kneaded up with the hand, whilst a stream of cold water is poured gently over it and allowed to run away, a fine white powder is seen to be carried off in the stream of water, and a sticky paste gathers about the hand. From this simple and easily performed experiment it appears that the flour of wheat is composed of two distinct ingredients, one which is not made sticky by water, but runs away with the flowing stream, and one which, on being moistened by the water, adheres to the hand like a mass of sticky paste. These correspond with the two different classes of products that have been named. The white powder, which is suspended in the water, is formed of three elements, carbon, hydrogen, and oxygen; the sticky paste, which adheres to the hand, is made of four elements, nitrogen being added to the three used in the other case.

These two distinct products, which are mingled together in flour, are types of the two classes of food-substances prepared by the instrumentality of plants; and of the two, the sticky paste is the more complex production. It is called the **gluten,** or fibrin, of the wheat grain. The word gluten, it will be observed, bears a resemblance to the more familiar term **glue.** It is, indeed, *vegetable* glue, and the name gluten has been conferred upon it for that reason. It is that particular result of the building-up operations of the plant which is prepared to be turned into the actual substance of the living animal frame, and which is itself consumed in the production of movement and power, after it has been so turned. There are various other vegetable products which bear a close resemblance to the gluten of wheat. Such, however, agree in being made of four elements, and in their molecules being of a very complicated character—that is, each molecule has a considerable number of the different kinds of atoms which compose it. They are all on this account classed together under the general term **glutinous**, or glue-like. Another word that is not unfrequently used to distinguish them, and that is a very good term when its proper meaning is known, is plastic. The plastic substances are simply those which are ready to be *moulded into shape*. The word is derived from the Greek **plasso**, which signifies to *form*, *fabricate*, *or mould*. The old Greeks called the soft clay, which was prepared to be moulded into the shape of their statues, **plasma.** In this sense the glutinous products of vegetable constructive activity are plasma, for they are prepared to be moulded into the various parts of the animated frame, and are properly of a plastic, or mouldable nature. Another way in which these more complex productions of vegetable construction may be distinguished is by the use of the epithet **nitrogenous.** They are all of them characterized by having nitrogen mingled in with the other elements of their molecules.

There are other names employed for this same group of substances, which must be known, because they are constantly met with in printed books. Thus the plastic, nitrogen-containing products are by some authorities termed **proteinaceous.** This means that they are in the first state in which living substance is found.* By other writers again they are often spoken of as **albuminoids**, which signifies that they are of a similar nature to albumen, or white of egg. It is necessary to bear in mind in regard to this long series of names only that

* Protein, from the Gr. prōtenō --to hold the first place.

glutinous, fibrinous, plastic, nitrogenous, proteinaceous, and albuminoid substances, are the same things. The names are all only so many different words for expressing one general fact of composition.

There is yet another name, occasionally used in connection with these bodies, designed to express the purpose and end to which they are destined. They are frequently called **flesh-formers,** because they are so largely employed by the animal in the construction of its flesh, or the substance of its body. The particular destination of this class of food-substances was first strongly insisted upon by the distinguished German chemist, Baron von Liebig. But the interesting fact that the complex base of the whole class of these flesh-forming substances is first put together in the plant for the service of animal life, and that the glutinous or nitrogen-containing products of the plant are essentially the same things as the nitrogen-containing or albuminoid structures in the body of the animal, was first clearly affirmed by the Dutch chemist Mulder, who introduced the use of the term **protein.***

The exact composition of the molecule of these complex, nitrogen-containing substances is not yet fully known. But that it must be of a very complicated nature is shown by the circumstance that the best chemists suppose there are at least forty-eight atoms of carbon, thirty-six atoms of hydrogen, six atoms of nitrogen, and fourteen atoms of oxygen, with a small trace of sulphur and phosphorus, grouped together in every such molecule. The formation of this more complicated body by the plant is, nevertheless, of quite a similar character to the production of rice. A large quantity of carbon is seized and worked up with the proper quantities of hydrogen and oxygen into the new compound, but a small quantity

* Protein, from the Gr. prōteno—to hold the first place.

of nitrogen and a little sulphur and phosphorus are added as well. The superfluous quantity of oxygen, which had served as the carrier of carbon, is returned free into the air, to keep it pure just as in the case of the rice.

The peculiar character of nitrogen as an elementary ingredient of living structure, is brought prominently into view in connection with these nitrogen-containing compounds. The great chemical characteristic of nitrogen, it will be remembered, is that it is indolent and slow to contract union with other elements, and that when it has once been constrained to do so, it holds to the union as lightly as possible, and escapes from it upon the first opportunity that offers. It is for this reason especially fit to be employed as a material in the structure of animal bodies, since so much of the action and movement of those bodies depends upon the consumption of their textures, and the resolving of the compounds, of which they have been built, into their primary elements.

LESSON XIV.

AMYLOID, OR UN-NITROGENIZED FOOD-SUBSTANCES.

The white powder washed away from wheaten flour, when water is poured over it as it is kneaded up by the hand, is in no way softened, as the gluten is, so long as the water is cold. It all settles down to the bottom as soon as the water is left still, just as so much sand would do under the same circumstances; and if after it has settled, the water standing above be poured away, the powder can be dried and examined by itself. When this is done it is found to be made up of a vast number of small round grains. It is, indeed, neither more nor less than the well-known substance, starch, which is used for the stiffening of linen, and which forms the greater part of rice. The flour of wheat thus consists of gluten and starch, mingled together and stored away in the little bag-like seed-coats of the grain. There is, however, a larger quantity of the starch than of the gluten. Nine ounces of starch are mingled with every two ounces of gluten—that is, the starch is four-and-a-half times the more abundant substance of the two. Both the starch and the gluten are made by the living activity of the plant, and by the thickening of their other ingredients with large quantities of dense carbon. The starch, however, is formed without any help from nitrogen, whilst in the gluten *nitrogen* is employed. Hence, as has already been shown, gluten belongs to the nitrogenized, or nitrogen-containing, groups of vegetable products, whilst starch belongs to a group which is characterized, on the other hand, as being un-nitrogenized, or without nitrogen.

The word **amyloid**, or starch-like, has been adopted as the general name for the entire class of simpler compounds formed by the plant out of the three elements alone, because they are all, more or less, of the character of starch. The word is derived from the Greek **amulon**, the name for a vegetable compound, very much like starch, with which the Greeks were acquainted. Another word, more commonly used in much the same sense, is **farinaceous.** That word is derived from **farina**, the Latin name for the meal of flour. The amyloid and the farinaceous products of vegetable life are, therefore, to be understood as the less complex bodies that are formed without nitrogen, and that have only the other three elements contained in their molecules. Sugar and gum are vegetable products of this character, and therefore belong also to the amyloid group. Sugar is a substance the molecule of which has its carbon a little further diluted by the gases that are mingled in with it than is the case in starch. When sugar is formed, twenty-four atoms of hydrogen and twelve of oxygen are used with each twelve atoms of carbon in the fabrication of every molecule.

The vegetable substances, which are sweet from the presence of sugar, are technically called **saccharine**, but that means nothing more than **sugary**. The word is derived from **saccharum**, which is the Latin name for sugar.

The amyloid or farinaceous food-substances are of special interest, on account of the view as to their nature and use which was held by the great German chemist Liebig. He maintained that the farinaceous and amyloid principles of food do not contribute at all to the building up of the structures of animal bodies, but are *used only for the production of warmth and heat.* Thus, according to this notion, when eleven ounces of wheaten flour in the condition of bread are eaten by a human being, the two ounces of gluten are turned in the body into flesh, or some other kind of animated structure; but the nine ounces of starch are all burned up in the blood, for the mere production of warmth, just as oil is burned up in a lamp for the mere production of light.

This broad distinction, betweeen the *flesh-forming* and the *warmth-giving* ingredients of the food, is not now as undoubtingly maintained as it was when first insisted upon by Liebig. It is still believed that the food-substances containing nitrogen have the most to do with the texture-building work of the body, and that the food substances without nitrogen have the most to do with the production of its warmth. But it is now known that some warmth is also contributed from the destructive consumption of the textures of the body, which have been built out of the nitrogen-containing substances; and that some part of the carbon of the un-nitrogenized foods is used in the texture-building work. The force of the living body, that is, its power of feeling, moving, and acting, is now also attributed to the destructive consumption or using up of both classes of food-substance, instead of being held due to the former of the two only, as Liebig supposed.

The distinction of the two different kinds of food-substances, namely, the *nitrogen-containing* and the *un-nitrogenized*, nevertheless, continues to be of great practical value, and for this reason. It is now known that for the support, in a healthy and natural state, of a full-grown human being, whose body is of the ordinary weight of 150 pounds, about **5000 grains of carbon** and about **300 grains of nitrogen** must be furnished in the form of food every day. These 300 grains of nitrogen, it is plain, can be supplied only by the nitrogen-containing substances, such as the gluten of wheat. The 5000 grains of carbon, on the other hand, are furnished partly by the nitrogen-containing ingredients of the food, and partly by those which have no nitrogen in them. What is required, therefore, in food, by a human being every day, is that nitrogenized substances, containing the essential 300 grains of nitrogen, shall be supplied, and that then as much more merely amyloid substances as are sufficient to make up the full allowance of 5000 grains of carbon, shall be added to them. When the sufficient quantity of these two most essential elements is provided, there is certain to be also an ample supply of the two other elements, hydrogen and oxygen, which have to be associated with them in building up and warming the body.

If more nitrogen and carbon than the quantities which have been named are furnished daily in the food, the superabundance is of no value whatever, but merely has to be rejected from the body as useless waste.

The amyloid group of food-substances is sometimes called **carbonaceous**, as another way of marking it out from the nitrogen-containing class. There is, however, the obvious objection to this designation, that the nitrogen-bearing substances have large quantities of carbon in them, and are in that sense, therefore, carbonaceous also. If the distinction be understood to express merely that all the nitrogen which is used in the actions of the living animal body, is taken from the one group, and that the principal part of the carbon is taken from the other, there is no objection to the employment of the word. But it must even then be kept clearly in mind that the carbonaceous food-substances are so called simply as furnishing the supply of carbon needed to make up the quantity to the daily necessity of 5000 grains.

There is a subordinate group of starch-like or amyloid food-substances prepared by plants, in each molecule of which a yet larger quantity of hydrogen is found than in the case of starch, sugar, or gum.

These substances, indeed, are starch which has been deprived of very nearly the whole of its oxygen. They are all of the nature of oil, and are termed **oleaginous**, or oily, compounds. Most of them are of a liquid, or nearly liquid consistence, and, on that account, are stored away in the plant in little bags or sacks. Each molecule of vegetable oil contains twelve atoms of carbon, twenty atoms of hydrogen, and one atom of oxygen. When these oily substances are used as food by animals, they are still more "heat-giving" than the true amyloid products.

LESSON XV.

ORGANIZED STRUCTURE.

THE word **structure** means something which has been built. In this sense, a house is a structure, because it is built up of bricks, and mortar, and wood; and so, also, a molecule is a structure, because it is built up of a number of atoms, grouped together and combined into close connection. So again, wood, starch, sugar, and gluten are all structures, because they, in their turn, are built up of a great number of molecules put together. An atom, on the other hand, is not a structure, because it is not built up. It is the smallest form of each element that is known, and can in no way be shown to have been originally made by the putting together of yet smaller parts. The word structure, is derived from the Latin **struo**, which signifies to *pile up*, or *build*.

There is, however, one particular form of structure, which, being built after a particular fashion, is called by a distinctive name, that has a very important meaning. An organized structure is a structure which is built up of subordinate and different kinds of organs, each one of which has some appointed part to play, and some appointed work to perform in a general service. Thus a plant is a structure, because it is built up of molecules that are composed of carbon, hydrogen, nitrogen, and oxygen; but it is also an ORGANIZED STRUCTURE, because it is made up of roots, stems, branches, leaves, and flowers, each of which is an organ, or instrument fashioned for a particular purpose. The root insinuates itself into the moist porous ground, and drinks in water. The stem holds the branches above the ground, and carries the sap up into them from the soil. The branches spread out the leaves into the air. The leaves expose the sap to the sunshine, and afford a convenient outlet for the escape of oxygen; and the flowers perfect and ripen the seed. These different parts are all instruments contrived for a particular purpose. They are called organs because they are instruments; the word **organ** is derived from the Greek work **organon** which means an *instrument.*

The animal body is also an organized structure, because it, like the plant, is built up of organs. The organs, that are put together in the construction of the animal body, are the heart, stomach, lungs, liver, kidneys, brain, blood-vessels, muscles, nerves, and other analogous things. Each one of these is an instrument, which has some particular work of its own to perform. The heart and the blood-vessels have to circulate the blood; the lungs, to breathe and introduce air; the muscles have to move, the nerves to feel, and the brain to think. The body is a structure in which all these several organs are built up together: and therefore it is an organized structure.

Organized structures are at once marked out from unorganized, by the one great fact that their own substance *is always in a state of internal change.* In some, the change is more slowly performed; and in some, it is very quick. But in all there is change of some kind; and that change is, in every instance, due to the complex molecules, of which the substance is built, falling asunder into their primary atoms, or elements. In organized bodies, this change takes place in every organ of which the body is composed; and *life is intimately connected with this incessant molecular movement.*

There is another word, which looks very much like organized and which is in constant use in connection with it, but nevertheless has quite a different meaning. An organic substance is not one which is *built up of* organs, but a substance that has been *built up by the instrumentality* or by means of organs, and that cannot be made without their help. Thus gluten, starch, and sugar are not organized substances. They have no organs in themselves; they are not built up *of* organs. But they are all organic substances, because, although not organized, they have been built up *by* the operation of the living organs of plants. The food substances, which are prepared for the use of animals, by plants, are all in this sense organic bodies.

Organized structures are generally at once distinguished from unorganized, by their curved and swelling outlines, and by the softness of the substance of their different parts. The softness is almost universally due to the mingling of solid and liquid matters in that substance, and is one of the means by which provision is made for the unceasing change it is destined to undergo, so long as it forms part of a living organization. Hardness is conferred upon an organized body only, when it has some mechanical office to fulfil, as in the instance of the wood of trees and the bones of animals.

Organized substances become hard, like minerals, when they have to be turned to account in some merely unliving, or mechanical way. But organs that are performing active work in any of the processes of life, are always of a soft nature, and so much the more soft according as the work which they accomplish is the more energetic. Thus the flesh, which moves the limbs of an animal, is softer than the gristle, or bone; and the brain is, in its turn, very much softer than the flesh.

LESSON XVI.

THE COMPOUND GAS AMMONIA

The next stage, in the history of the building operations of plants, has to consider the question of whence all the vast stores of nitrogen, employed in constructing the plastic or nitrogenous substances of the food, are derived. It is obvious that in the air there are vast stores of this gas. But it is well ascertained that those are of no use whatever for this particular purpose; because, as it exists in the air, nitrogen is so unwilling to unite with other elements that not even the active oxygen with which it is there so abundantly mingled, can, even under the quickening influence of bright sunshine, induce it to abandon its obstinate resistance. Nitrogen remains almost unaltered and unchanged in its vast reservoir the atmosphere.

The great source from which this most important element is obtained, to meet the vast demand set up by the building operations of plants, will be best understood if a new body, not hitherto spoken of, be introduced upon the scene, in the state in which it was first presented to the notice of observing men. There is a hard, white salt, somewhat largely employed by the chemists at the present day, which is called **sal ammoniac.** It bears this name because it used to be brought, as an article of commerce, many centuries ago, from the Libyan Desert, which lies to the west of Egypt. It was there found, in the first instance, mingled with the soil in the neighbourhood of an old temple, dedicated to the heathen divinity known as Jupiter Ammon. The salt was for this reason called the **Ammonian salt,** or sal ammoniac.

If a small quantity of this sal ammoniac be mixed with about double its weight of quicklime, there immediately rises up a vapour that has a pricking, or pungent smell. This pungent vapour is, in reality, a gas, which was fixed in the salt in large quantities, and which is set free from it by the influence of the lime. The gas can be collected in a bottle. When it is so collected, it is found to have such a strong inclination towards water, that if a jar filled with it be placed with its mouth in a basin of water, the gas all rushes down into the water, as if in a flash, and the water rushes up in the same impetuous way, to take its place in the jar. The mutual attraction between the water and the gas is indeed so exceedingly strong, that one pint of water will take up into itself, and dissolve away, 670 times its own bulk of the gas; or, if estimated by weight, one pound of water will dissolve half a pound of the light gas.

But the water, which has dissolved the gas, is then found to manifest its leading properties; to be, in its turn, pungent or pricking to the smell and burning to the taste. In fact it is then neither more nor less than the strongly smelling spirit familiarly known as **harts-horn.** The more scientific name for this pungent liquid is, the solution of ammonia. Ammonia, therefore, is a gas extracted from sal ammoniac, and readily dissolved in water. The name, it will be perceived, is directly derived from that of the salt; ammonia being simply the gas which is contained in the salt originally brought from the neighbourhood of the temple of Jupiter Ammon in Libya.

The nature of this gas, however, is such as largely increases the interest with which it has to be contemplated. It is not a simple element, like oxygen, hydrogen, or nitrogen; but is a compound gas, which, like carbonic acid, can be resolved into its elements. This was for the first time discovered, about three-quarters of a century ago, by the distinguished chemist, Dr. Priestley. He took a quantity of pure dry ammonia, that is, in the state of transparent gas, and shut it up in an earthenware tube. He next made the tube red hot, and found that no change took place in either the appearance or in the quantity of the gas. There remained just the same weight and bulk that he had put into the tube. But all the pungent smell was gone. In fact the ammonia had disappeared, and there remained in its place two different gases, mingled loosely together, very much as nitrogen and oxygen are mingled in the air; one of the two indeed was *nitrogen*, possessing all the properties of the nitrogen of the air; but the second gas was not oxygen. It was a much lighter gas and burned with a pale flame; and when burned in connection with oxygen, it was at once converted into water. In short it was *hydrogen* gas in its purest form. Ammonia, therefore, is a compound gas, made of nitrogen and hydrogen, intimately combined or in chemical union. The proportion in which they are combined is one part, by measure, of nitrogen, and three parts, by measure, of hydrogen. The gases remaining in the earthenware tube after Priestley's experiment were in these relative quantities. When nitrogen is turned into ammonia, this, therefore, is what happens. Three atoms of hydrogen seize upon one atom of nitrogen and form it into a compound molecule, which then is a molecule of ammonia, possessing a pungent smell, great solubility in water, and the other properties which have been described as characterizing this gas.

Carbonic acid and ammonia, then, are both invisible, transparent, gaseous bodies, at the ordinary temperatures of the earth; and they also further agree in being both compound gases made by the union of two elements. Carbonic acid is formed by the union of carbon and oxygen; and ammonia by the union of hydrogen and nitrogen. Carbonic acid is one-half as heavy again as oxygen, because the oxygen is weighted by the dense element, carbon, mingled with it to constitute the compound gas. Ammonia, on the other hand, has only one-half the weight of nitrogen (or oxygen), because in it the nitrogen is lightened by mingling with the light gas hydrogen.

Thus, carbonic acid and ammonia contain in themselves, when taken together, all the four elements that are chiefly used for the construction of living, organized textures, and of the nearly allied organic substances; they contain, namely, carbon, oxygen, hydrogen, and nitrogen. If, therefore, carbonic acid and ammonia be supplied in sufficient quantities to living plants, these have nearly all the materials they require for their constructive operations. As both these compound gases are soluble in water, such supplies of them as are needed can be easily carried into plants by water.

Carbonic acid and ammonia then resemble each other in that they are both compound gases, and are both drawn upon as the chief sources of building material by plants. They differ, however, from each other in one very remarkable circumstance, which needs to be well kept in mind. Carbonic acid is easily made by the artificial combination of its elements; but, when once made, can only be unmade, or turned back again into those elements, by the separating or resolving powers of vegetable life. Ammonia, on the other hand, cannot be made out of its elements by artificial means, but can easily, by those means, be resolved, or separated back into them. Ammonia, however, is made by the operations, not of vegetable, but of *animal*, life. It is a product of the decomposition and decay of the nitrogen-containing substances of animal bodies. When those substances are decomposed and turned back into their component elements, the hydrogen and nitrogen, at the instant of dismissal from them, linger together for a certain time, and in that lingering and transitional state constitute the pungent gas ammonia.

All the supplies of ammonia, which are furnished for the building work of living plants, are derived from this source. They are all taken from the vapours that result out of animal decay. The wide intervals which lie between the broadly scattered atoms of the gases of the atmosphere are at all times convenient lurking places for the molecules of both carbonic acid and ammonia. Both those compound substances are poured out into the atmosphere in never-ceasing gaseous streams, alike from living and dead animal bodies. In what is ordinarily considered pure air, even in the free open spaces in the country, there are always some traces of carbonic acid and ammonia floating amidst the air-particles, ready to serve for the building work of plants.

One of the most wonderful facts, perhaps, that is met with in this interesting region of investigation is the large results which are worked out from apparently the most trifling, and, what may in ignorance be conceived, quite inadequate means. Thus, the quantity of ammonia contained in the air very seldom amounts to more than the $\frac{1}{100000}$ part of the whole. That is to say, it would require about 100,000 pints of air to furnish a single pint, or five grains weight, of ammonia. The quantity is kept down to this very small amount, on account of the ready way in which ammonia is washed out of the air by the rain. Nevertheless, as much as

30 pounds weight of this pungent gas is furnished to one acre of ground, by the rain, every year. The amount of carbonic acid gas contained in very pure air amounts to about three parts in every 10,000. There is indeed about one pint-measure of carbonic acid gas in every 3333 pints of air. Carbonic acid is also washed out of the air by the rain and carried to the ground in such abundance, that not less than 900 pounds weight of it are furnished to every acre of ground in a year.

Plants, therefore, get the enormous supplies of carbon, nitrogen, hydrogen, and oxygen which they need for carrying on the important work of fabricating food-substances and their own structures, from the rain bringing down carbonic acid and ammonia into the soil, and from the winds blowing those gaseous compounds against their porous leaves. The comparatively small quantities of other ingredients, which are also required to be worked up with those elements, are obtained from the soil and carried by the water, washing through it, to the roots of the plant.

II.—Classification of Food-Substances.

LESSON XVII.

VEGETABLE FOOD-SUBSTANCES—GRAIN OR CORN.

THE most valuable of all the numerous food-substances which are prepared out of the raw material of nature by the plant, are the products familiarly known as **corn**, or **grain.** These are properly the seeds of different kinds of grasses. The wheat-plant is a grass of a large kind, which is now spread over all the temperate parts of the earth, on account of its great value to human beings, and which has been so long thus spread and artificially cultivated, that it is not even known where it was in the first instance found.

The vast importance of the natural family of plants, known as grasses, is shown by their great numbers. About 82,000 different species of plants have been distinguished by scientific men. Nearly one-twentieth part of these, or about 3800 of the whole, are different forms of grass. But the individual plants of each different form are, over and above this, in such exceeding abundance, that it has been roughly estimated as many as one-half of the plants living at one time upon the earth are grasses.

Corns or grains are the seeds, then, of these grass-plants. Both names have been used amongst men from the earliest periods of human history. Corn is the word which was employed by the Anglo-Saxon forefathers of Englishmen. Grain is derived from the old Latin or Roman name for the same class of seeds. In every one of these seeds, just as in wheat, the hard dry part contained within the outer coats of the grain is made up of a mingling together of the gluten and starch, which have been fabricated by the growing leaves of the grass. The seeds are therefore, in every case, little fixed stores of food-substance, packed away in coats or husks. The purpose for which these stores are, in the first instance, provided is, no doubt, to furnish food to the germ of the new plant which is packed away amid them in the seed. When the seed is placed in moist ground, and the germ or young plant begins to shoot, these fixed stores are drawn upon for its earliest nourishment, until the new grass has thrust its own little rootlets well into the soil to take up the work of feeding it.

In the case, however, of the more valuable grass seeds, or grains, such as wheat, man takes possession of much the larger number of them on his own account, before the young plants have been allowed to use them as food. But there is no real loss in the end in this apparent robbery, because by the art of agriculture man multiplies the plants at the same time that he consumes the seeds. He ploughs and loosens the ground, and causes it to grow grain-bearing plants, where only weeds would have flourished without his care.

Wheat is, on the whole, the most valuable of these corn-yielding plants, because its seeds contain in themselves an ample provision of nearly all the ingredients that are required for the support of the living animal body. If enough wheaten bread be taken to supply the 300 grains of nitrogen and the 5000 grains of carbon that are needed daily by a human being, life can be sustained for a long period on bread and water alone. As a matter of fact, if enough of the wheat be taken to furnish the 300 grains of nitrogen, there is sure to be more than enough of the carbon as well. Two pounds and a half of good wheat flour contain 300 grains of nitrogen, but they also contain 6600 grains of carbon. A human being, therefore, who is dieted upon wheaten bread made from *two pounds and a half of flour*, has all the nitrogen which is necessary for the support of the living actions of the frame, and 1600 grains more carbon than is required, which therefore has to be daily disposed of as waste.

The corns which stand next in value to wheat, as food-substance for man, are oats, barley, rye, maize, and rice. These, including wheat, are all, however, only of this superior value on account of their large size. They all have abundant stores of gluten and starch packed away in their dry husks or seed-coats, whilst a great number of other kinds of grass seeds are so small that they are not worth the trouble of grinding into meal. But for this reason all grass seeds might be turned to the same good account, as they all fabricate gluten and starch.

Oats are chiefly of value because the plant is of so hardy a nature that it can be cultivated in many poor soils and cold situations which would not yield wheat. The meal which is made from grinding the grain is rich both in gluten and starch. It is considered, indeed, by many authorities, to have a larger proportion of the glutinous ingredient, weight for weight, than the meal of wheat. Its disadvantage, in comparison with the wheaten meal, is that it is not as easily preserved for use, and that it cannot be turned into palatable fermented bread. When it is used as food, as it is in some parts of the north of England and throughout Scotland, it is either formed into close unfermented **cakes**, by mixing and softening with water into a paste and baking upon hot plates, or it is made into porridge, in which state it is a most nourishing food, especially if eaten with milk. **Gruel**, which is so commonly prepared as a light food for sick people, is only a thinner and more delicate form of oatmeal porridge. It is made of oats which have been entirely freed from their outer husks, and which in that state are called **groats**.

Rye is a grain produced by a grass that resembles wheat in many particulars, but is distinguished from it by having its ears bearded like barley, but with shorter hairs. It is a coarser and harder grain than wheat, and two or three centuries ago was much used in England for bread. Rye bread is now rarely seen in this country, but the grain is still used in the northern parts of

Europe, as in Sweden; hard dry cakes, made from **rye**, there take the place of bread. They are, however, both a coarser and poorer food than oat-cake.

Barley is chiefly used for the production of **malt**, from which beer is brewed. The meal is quite as unsuitable as that of oats for making bread; but the grain is, nevertheless, nourishing in itself. **Pearl barley**, which is commonly used as an agreeable addition to soups, is merely the grain of the barley freed from its seed-coats. It is so hard as to require as much as three or four hours' boiling, in liquid of some kind, before it is fit for use.

Rice is a grain which can be grown only in warm climates, and in situations where there is abundance of moisture. Thus, India and China are the great centres of its production, and in those countries it takes the place which wheat has in lands circumstanced like England and the temperate parts of Europe. In India and China, the poorer classes are fed almost exclusively upon rice. It fortunately happens that the grain is of so firm and dry a character as to be easily sent from the countries where it is grown to distant places like England. It is capable of forming there an agreeable and useful addition to the diet of all classes of people, on account of the way in which it can be mingled, in cooking, with other articles of food. The leading peculiarity of rice is, however, the very *large proportion of starch* and the very *small proportion of gluten* which it contains. In rice there is no more than one part of gluten to every thirteen parts of starch, instead of there being two parts of gluten to every nine parts of starch, as is the case with wheat. It is on account of this peculiarity that rice is so commonly used for the manufacture of laundry starch, in the preparation of which substance the more common and least valuable kinds are employed. When the rice is still enclosed in its outer husks, it is of a dark colour, like most of the other corn-grains, and in that state bears the name of **paddy**, or **paddee**.

There is one other grain which is also of great value in warm parts of the earth where wheat cannot be advantageously grown. It is called **Indian corn**, on account of being the grain that is extensively used by the natives, or Indians, of those regions. The Indians, however, who are referred to by the name, are not the inhabitants of Hindostan, but the Indians of the western continent of America, first known from the conquests and settlements of the Spaniards and Portuguese. Another name for this grain is **maize** (Zea Mais). The maize plant is considered to have been originally a native of America, but is now found cultivated in the greatest abundance throughout the wildest and most remote districts of equatorial Africa; and, as in the case of wheat amongst more civilized peoples, there is no reliable account of the period or manner of its first introduction into these parts.

The maize plant is a very interesting illustration of the way in which vegetable forms are converted into structures of giant growth by the quickening influence of sunshine and moisture in the hotter regions of the earth. Most people have heard how brakes, or ferns, become large trees under such circumstances. The maize is a grass developed after the same fashion by warmth into giant proportions. It might almost be termed a tree-grass. Its stem is as thick as a stout walking-stick, and grows seven or eight feet high. Its ear is a great club-shaped cob, several inches long and round, and its seeds or grains are sometimes as large round as a threepenny silver piece, and are packed closely about the cob. The maize also affords a very interesting illustration of the wonderful powers of increase of grain-plants of this character. There are commonly as many as 400 seeds packed round upon the club-like top of a single cob. When a man plants all these seeds in the ground, and in due time gathers the crop of grain which they yield, he has virtually increased the numbers of this useful plant four hundredfold in one season of growth.

Maize does not bear storing and transport as well as wheat and rice, and on that account it is not used in any very large quantity in England, except as food for horses, cattle, pigs, and poultry. It is principally consumed as the staple grain-food of the countries where it is grown. Maize contains very nearly the same proportions of gluten and starch as wheat, the standard grain which is the great staff of life in the temperate regions of the globe.

It is a notable, although not always understood, fact that in all these food-grains there is present a small quantity of oil, in addition to the large stores of gluten and starch. The different kinds of grain have larger or smaller amounts of it, and are found to be more or less heating as food accordingly as there is more or less.

From one to four ounces of oil can be extracted from 100 pounds of wheat.

In oats there are two or three times as much oil again.

In Indian corn the oil sometimes amounts to a twelfth part of the weight of the grain, that is in favourable circumstances. Eight pounds of oil can be extracted from 100 pounds of maize.

Rice, on the other hand, contains the smallest perceptible trace of oil.

The husk of corn-grains, which is removed in the process of manufacturing fine flour, is mainly a stout and tough great-coat provided for the protection and safe storage of the inner and more valuable part. There are, however, in all these seeds two distinct coats, an outer and an inner one, and of these the outer is the coarser and stronger. It is, indeed, made proof against moisture by a kind of varnish or glaze of flint. The inner coat contains small quantities of various earthy substances that are used in the building process of the body; such, for instance, as phosphorus, magnesia, potash, and some other like compounds.

Even these husks of the grain, therefore, are capable of rendering good service when they are judiciously mingled with the food, especially if these mineral ingredients do not chance to be supplied from any other source. This is the real reason of the value of brown bread. In brown bread all, or a considerable part of, the husk of the grain is ground in with the flour, that is, with the gluten and starch. As, however, the husk is apt to be somewhat hard to digest in its unbroken state, the best brown bread is that which has had the husks removed carefully, ground into fine powder by themselves, and then restored to the flour. Husks or bran, which have not been treated in this way, may prove irritating to persons with a delicate digestion. Brown bread is nevertheless held by some authorities to be more digestible and more nourishing than white.

LESSON XVIII.

FRESH VEGETABLE FOOD-SUBSTANCES.

The seeds of the grain-plants are the most serviceable and valuable form of vegetable food-substances, because in them the gluten and starch prepared by vegetable life are condensed and packed away in a small space. It is on this account that in something less than three pounds of wheat there is food enough for the support of a fully grown human being for a day.

But all the food-substances made by the plant, and stored away in its seeds, are also found in a less condensed form in its soft tissue and juices. Animals can therefore feed upon the fresh green corn-plants themselves, as well as upon their ripened seeds. This is familiarly shown by the way in which large animals, such as sheep, oxen, and horses, build up and sustain all the textures of their bodies, though eating nothing but fresh grass. There is an abundance of both gluten and of a principle nearly approaching starch in character, in the green blades and in the juices of grass, and these are secured by the animals when they graze in the pastures.

So, in the same way, there are many fresh vegetables eaten by men that contribute materially to the nourishment of their bodies. First and foremost among these is the one which is found upon every table, and which is known to everyone as the **potato.**

The POTATO was originally a native of America, where it was first seen and described, so far at least as English observers are concerned, by the companions of Sir Walter Raleigh, in one of his expeditions of discovery during the reign of Queen Elizabeth. The plant was, however, previously known to the Spaniards and Portuguese during their early visits to Quito. The word potato is merely a corrupted form of the Portuguese name, **batata,** which means *apple of the earth;* the same thing as the French *pomme de terre.*

The part of the potato used for food is the **tuber.** which is properly an *underground portion of the stem* of the plant, swelled out and enlarged into this state by deposits sent down into it from the growing leaves. These deposits are intended, like the food-substances stored up in grain, for the first support of the progeny of the plant. The potato plant multiplies itself by sending out shoots under the ground, and then pushing out tubers from them. The so-called eyes upon the potato are the germs from which the new potato plants spring. The potato tuber is, therefore, only a different kind of food-store to that found in seeds, and is prepared for the nourishment of the next generation of the plant. Several tubers, or swellings of the underground stem, are formed by each plant, but these are connected together into a kind of bunch by string-like fibres running from tuber to tuber. All the food-substance, however, which is deposited in the tuber of the potato is, in the first instance, formed in the leaf of the plant out of the sap, and is then sent down to be stored away in the underground stem.

The food-substances which are packed away in the swellings of the underground stem of the potato are of almost the same nature as those found within the seed coats of corn, excepting that they are very much more moist and less condensed. They are gluten and starch. The starch is, however, in even larger preponderance than it is in rice; and the quantity of water is in yet larger amount than the starch. As much as *three-fourths of the weight of a full-grown potato is water*, and of the remaining fourth about a sixth part is gluten, and the other five-sixths are starch. From three to four ounces of starch may be extracted from a pound of fresh potatoes.

It is a curious fact that the potato is the produce of a poisonous family of plants. The poisonous principle, however, is in this case very largely diluted by the rapid and abundant production of starch, and the small trace of it which remains is chiefly confined to the outside coat, and is entirely taken away by the use of boiling water in cooking. The water in which potatoes have been cooked is for this reason always carefully separated from them.

Carrots, turnips, and **parsnips** are used for food in a fresh state much as the potato is. They are, like it, deposits of food-substances which, having been first manufactured in the leaves, are then stored away in a moist state in the root, to be employed afterwards in the abrication of fresh shoots. They all contain small quantities of gluten in their juices, but for the most part not more than one or two per cent. of the weight of the whole. They have more water even than the potato, and the amyloid or starch-like ingredient is changed from the insoluble condition in which it is found in starch, into the sweet and soluble state known as sugar. The sweetness of these fresh vegetables is caused by the presence of sugar, of which the carrot and parsnip contain a larger quantity than the turnip. The peculiar flavour of fresh vegetables of this kind, which makes them agreeable to the taste, is a minute trace of a still more complicated substance, made by the leaves of the plant and then mingled in with its juices. In **beetroot,** which is used for the food of oxen and sheep, and employed also as a fresh vegetable by human beings, the sugar is so abundant that the plant is sometimes grown as in France for the purpose of extracting and manufacturing it.

In the **cabbage** it is the large leaves which are boiled for food. As much as *nine-tenths of their weight is simply water*, but there is dissolved in this liquid, to form the juices of the leaf, some considerable quantity of a glutinous compound, capable of affording nourishment. The same thing also is true of **broccoli** and **cauliflowers**, in which it is the young and not fully expanded flower buds just opening upon the top of the stalk that are eaten. The broccoli and cauliflower belong to the same great natural family of plants as the cabbage, as do also the water-cress, garden cress, and mustard, the leaves of which are eaten uncooked; the radish, so pleasant as salad; and horse-radish, employed to garnish and flavour roast beef. In the whole of the vegetables of this class, however, it appears that there are yet other ingredients contained in the juices or textures of the plants, which seem to exert some useful or advantageous influence upon the animal structures that are built up out of them. Such vegetables, therefore, are held to be very wholesome when taken in connection with the stronger and more condensed foods.

Onions, which are the succulent bottoms of the leaves of another kind of plant, turned into a bulb or false root beneath the surface of the ground, and which are eaten both in a raw and cooked state, contain an unusually large store of glutinous nourishment. They are used, however, rather on account of the strong flavour mingled with their juices, as one of the products of the growing operations of the leaves, than on account of their nourishing properties. They are hence employed rather as an addition to other foods which are wanting in flavour than as a food by themselves. They are very wholesome when thus employed. Their flavour is due to a volatile principle, analogous to the essential oils of which strong scents are composed. The odour is not easily got rid of, and is not agreeable to everyone. The onion is, therefore, not as universally used as it would probably be but for its strong taste and enduring scent. **Leeks, chalots,** and **garlic** are all of a somewhat similar nature to the onion, in that they all contain a strongly-smelling essence, to which the same objection applies, and especially in the case of garlic.

There are yet some other kinds of vegetables to be added to this already large list, but they are all of a more or less analogous character to those which have been described, and are chiefly acceptable on account of the pleasant variety of food they afford. **Asparagus** is furnished by a kind of lily, and it is the young shoots of the plant which are used. **Spinach** is a kind of goosefoot, belonging to the same family of plants which yields beetroot, and it is the young leaves of it that are eaten. **Vegetable marrow** is the fruit of a kind of cucumber or gourd. The **cucumber** itself is the fruit of another plant of the same group, which is, however, so succulent, juicy, and pleasant in flavour, that it can be eaten without cooking. The **lettuce** consists of the young leaves of a plant belonging to the same great natural tribe as the sunflower and the daisy, which are also so succulent that they can be eaten raw. **Celery** is the crisp juicy stem of a plant of the poisonous hemlock tribe, but the hurtful ingredient of the juice is prevented from being matured in any strength by growing the plant in trenches in comparative darkness. **Rhubarb** is the young soft stem of a plant of the dock or buckwheat family, which has such a pleasant taste that when boiled and sweetened with sugar it takes the place of a fruit, and proves as wholesome to most people as it is agreeable to the taste. It is very welcome on account of being ready for use in the early spring, before any of the real fruits can be had, but the peculiar acid which it contains does not agree with everyone, being indeed poisonous in a concentrated state.

Peas, beans, haricots, and **lentils** are the seeds of that natural family of plants which has gay butterfly-shaped flowers, and which ripens its seeds in pods. The entire pod of some of the beans, called **scarlet runners,** and **dwarf French beans,** is used before it is fully formed. The seeds themselves of both peas and beans are remarkable for the very large proportion of gluten or the nitrogen-containing ingredient which they possess. This product, in the case of the pea and bean, has, however, a new name given to it. It is called **legumin,** a term derived from legume, which is the learned name for a pod. These seeds rank even above wheat in the quantity of the nitrogen-yielding principle which they contain. One-fourth part of the weight of dried beans or peas is legumin. Two pounds of peas contain something more than 5400 grains of carbon, and 500 grains of nitrogen. That quantity, therefore has in it more than the amount of these two important ingredients which a living human body requires in a day.

But although peas and beans are of a highly nutritious nature, the nourishing substances are in so hard and condensed a state that the seeds require careful, and in some measure skilful, preparation by cooking before they can be turned to account; and very few people would like to live on two pounds of peas a day. They are, indeed, better suited to be mixed in moderate quantities with other kinds of food than to be used by themselves. The pea and the bean have their condensed stores of legumin deposited in them for precisely the same reason that gluten is stored in wheat. They are intended to be used as the first nourishment of the young plant which would be developed from the seed if it were made to grow. It will be perceived that peas and beans or pulse, although not properly of the plant group which yields corn, are nevertheless allied to it in this peculiarity, and in reality stand in a sort of intermediate position between corn-grains and the fresh vegetable substances that are employed as foods.

LESSON XIX.

MANUFACTURED FARINAS AND SUGAR.

STARCH, in a dry and very pure form, is extracted from some other kinds of plants in which it is produced in great abundance, besides rice, in order that it may be turned to account afterwards as the food of living human beings.

Arrowroot is one of the best known kinds of farinaceous food-substance manufactured in this way. It is procured from the *root of a plant* very nearly allied to the family which yields ginger, and can be grown only in warm countries. The root is dug up and crushed in a mill when it is one year old, and is then washed in successive streams of water until all the abundant starch-grains it contains have been extracted. These are then allowed to settle down in shallow troughs into a kind of white pasty mass, which is afterwards dried in the sun, and packed in boxes for transport. Arrowroot, when properly made, consists of almost pure starch.

Sago is prepared in a somewhat similar way from the *pith of a palm*. A farinaceous paste is extracted from the pith, which is squeezed through a sieve, and then dried in a hot iron pot into the granular or grain-like form in which it is sold for use. The grains of the sago are thus not seed-grains produced by the plant, as in the case of rice and pearl barley, but little round masses formed out of paste by an artificial process. **Tapioca** is the starch extracted from the root of a spurge plant which grows in the hot parts of South America. The root is grated and washed, and the starchy remainder is dried upon hot plates and broken up into granules.

The preparations sold under the names of **corn-flour, oswego,*** and **maizena** are made from Indian corn, or maize. They are nearly all pure starch. They do not contain at the most more than from sixty to seventy grains of gluten in the pound, and very often not more than one-third of that quantity. The whole of these farinaceous preparations stand in the same position as regards their employment as food. In consequence of the almost entire absence of gluten, or of any nitrogenous compound analogous to it, they are not sufficiently nourishing to be used by themselves. But they are very delicate and excellent additions to more concentrated kinds of food. Thus they are all suitable for consumption with milk, which is rich in nitrogenous ingredients; and are also very serviceable in soups and broths, and when made into puddings with eggs and milk.

Sugar is by far the most valuable of the various unnitrogenized articles manufactured from vegetable substance by the skill of man. This product is formed naturally in the juices of various kinds of plants, and can be extracted from them. It is, however, almost exclusively prepared in any large quantity from the sugar cane and from beetroot.

Sugar is very nearly allied in nature to starch. It is, indeed, merely starch which has a trifle more hydrogen and oxygen mingled with its dense carbon. Each sepa-

* Oswego, a large town on the south shore of Lake Ontario in New York State.

rate molecule of sugar contains twelve atoms of carbon, twenty-two atoms of hydrogen, and eleven atoms of oxygen. This comparatively slight change in the composition of the molecule has, however, a very important result. Sugar is very soluble in cold water, which starch is not. A single ounce of water can dissolve away as much as two ounces of sugar into itself. The consequence of this is, that whenever sugar is made in a plant it is at once dissolved in the sap and juices. The presence of sugar is immediately distinguished by its sweet taste, but starch has scarcely any taste whatever.

The very close relationship between sugar and starch is also shown in another striking way. Sugar is easily made out of starch. All the condensed deposits of starch, which are formed in living plants as fixed stores of nourishment to be used by the young growing grains and new shoots, are first turned into sugar, in order that the nourishing substance may be dissolved in the sap and carried to the place where it is wanted. *All seeds become soft and sweet when they begin to grow.* This is very strikingly seen in the process by which the grain of barley is converted into malt. The grain is soaked in water, and then kept warm until it begins to sprout, as it would have done if it had been placed in the ground at the beginning of spring. As soon as the sprouting of the grain has proceeded to a certain point, the seeds are dried in kilns by artificial heat, and it is then found that the starch of the grain has been converted into sugar, which can be extracted by water. The grain has then ceased to be horny and hard, and has become sweet and soft instead. In that state it constitutes what is called **malt**. Malt is merely the grain of barley made sweet by the conversion of its starch into sugar, through an artificial process of germinating or sprouting.

The chief part of the sugar imported into England is prepared from the juice of **a giant grass** called the **sugar cane,** which is cultivated for the purpose in many of the warm countries of the earth. This cane grows as high as fourteen or fifteen feet, and is nearly as thick as a man's wrist. The sugar is formed in richest abundance just before the opening out of the flowers of the plant. The cane is therefore cut down at that time, which is about a year after it has been planted, and is then crushed between large iron rollers. The sweet juice which is squeezed out is first mixed with lime to remove its glutinous ingredients, and is then thickened by boiling, until at last it is so thick that it becomes sugar when allowed to cool. **Loaf sugar** is made by melting brown or moist sugar over again, and still further purifying it by the action of lime and charcoal. Brown sugar is somewhat sweeter than white.

The same kind of refined or white loaf sugar is also manufactured from the juice of the beetroot. The great value of sugar as an article of food is very well expressed in the fact that as much as 700,000 tons of loaf sugar are made from beetroot every year in the various countries of Europe, and that as much as 1,400,000 tons of cane sugar are brought to those countries in the same space of time from warmer parts of the earth.

Molasses and **treacle** are the coarser parts of the sweet juice of the sugar cane, which do not harden into crystals when cooling. They are separated from the crystallized portion by various ingenious contrivances, the best of which causes them to be whirled out as a kind of spray when the sugar is placed in rapidly revolving cylinders, or drums, pierced through the outer sides with holes. Although treacle is of a less delicate character and flavour than sugar, it still contains a large quantity of the sweet nourishing substance. As much as three-quarters of the weight of treacle is of a nutritious character, and it is both wholesome and palatable when judiciously used in combination with other kinds of food.

Cane sugar is a very important substance on account of its nourishing powers. It is capable of yielding to the structures of living animals large quantities of both carbon and hydrogen. Every pound of good sugar contains something more than six and a half ounces of carbon, the remaining nine and a half ounces being made up of hydrogen and oxygen. The great abundance of carbon may be made perceptible to the eye by a simple experiment. If a thick solution of white sugar be placed in a wine glass, and a little strong oil of vitriol, or sulphuric acid, be added to and stirred up in it by means of a glass rod, the whole is immediately turned into a thick black mass from the setting free of the oxygen and hydrogen, and the leaving the carbon by itself. The oil of vitriol destroys the sugar by taking away the hydrogen and oxygen from each of its molecules. The atoms of carbon which are thus left accordingly appear in the liquid, and turn it black, just as the same quantity of charcoal powder would do, if stirred into it.

When cane sugar is used as food by a living animal it is, however, slightly changed before it is really turned to account, by being deprived of a minute quantity of its carbon, and so made a trifle less sugary or sweet. This change is effected in the stomach by the action of digestion. In the less condensed or less sweet form it thus assumes, the sugar becomes a new substance, which is known as **grape sugar*** because it is found in the juice of ripe grapes. This form of sugar is produced, indeed,

* Each molecule of grape sugar consists of twelve atoms of carbon, twenty-four atoms of hydrogen, and twelve atoms of oxygen.

in the ripening of nearly all kinds of fruits, and is the immediate cause of their sweetness. It is also much more generally present in the products of vegetable life than cane sugar, which is found in only a limited number of plants. Grape sugar, on the other hand, is found more or less in the juices of all plants. When grape sugar is taken into the bodies of living animals it is used as a food without needing to undergo any intermediate process of digestion. On account of this important difference in the properties of the two classes of sugars, it has been found convenient to distinguish them from each other by exact names. **Cane Sugar** is scientifically spoken of as **sucrose.** Grape sugar as **glucose.** There are about 147 grains less of carbon in one pound of grape sugar than there are in one pound of cane sugar.

Honey is simply grape sugar that has been made by plants for the nourishment of some important parts of their flowers, and that has been gathered from the flowers by bees. In five ounces of honey four ounces are glucose, or grape sugar.

It is grape sugar also that is formed in malt when barley is malted by the process of artificial germination. One pound of grape sugar can be extracted from five pounds of malt.

LESSON XX.

EDIBLE FRUITS.

In all kinds of ripe fruit the grape sugar which confers upon them their sweetness is made by the living plant as nourishment for itself. When a ripe fruit is plucked from the tree and eaten by human beings, the food intended for the perfection of the seed is diverted from the purpose for which it was designed by the plant, and made serviceable to men, exactly as happens in the case of the corn-grains that are harvested and ground to be converted into flour and bread.

The grape sugar manufactured in ripening fruit is mingled with some other ingredients that are of scarcely inferior importance, because, taken together with it, they render the fruit to a certain extent nutritious to animals.

There is in all ripe fruits a small quantity of a gluten-like substance dissolved in the juice; and there is also another somewhat similarly built-up substance termed **pectose**, which possesses the curious peculiarity of being turned into a kind of jelly, alike by artificial heat when the fruit is cooked, and by the natural heat of the sun when the fruit is ripened upon the tree. One of the most useful of English fruits, the **apple**, is a good illustration of these properties of all kinds of edible fruits. By far the larger part of the weight of an apple is composed simply of water. In this, grape sugar, pectose and the gluten-like compound are dissolved; and the solution, mingled with a peculiar acid production upon which the sharpness of the fruit depends, is then packed away in the pulp, or flesh, in little intermeshed chambers formed of thin plates of vegetable texture. In ripe apples there are more than 13 *ounces of water in every pound;* and about 430 grains, or nearly 1 ounce of the sugar, pectose and gluten, or the substances capable of being turned to account as food. The peculiar acid (which in the case of the apple is called **malic**,) amounts to 70 grains in the pound, and the thin plates of firm structure provided to give substance to the whole, to 224 grains. The pips, or young seeds, are stored away in the midst of the fleshy substance of the fruit in little cavities.

The various other fruits which are ripened in England, all contain similar ingredients to the apple. The only difference is that the more juicy fruits have smaller quantities of the jelly-like pectose, and of the compact flesh. It is the proportionally large quantity of those substances in the apple that constitutes its superior firmness and durability. On account of this quality, and of its dryness, the apple can be preserved a long time, especially if gathered before it is quite ripe, so that the pectose is left to be converted into soft jelly by keeping, or the art of cooking. The more juicy fruits cannot be preserved in this way, but decay almost as soon as they are thoroughly ripe.

The most esteemed of the fruits grown in England are the strawberry, raspberry, gooseberry, currants black, red, and white, the cherry, plum in many varieties, peach, nectarine, apricot, mulberry, apple, pear, and grape. The difference of flavour in these, and in all fruits, depends upon the formation by the plant of a delicately elaborated ingredient, which is termed **essential oil.** This is a thin oil-like liquid, which is packed away in little membranous bags or sacs, suspended in the pulpy flesh, or in the skin of the fruit, and which is of so volatile a nature that it can be entirely evaporated by heat. If a piece of paper be stained by a *fixed* oil, the greasy spot remains, however much the paper may be warmed. But if a stain be made upon paper by an *essential* oil, it can be quite driven away by heating it before the fire. All the **essences** which have strong flavour and fragrance, such, for instance, as peppermint, carraway, lemon, and the rest, are of this volatile nature. They are all procured by distillation from the vegetable textures in which they have been primarily stored. The molecules of these essential oils are all made of varying quantities of the four principal elementary atoms of organized structure, united with very minute quantities of some other ingredients which determine their flavour and odour. The almost endless diversity of fruits depends upon the enormous variety in which these flavouring substances are fabricated by nature.

There are many fruits which can be grown to perfection only in warmer countries, but which, nevertheless, can be brought to England in a good state. The chief of these is the **orange.** The success with which it is imported is mainly due to its being gathered and packed for transport before it is quite ripe. The juice of the orange contains about 10 per cent. of grape sugar, mingled with small quantities of pectose, gluten, essential oil, and citric acid. Some of the imported fruits are preserved simply by the large quantities of sugar which they contain. The ripe fruit is dried by the evaporation of the more watery part of its juice, until the sugar has become thick, and encrusted into a mass. **Raisins, sultanas,** and **currants** *are all grapes* dried in the sun and air after they have been gathered as ripe fruit. Raisins are so called from the Latin word **racemus,** a bunch of grapes. Sultanas have no seed stones. **Currants** were once called **Corinths,** because they were first brought from the port of Corinth. All **French plums, dates,** and **figs** are dried sugary fruit. Dates and figs contain as much as eight and nine ounces of grape sugar in the pound. All such sweet dried fruits possess in an eminent degree the nutritious character of the grape sugar which is so abundant in their constitution. Large quantities of all these dried fruits are brought from the southern countries of Europe.

Nuts, which are fruits of another character, have the nourishing substance deposited round the seed, in a firm and dry state. A large part of that substance is a glutinous or nitrogen-containing principle, which, in the case of the nut, is called *vegetable albumen*, on account of its very close resemblance to hard-boiled white of egg. The albumen of vegetable seeds is, indeed, so very nearly of the same nature as hard-boiled white of egg, that the chemist can scarcely find any difference in the composition of the two. In most of the nuts, however, this albumen has a large quantity of fixed oil mixed up with it, which can be squeezed out by strong pressure. **Almond oil** made from almonds is of this character. The **colza oil**, made from rape seed, which is burned in lamps, is all pressed out from the albuminous substance of the seed. The common **walnut** is a very good illustration of this peculiarity of composition. One pound of walnuts contains two ounces of albumen, and five ounces of oil. This nut is grown in France and Switzerland for the production of oil.

All the plants which yield food-substances that are of value to man resemble each other in one very notable characteristic. They are all improved in their capabilities of production by continued cultivation, and they all mature a very great variety of their own particular kind of food-substance when cultivated with care and skill. A very remarkable illustration of the truth of this statement was afforded in the early history of the potato. The potatoes which were at first grown in the British Islands were of such an inferior quality that no store was set by them. The cultivation of the plant was on this account confined to gardens for a century and a half after its introduction into England. It was not made the object of field or farm cultivation in Scotland until the year 1732. Now there are almost endless varieties, which have been raised from seed.

The way in which fruits are improved by cultivation is also well illustrated, when the wild crab, which is the only English native representative of the apple, is compared with the Ribston pippin; or when the wood-strawberry is compared with the fruit which is now sold by market gardeners under the name of The British Queen. The immense diversity of fruit that can be produced by the ingenuity and skill of the gardener is instanced in the case of every kind which, like the apple, pear, and strawberry, has a high place in general estimation.

LESSON XXI.

ANIMAL FOOD-SUBSTANCES—MEAT.

Living plants build up the complex substances that are required for the construction of the bodies of animals. The substances thus prepared in the textures of the living plant constitute **vegetable food.** When this vegetable food is consumed by animals it is rearranged and redistributed into the different structures of their bodies. Still it is in those new forms essentially the same substance, and therefore capable of being used as food over again. Consequently numerous flesh-feeding, or carnivorous animals, such as lions and tigers, get all the nourishment of their bodies out of the bodies of the weaker vegetable-feeding animals, which they catch and devour. The carnivorous animals then, do, with their vegetable-fed prey, precisely what man does with the grain-substances he feeds upon. They take that which has been provided for the support of the living operations of other bodies and appropriate it to their own use as food.

Human beings, in some degree, follow the example of these flesh-feeding animals. In doing so, however, they again adopt the plan of increasing, by skill and care, the numbers and varieties of the creatures best suited to furnish them with this kind of animal food. They breed them upon farms, and nourish them with vegetable crops grown for the purpose upon cultivated ground. In the earlier periods of human history, men used to hunt down the animals they employed as food, very much as the lions and tigers hunt their prey; and it was only after a time that they learned the better plan of keeping them for use, and feeding them upon enclosed pastures and cultivated crops. When they had once entered upon this course, they soon made the further discovery that they can improve the breeds of food-animals by this artificial care, just as they can obtain improved kinds of vegetable foods and fruits by skilful cultivation.

The animals which are bred and fed artificially by man for increasing his supplies of food are principally the **ox**, the **sheep**, and the **pig**. The food which is furnished by them, **beef**, **veal**, **mutton**, **lamb**, and **pork**, goes by the general name of butchers' meat.

In all these varieties of meat there is a mingling together of the two different kinds of food-substances that are previously built up by the plants, namely, of the more complex nitrogen-containing compounds with the more simple amyloids, which are destitute of nitrogen, and in that sense are of the nature of sugar and starch. But meat is at once distinguished from the vegetable food-substances out of which it is formed, by the fact that in it the nitrogenized or plastic compounds are in much greater abundance than they are in vegetable food. *The animal foods are more plastic and more flesh-forming, or structure-supporting, than the vegetable.* This is only what is to be expected when it is borne in mind that meat is in reality *already* flesh. When an animal feeds upon meat it merely transforms the already formed flesh of another body into its own.

In meat, the plastic or nitrogen-containing compounds originally extracted out of the grass of the pasture are found in three distinct conditions, or forms, which are nevertheless alike in being all nearly allied in their nature to the gluten of vegetable grain. But a diversity in certain subordinate characters makes it nevertheless convenient to distinguish each different form by a separate name. In point of fact each is vegetable fibrin, or gluten which has been slightly altered within the animal body by some additional fashioning process, to fit it for the accomplishment of some particular service or work.

The first to be noticed of the nitrogenized compounds contained in meat is a substance that is entirely insoluble in water. If some shreds of raw beef are washed again and again in water, they are turned at last into the condition of pale stringy fibres, or threads, which have lost all their colour. This part of meat is not soluble, even in boiling water. It is called **fibrin**, on account 1
of the fibrous stringy form in which it exists when separate from other ingredients.

If the water, which has been used to wash the fibrous part of beef, be heated to nearly the boiling point, viz. 212° F., it is found that a white substance is deposited from it in flakes. This substance appears to be of precisely the same nature as white of egg, which is made solid in the same way by the heat of boiling water. It is on this account called **albumen**, which is the proper name for 2
white of egg. The essential property of this form of nitrogenous compound, therefore, is that it is soluble in cold, but not at all in very hot, water.

The third form of nitrogenous substance in meat also remains in the water after the fibrin has been removed; and it may be procured from it in the condition of a firm jelly, if the quantity of the water be diminished by long boiling, and if the liquid be then allowed to become cold. This substance, therefore, is distinguished by being soluble in hot water, and not soluble in cold; and it is
3 called **gelatin**, from the jelly-like appearance which it assumes when procured separate from the other ingredients of the meat. It is the firm part of all jellies. The gelatin sold in the shops, and the substance familiarly known as isinglass are preparations of this compound artificially extracted from various animal substances.

In mutton and beef these several ingredients are so proportioned to each other, that one pound of either contains about 420 grains, or nearly one ounce, of fibrin, and 120 grains, or a little more than a quarter of an ounce, of albumen. The gelatin contained in lean meat rarely amounts to half the quantity of albumen; and on this account jellies are prepared from the tough and sinewy parts of animal structures, and even from gristle and bone, which all contain much larger quantities of gelatin than the more fleshy portions. The actually nourishing part of beef and mutton—that is, the portion of the meat capable of being converted into the living structure of other animal bodies—probably does not often exceed two ounces in the pound. Something more than seven ounces of the rest of that weight is made up of water. Uncooked meat is so full of moisture, or juice, that very nearly half its weight is due to water. The juice of the meat contains the albumen, which is soluble in cold water, and a small quantity of other nourishing compounds that are soluble in the same way, and more or less allied to it. The flesh of animals that are not fully grown and mature, such as veal and lamb, contains generally as much as two ounces more water in the pound. It has also a considerably larger quantity of gelatin, and proportionally less fibrin, than older meat.

The unnitrogenized food-substances contained in meat, which are the representatives of the sugar and starch of the vegetable substances from which meat is formed, are all found in the condition of **fat.** Fat is simply oil made by the further condensation and more rich carbonization of sugar and starch, and by some admixture of a thickening substance which converts it into a kind of pulpy material more convenient for storing away. This thickened oil, or fat, is deposited in a series of small sacs or bladders, constructed of membrane for the purpose. Each molecule of fat is formed of atoms of carbon and hydrogen, worked up with much smaller quantities of oxygen than are contained in sugar or starch. Fat is for this reason much more heating, or warmth-giving, when consumed in the animal body, than sugar or starch. It is, as everyone knows, of so combustible a character that it will burn with a bright hot flame when set light to.

The quantity of the unnitrogenized food-substance, or fat, that is contained in meat, varies considerably in the different kinds. But there should be at least six ounces of fat to the pound of meat that is used for food.

Beef is the most nourishing of the three principal kinds of butchers' meat, and contains the largest quantity of firm flesh-forming substance. It is the best meat for hard-working people, but not the easiest to digest. **Mutton** is less nourishing but more easily digestible than beef. On this account it is altogether the more wholesome of the two. But it has economically the disadvantage that it loses more weight in cooking than beef, because it is less firm and fibrous, and because it contains more fat.

Pork is the meat which is most used by human beings, after mutton and beef. The value of the pig as a food-animal is chiefly dependent upon its ability to form its own substance out of all kinds of waste materials, and the readiness with which it fattens. Pork generally contains very much less fibrin and albumen than mutton and beef, and very much more fat. One-half of the weight of pork is commonly due to fat; and considerably more than this when the pig has been fed for the production of bacon. Bacon not unfrequently contains as much as three-fourths of its weight of fat. Although pigs will eat nearly all kinds of otherwise waste substances and fatten upon them, they must have been fed upon better food, such as milk, peas, beans, potatoes, and barleymeal and oatmeal, for the pork to be of the best quality. Pork is both less digestible, and less nourishing, than either mutton or beef; and so is veal, which is nevertheless sold for a higher price. Lamb, in the same way, is less nourishing and more expensive than mutton.

The quality of meat has a great deal to do with its value as food. It is hence of consequence to know what appearance and condition flesh-foods should present. This is best learnt by observation and experience; but, in anticipation of these, it should be understood that *good beef is of a full red colour* in the flesh, and slightly yellowish in the fat, which should be mingled in or *marbled* with the flesh. The flesh should also be firm and plastic so that it rises up quickly again after being pressed by the fingers. Soft, flabby beef is always of doubtful quality. *Mutton should be bright-coloured*, fine-grained, and tender to the touch, with firm white fat. *Pork should have a thin rind* which feels cool to the touch, firm flesh, and fat free from kernels

LESSON XXII.

POULTRY, FISH, AND PRESERVED MEAT.

Poultry of various kinds kept in a domesticated state to be turned into food, such as fowls, ducks, geese, and turkeys, all yield a meat which is characterized by the abundance of water it contains, and by the almost entire absence of fat. The same, also, is the case with the wild animals, whether with or without wings, which are killed as game, such as pheasants, partridges, and hares. The flesh of the barn-door fowl has three-fourths of its weight made up of water, and contains about two ounces of fibrin and albumen in every pound. Flesh of this kind is very delicate and nutritious, but needs to be eaten with some kind of food that contains the un-nitrogenized principles, such as sugar, starch, or fat, in which it is itself deficient. It will be observed that all the food-animals of this class are themselves nourished either upon grains or grass. The fitness of game to be eaten without any injurious result, when it is somewhat advanced towards decomposition, is generally considered to be due to the absence of fat. The flesh of poultry and game is, upon the whole, more delicate and more easy of digestion than butchers' meat, but is more costly.

Fish contains essentially the same kind of ingredients as butchers' meat. There is a considerable quantity of albumen and fibrin, and in some instances, of gelatin also, in it; and fat is represented by more or less abundant stores of oil. Mackerel often yield two ounces of nitrogenized food-substance, and two ounces of oil in every pound. Eels, salmon, and herrings are all oily fish. Whiting is the least oily kind that is used as food. Flounders, plaice, soles, cod, and turbot stand next to the whiting in this particular. The least oily kinds are the most wholesome and nourishing, but all varieties of fish contain such an abundance of nitrogenized substance that they need to be eaten with the addition of some kind of unnitrogenized food.

Shell fish also furnish a great deal of nourishment, owing to the large quantity of nitrogenized substance that is present in their flesh; but some of them, as lobsters and crabs, are by no means choice in their own habits of feeding, and are apt, therefore, at times to furnish unwholesome food for human beings. The oyster is eaten raw, because much of it is converted into a tough and not easily digested substance by cooking. Raw oysters contain more than two ounces of nitrogenized food, and nearly thirteen ounces of water, in every pound of their flesh. Shrimps and prawns are of a similar character to the lobster.

Various plans for **preserving meat** from the rapid decomposition to which it is prone, so that it may be kept for some time in store, or be transported for long distances, have been adopted from time to time. The oldest and best known method consists simply of drying the flesh by heat, and exposing it at the same time to the smoke of burning wood. The drying drives off the abundant moisture, of the natural juices of the meat, that favours the molecular changes upon which decomposition depends. The influence of wood-smoke is due to there being present in it a peculiar substance, known under the name either of creosote* or carbolic acid, which has the property of arresting the decomposition of complex bodies containing nitrogen. Various kinds of

* Creosote; from two Greek words—*creas*, flesh; *sozo*, I preserve.

fish, such as the salmon, haddock, and herring, are very effectually preserved by this simple process, and retain their nourishing qualities. There are as much as fourteen ounces and a half of fibrin, and one ounce and a half of oil, in each pound of dried haddocks and herrings.

When fresh raw meat is soaked for some time in strong solutions of salt, or pickled, as it is termed, the fibre of the meat is hardened and dried by the power which the salt has of drawing the moisture of the flesh away from it. Meat which is hardened in this way is found less prone to the loosening of its molecules, which is the first step towards decomposition. Bacon and hams are preserved by a combination of the salting and smoking processes. They are first soaked in brine, and afterwards smoked in the fumes of burning sawdust or wood. The substance of the meat is, in consequence, materially changed. It is deprived of a considerable part of its moisture, and at the same time the fat is rendered more easy of digestion, and more suitable to be used as food. In well-prepared bacon there are not more than three ounces and a half of water to the pound. But there are more than ten ounces of fat; and each pound is considered to yield very nearly one ounce of nitrogenized food.

The great economical value of this method of preserving meat will be at once understood from the statement that in the year 1875 more than 130,000 tons of bacon and hams were brought into England from beyond the sea for consumption as food. As there are 2240 lb. in a ton, this means rather more than 9 lb. each for every man, woman, and child in Great Britain.

In the case of the preserved meats which are sent from America and Australia, an entirely different principle is brought into play. The method in those instances is to drive away all air and some of the moisture from the meat, and then to seal it up in tin boxes, so that no fresh supply of air can get to it until it is about to be consumed. The efficacy of this method depends upon the fact that, in all cases of decomposition and decay, it is the restless and ever-corroding oxygen of the air which causes and keeps up the destructive change. Atoms of the oxygen seize upon atoms of the combustible part of the meat and carry them off, just as they seize upon the atoms of the charcoal when it is made red with heat, and the loosening of the molecules of the meat is due to this decomposing interference of the oxygen. In order to exclude the air the meat is first packed into tin boxes, in which only a very small hole is left These boxes are placed in a bath of strong solution of chloride of lime reaching nearly to their tops. The solution is then made to boil by a fire beneath; but it does not do this, on account of the salt which it contains, until it is some considerable degree hotter than boiling water. All the air is thus driven out from the insides of the cases by the rush of steam, and the small hole of each is instantaneously soldered up, so that no more air can get in. If the top of an Australian meat-tin is examined it will be found that it is a little concave or bent in. This is caused by the external pressure of the atmosphere.

The Australian meats prepared in this way have all their nourishing principles preserved in them. The chief disadvantage which belongs to them appears to be that they are in some measure over-cooked from the great heat used in their preparation. On this account they are not altogether convenient or suitable for cooking a second time. They may, however, be made very palatable and useful by the exercise of a little skill, and they ought to be considered welcome additions to the food-stores of a densely populated land like England.

LESSON XXIII.

MILK, BUTTER, CHEESE, AND EGGS.

Before young animals are able to eat solid food, they are nourished entirely upon **milk**, which is provided for them by their mothers. It hence follows that all the ingredients which are necessary to constitute a perfect food must be present in milk. Milk is nature's own pattern of the composition of food, at least so far as the need of very young animals is concerned.

Human beings when they have passed the years of early childhood still make very free with cows' milk just as they do with ox flesh, and they keep large numbers of cows to furnish them with daily supplies of this nourishing food. The milk-supply has also a notable advantage over that of beef, for the same animal, if well fed and cared for, can go on yielding milk for considerable periods of time, whereas the meat-supply furnished by one animal of necessity ends when it is killed.

As milk is the pattern-food prepared by nature itself, it has in it both a plastic or nitrogen-containing substance, and a starch-like compound which is destitute of nitrogen. In milk, however, both these necessary ingredients are suspended in water in the form of what is termed "an emulsion." This means a liquid in which matters that are not actually soluble themselves are kept mixed up with the water by the help of some thick or mucilaginous substance.

A pint of milk, therefore, is considerably heavier than a pint of water, on account of the solid substances suspended in it, and weighs nearly 21 ounces. Of these about 17¾ ounces are water; 370 grains, or nearly one ounce, nitrogenous or plastic substance; 333 grains, or about three-quarters of an ounce, unnitrogenized substance, or oil; and a little more than one ounce is sugar, which is dissolved in the water, and in this instance is called **lactose.** Lactose is the name given to *the sugar of milk*, which is of a nature very nearly resembling glucose, or the sugar of grape. It is the lactose of milk that confers upon it its pleasant sweet taste.

When fresh cows' milk is allowed to stand quietly in broad pans, there soon spreads all over its surface a layer of **cream,** a substance which is of a thicker consistence than the milk itself. This covering over of the surface with cream is due to the rising up from the milk of a vast number of little particles previously diffused through it, which are the cause of its "milkiness," or thick whiteness. These particles rise to the surface, instead of sinking to the bottom, because they are lighter than the rest of the milk. They float upon it as corks float upon water, and are in reality little globules of fat, or oil, contained in thin, bladder-like films of albuminous membrane. *Cream is therefore the oil of milk.*

When cream at a temperature of about 60° of Fahrenheit's scale—that is, at a temperature at which the air feels pleasantly warm to the skin—is kept moving round in a churn, the oily part soon collects, in consequence of the breaking up of the filmy coats of the globules, into a kind of adhesive mass, or lump, which is called **butter.** Butter is simply the oil, or fat, of milk collected together into a lump. Twenty-three pints of milk should yield sufficient cream to furnish one pound of butter.

The milk, which remains when the cream has been taken away from its surface, is called **skim milk.** It is milk which has been deprived of the greater part of its oil.

If milk be allowed to stand freely exposed to the air it sooner or later becomes slightly sour, and separates of its own accord into two parts—a firm white flaky deposit, and a thin greenish-white liquid. The flaky deposit is called **curd**, and the thin liquid **whey**. The whey is principally a solution of the milk-sugar, or lactose, and of minute quantities of less important soluble matters. The curd holds nearly the whole of the oil-globules, or butter; but it contains something besides of a firmer consistence, which imprisons those globules. The firmer and denser part of the curd is the nitrogen-containing substance of the milk, which has a name of its own, although in composition it is very like indeed to gluten, or albumen. It is called **caseine.**

But the caseine of milk can be separated from it in another way, and is so separated from it to make cheese. The liquid is not left to grow sour of its own accord; but there is added to the still fresh milk an acid, procured by placing a piece of the stomach of a calf in water. This is called **rennet.** A very small quantity of rennet is enough to throw down the curd from a large quantity of milk. The curd, which has been separated in this way, is dried and pressed until it forms the more or less firm substance known as **cheese.** Cheese is merely the nitrogen-containing, plastic portion of milk separated from its other ingredients. The name caseine, which is given to the firmer part of this curd, is derived from **caseum**, the Latin for cheese.

But when these particular ingredients of milk, the butter and the cheese, are taken out from the liquid by the processes just described, the separation of the two different kinds of substance is not complete. There is always a little of the caseine and some of the lactose or sugar mingled with the butter; commonly about 70 grains of caseine, and about 20 grains of sugar, in every pound of butter. On the other hand, large quantities of butter are entangled in the curd of cheese. In the best kinds of cheese there are four ounces of oil, or butter, as well as four ounces of caseine in each pound. The exact proportion, however, differs materially in different kinds, because different processes of manufacture are used in different places. Thus, in some kinds of cheese, the entire milk, with all the cream in it, is employed; in other kinds, only the milk from which the chief part of the cream has been skimmed away. And in yet others, further quantities of cream are added to the milk.

Stilton cheese, which is a highly esteemed kind, of English make, is formed from the entire natural ingredients of a good quality of milk. **Cheddar** cheese has rather less oil in its composition. **Cheshire** and **Gloucester** cheeses have less oil again. The **American** cheeses have less than the Cheshire and Gloucester; and the **Dutch** cheese is made from milk as far as possible deprived of its cream. **Cream cheese,** which in some places is made wholly of cream and in others of milk with an additional quantity of cream, is allowed to retain a considerable proportion of water, because it is intended to be eaten new, instead of to be preserved, as the drier and firmer cheeses are. Whole milk cheeses are considered to contain about equal quantities of oil, caseine, and water; whilst skim milk cheeses contain less oil and more water. Cheese, however, of whatever quality, is a very plastic, nutritious, and condensed form of food, and, unless when soft and new, not easily dissolved or digested in the stomach. It should, consequently, be used in small quantities, and mixed with a considerable amount of bread, rice, or some other kind of farinaceous food. It is generally considered that *one pound of good cheese* can yield, or build up, as much as *five ounces of animal flesh.*

One pound of cheese contains about five ounces of water; one pound of butter, on the other hand, as much as fourteen ounces of oil, or milk-fat, and scarcely more than one ounce and a half of water. Butter is a very valuable article of food, on account of the readiness with which it is digested and received into the system, and of the great warming power it possesses. *One pound of good butter has more warmth-sustaining power than two pounds of starch.* Its flesh-forming powers, on the other hand, are comparatively small, and on this account it requires to be used in connection with nitrogen-containing substances.

One pint of new milk yields 546 grains of carbon and 43 grains of nitrogen; one pint of skim milk 437 grains of carbon and 43 grains of nitrogen. Seven pints of new milk per day would yield as much nitrogen as a full-grown man requires, but would not give more than two-thirds of the necessary carbon.

Eggs take the same place amidst animal food-substances that seeds hold among plants. They are stores of perfected nourishment packed round the germ of a new creature, in order that it may be duly fed in the early and helpless period of its growth. In the seed such stores are deposited in a dry, condensed state within the husks, or outer coverings of the grain. In the egg they are placed in a soft and moist state within the hard, brittle case, which is known under the name of the shell.

The egg in most common use is that which is furnished by the barn-door fowl. It consists, as do all eggs, of two parts—a deep yellow, and nearly opaque ball of thick, viscid substance floated in the midst of a transparent, much paler yellow, glairy liquid. The inner yellow ball is called the **yolk**, and the outer glairy investment the **white** of the egg. The latter portion is termed the white, because it becomes firm and of a milk-like whiteness, when heated in boiling water. Another name by which the white portion is known is **albumen**; that word being derived from **album**, the Latin term for white. The yolk of the egg seems to float loosely within the white; but it is really suspended, or hung, in its position there by a couple of cords which stretch out from either end of it to the shell. The yolk of the egg also becomes somewhat hard on being boiled; but much less so than the albumen. When boiled to its hardest, it is still a comparatively soft or pasty substance, much more easily broken up than the white.

The average weight of a hen's egg is about one ounce and three-quarters. Of this weight, 75 grains belong to the shell, and to a delicate film, or membrane, by which it is lined. Four hundred and fifty grains belong to the white, and a little more than 200 to the yolk. Both the yolk and the white have a large quantity of nitrogen-containing substance in them.

The amount of albumen in the white is 90 grains. In the yolk the albumen is mixed with caseine, and the two amount to 112 grains. In the white there are also about 15 grains of oil, or fat; whilst in the yolk, the oil amounts to 225 grains.

The water of the white, on the other hand, is 640 grains, whilst of the yolk it is about 380. If the white and the yolk of an egg be taken together, one pound of the mixed substance contains eleven ounces of water; two ounces and a quarter of albumen and caseine, or of flesh-forming material; and one ounce and a quarter of oil, or of heating material. Eggs are consequently very nutritious articles of food.

One pound of egg is capable of building up something more than two ounces of flesh; and is about equal in nourishing power to the same weight of butchers' meat. It is generally considered that eighteen average-sized hen's eggs contain enough food of all kinds for a full-grown man for a day.

In considering these numbers, it is well to bear in mind that there are 7000 grains in a pound avoirdupois, and, therefore, 437½ grains in an ounce.

LESSON XXIV.

MINERAL, OR INCOMBUSTIBLE FOOD-SUBSTANCES AND CONDIMENTS.

The complex food-substances which are prepared or built up by the plant are all of a combustible nature—that is, they are all capable of being burned by the corrosive influence of oxygen, exactly as a mass of black coal is burned in the fire. But those containing nitrogen, before they are burned, first form part of the actual substance of the animal body which feeds upon them, whilst the simple compounds that are destitute of nitrogen are burned at once without having to fill the intermediate constructive office. The **nitrogen-containing substances**, in order to enable them to play their double part, are often so complex that they contain five different kinds of elements, and as many as *several hundreds of atoms* of the different kinds, in each of their molecules, whilst the **un-nitrogenized compounds** rarely contain as many as *twenty-one atoms* in each molecule. The immediate consequence, however, of the complexity of the flesh-forming substances, and of the presence of nitrogen in them, is, that they are all mutable in their composition, or prone to change. The operations both of growth and life, of destruction and decay, are favoured by this peculiarity.

In addition to these combustible substances, certain other ingredients are used in the fabrication of the textures of the living body, which are incombustible, or unable to be burned, because they are already combined with as much oxygen as they can unite with. These incombustible substances are used only in very minute quantities. Small traces of the different kinds are mingled in with the carbon and three principal gaseous ingredients, a little of one here and of another there, to form certain structures of the human frame. Thus **lime, magnesia,** and **fluorine,** with **phosphoric** and **carbonic acids,** are mixed with gelatin to constitute bone and gristle. About ten pounds out of the weight of a body of 154 pounds are due to its mineral and incombustible ingredients.

But next to lime and its salts, which are thus used to give hardness and firmness to the bony skeleton, the most important mineral ingredient is one which is an exception to all the rest upon two grounds. It does not occur in vegetable structures, and it is not combined with oxygen, although a compound body. This exceptional mineral substance has therefore to be added to food in a distinct and independent way. It is familiarly known as **salt.** There are always about seven ounces, or nearly half a pound, of this mineral ingredient in a full-grown human body. It is used, amongst other things, to form the red-colouring matter of the blood, the fibres of the flesh, the digestive juice of the stomach, and the bile. Salt is not acted upon by the corrosive power of oxygen, because it is already combined with another gas called chlorine, which plays a similar, although a subordinate part, to oxygen.

Salt is contained in small quantities in some kinds of animal, though it is not found in vegetable, food. Altogether from a quarter to half an ounce of salt in the day is required by an adult human being. As so much as this cannot be furnished in ordinary kinds of foods, salt is the only mineral ingredient that is taken by itself. It is, indeed, properly a food, as it is necessary for the building up and decomposing processes of vital action. In this sense therefore it takes rank as the one **mineral food.**

The mineral ingredients which take the place of salt in *vegetable* structures are **potash** and **soda.** Of these there are about four ounces in a human body. **Iron** also occurs in the blood in minute quantities. Of the whole of these incombustible mineral ingredients the same thing has to be said. They all aid in the construction of the combustible substances, and in the changes which occur when those combustible substances are burned and destroyed. It will be remembered that there are **eleven distinct elements** of a subordinate character in organized structures beside the **four primary ones,** carbon, hydrogen, nitrogen, and oxygen. Of the eleven, **chlorine** is a gaseous body, at ordinary temperatures, like oxygen, and is of a somewhat analogous character in its strong although rather less energetic tendency to combine with other elements, and even in its ability to produce light and heat as it combines with them. Thus salt, or **chloride of sodium,** is a combination of chlorine and sodium, as soda is of oxygen and sodium. **Fluorine,** which is found in the bones and teeth of animals, is probably somewhat allied to chlorine in its nature, but it has never yet been procured for examination in a pure and uncombined state. **Silicon** is the hardening ingredient of flint, and is used in the construction of the outer skin of many kinds of plants. **Phosphorus** and **sulphur** are soft solids that burn in their elementary state, but that cease to be combustible when they have combined with as much oxygen as they can retain. They are used with lime and magnesia in the formation of the earthy portion of animal bones. Sodium and potassium are metallic elements which are transformed into the well-known substances soda and potash, when united with oxygen, and which, in that state, are used as ingredients of a considerable number of organic products. Calcium and magnesium are both metals, which become lime and magnesia when combined with oxygen. The metal iron is contained in minute quantities in nearly all the structures of the animal frame, and especially in the red corpuscles of the blood, of which it is a very important ingredient. The metals, manganese and copper, are also present in the blood and brain, but in still more minute proportions.

The mineral ingredients of the food which are incombustible, are all easily procured apart from the more volatile substances that can be burned away and converted into vapour. The ashes, which are left when combustible vegetable substances, such as sugar, starch, gluten, and wood, are burned, are a mixture of the incombustible ingredients that were employed in the building up of their structures. In the same way, the ashes, which remain when animal bodies have decayed and putrefied, are the mineral and incombustible ingredients that formed part of their textures. The putrefaction or decomposition of an animal body after death, as well as the gradual change which its structures undergo whilst they still remain alive, are indeed only a modified and slow form of burning.

The very small proportion of the subordinate and incombustible ingredients that are used in the construction of animal bodies is strikingly shown in the comparatively trifling weight of ashes that remain, after all the combustible parts of an organized structure have been consumed. If twelve pounds be allowed for the lime and magnesia contained in the bones of a human body, not more than *three pounds three ounces and a half* of inconsumable ash is left as the residue of all the other incombustible elements.

Besides the substances that are used as food by human beings, various things are added to them in small quantities to communicate flavours which are agreeable to the taste. These subordinate additions to the food are called **condiments**; that word being derived from the Latin term **condimentum**, which signifies a seasoning or "flavour." The flavouring condiments are all formed by the building-up operations of vegetables, and are mostly due to the presence of small quantities of essential oils, fabricated by the plant, and then stored away in some portion of its denser textures, most commonly in the firmer parts of the seeds. The most generally used of these condiments are **mustard** and **pepper**, which are the seeds of two different kinds of plants. The seasoning action of the entire group is very well illustrated by the influence of mustard. It rouses up, or stimulates, the membranes of the mouth and stomach to produce somewhat increased quantities of the liquids or juices which are used in softening and dissolving the firmer portions of the food. Condiments of this class are, therefore, capable of being turned to good account, when used with judgment and care. Articles of food which are coarse and unpalatable in themselves, may be rendered agreeable to the taste, and in some instances more manageable to the digestion, by the help of seasonings and flavourings. But, in common with all unnatural stimulants, condiments should be employed with moderation. Black and white pepper, cayenne pepper, horse radish, dried herbs (as thyme and sage), capers, and the fresh vegetables already alluded to, namely, garlic, shallot, and onion, are all seasoning substances of this class. **Pickles** also belong to the same group; being vegetables that have had their flavours preserved and heightened by the action of condiments—of vinegar, spices, salt, and peppers. Like other condiments, pickles are very agreeable additions to certain kinds of food; but as they are not readily digested, they should never be taken otherwise than in moderate and restricted quantity. The condiments that are used with farinaceous and sweet articles of food are called **spices.** Their action and influence are the same as those of the seasoning condiments. They, too, are stores of essential oils packed away in some of the dense textures of a plant. They all have flavours peculiar to themselves, for each different kind of plant makes its own flavouring substance. The best known of the spices are ginger, cinnamon, nutmeg, cloves, mace, allspice, and carraway seeds.

III.—Preparation of Food.

LESSON XXV.

COOKING.

The purpose which is chiefly aimed at in cooking food is to render it more soft and soluble, so that it may be more easily broken up into separate molecules when placed in the digestive cavity of the animal body. Cooking may, indeed, be looked upon as the first step in the digestive process which converts solid food-substances into soft and half-liquid pulp. Food-substances which have been cooked are, when placed in the stomach, more easily penetrated by the liquids which are there prepared to complete their conversion into this state. The word, to COOK, is derived from the Latin term COQUO, which signifies to soften, or seethe, by moisture and heat

Some considerable amount of knowledge and skill is, however, necessary for the successful accomplishment of this purpose, because different kinds of food-substances are differently affected by the application of heat. The process of cooking, on this account, has to be modified to meet the circumstances of each case. The plan which softens and dissolves one kind of food, very frequently serves only to harden other kinds, and to make them less soluble and digestible. In addition to this, there is a still further object to be gained by cooking when it is judiciously performed; that, namely, of making the food as palatable to the taste as possible. Well-cooked food is always of an agreeable flavour, besides being tender. Ill-cooked food is as unpalatable as it is hard and indigestible.

No better instance of this truth can be offered than that furnished in the case of meat. Meat consists of fibrin, which is not soluble in either hot or cold water; of albumen, which is soluble in cold water, but hardened and made insoluble by heat; of gelatin, which is soluble in hot water; of the natural juices of the flesh, which are soluble things already dissolved in natural moisture; and of partially solidified oil or fat. The object of the various processes of cookery which are applied to meat is, to keep all these several ingredients in the best possible state for digestion, and to do this in such a way that the naturally pleasant flavours belonging to them are in no way interfered with.

When meat is cut up into small pieces, placed in a jar, and kept gently heated in a saucepan of water, all the juice of the flesh escapes from the insoluble fibre. This juice contains in itself much of the nourishment of the meat, and if it be kept hot until nearly all the water has been driven off by evaporation, there remains the peculiar substance which is called **extract of meat.** This extract is therefore destitute of the fibrous portion, which is one of the most nourishing of the natural ingredients of flesh, and its value principally consists in the fact that it is more readily digested than the fibrous part, and is therefore more suitable in some forms of illness where condensed and solid food cannot be as easily turned to good account.

In **roasting meat,** however, the primary design is not to draw these nourishing juices of the meat away, but rather to keep them imprisoned amidst the solid fibres of the flesh, so that both forms of nourishment may be preserved and eaten. This is managed by **exposing the meat at once to a clear, hot fire,** so that an outer case or coat of insoluble and impervious albumen may be quickly formed. When this outer case has been thus provided by the quick application of strong heat, the juices are kept inside the meat. The heat may afterwards be continued until it has sufficiently penetrated through the substance of the joint, and the meat will then consist of a well-apportioned admixture of coagulated albumen, fibres, and natural juices. It can be cut into thin slices after it has been cooked in this way, because the coagulated albumen keeps the fleshy substance compact and firm. Meat loses considerably in weight under the process of roasting, because some of the fat is melted and drips away from it, and because some of the water of its juices is driven off by the heat.

When **meat is baked** in an oven, it loses less weight than in roasting, because less of the water of the juices is steamed away. If a small opening be left in the door of the oven to allow some escape of the steam, an arrangement which constitutes what is called ventilating the oven, or if the door itself be left slightly open, meat may be so baked as to be scarcely known from that which is roasted before an open fire. When, on the other hand, meat is baked in an altogether closed oven, although it may be so cooked as to be quite tender, it acquires a taste, from the confined vapours, which at once distinguishes it as having been baked.

In **boiling meat**, if it be at first placed for about a quarter of an hour in **water which already boils**, an outer case of coagulated albumen is formed much in the same way as in roasting, so as to keep in the juices of the meat. If the saucepan be then drawn aside, so that the boiling goes on gently for a considerable time, the entire joint becomes tender, without loss of any material part of its nourishing juices. If, on the other hand, the meat be placed in cold water, and this be gradually heated until it boils, a considerable part of the nutritious juices is drawn out into the water and lost, although the meat may still be rendered quite tender. As a general rule, the tenderness of boiled meat is in proportion to the length of time and the slowness with which the process has been carried on. Tough meat is best made tender by not allowing the water to come to the boil at all, and by continuing the cooking for *several hours at a more gentle heat.*

Stewing is the most suitable mode of cooking for hard and tough meat. It is managed by placing the meat in a very small quantity of water, and cooking it at a comparatively gentle temperature for a long time. The time, indeed, is of more consequence than the heat. The juices under this management are drawn out from the meat, and the liquid which is so prepared on this account forms a part of the dish. In France, a stewing pot is always kept by the side of the fire, so that slow cooking may be constantly carried on. A little fresh water is added to the pot from time to time, and in this way nutritious broth and well-flavoured, tender meat are always at command. The flavour is improved by the use of vegetables, sweet herbs, and condiments of various kinds.

Soups are best made by slow cooking at a gentle heat, the object being to draw off in a liquid state all the nourishment contained in the materials employed. These therefore are put in the first instance into cold, and not into boiling water. They may advantageously consist of the hard and gristly, as well as of the more fleshy portions of meat, because such parts furnish the gelatin, or jelly, of the soup. Bones may also be used for the same reason, and are, indeed, even richer in gelatin than meat itself. They must, however, be broken in pieces before they are used, in order that the gelatin may be efficiently extracted from them. So treated, *two ounces of bones furnish more gelatin than sixteen ounces of meat.* Gelatin thus obtained is almost destitute of flavour, and meat of some kind must on this account be used with the bones. Such meat should be fresh and lean.

Broiling is a similar process to roasting, but differs from it in the fact that small pieces of meat, instead of one large piece, are exposed to the fire. The meat is turned over frequently on a gridiron placed above a clear fire, until a casing of coagulated albumen is formed to keep in the juices, and the exposure to heat is then continued until the fibrous parts within have been sufficiently softened. The chief requisites for good broiling are suitable tender meat in the first instance, and then a clear brisk fire, and frequent turning about during the cooking.

In **frying**, small pieces of meat are cooked in melted fat made hot in a frying-pan. There must be enough fat to cover the meat entirely, and its heat must not be too great. It should be well understood that *melted fat can be made considerably hotter than boiling water*, and that, if too great a heat be employed, the fibrous parts of the meat become hard and tough.

Fish is especially adapted to be cooked by frying, if the precautions of having enough fat entirely to cover the fish, and of taking care that it is of the right heat, be observed. The fish should be thoroughly dried, and dipped into a thin batter of flour and water before it is put into the pan. **Fish** may also be advantageously **baked**, and is very good when **boiled**, but is more likely to have some portion of its nutritive juices drawn wastefully away into the water, when so prepared.

Vegetables, as a general rule, require to be boiled in plenty of water containing a little salt, and to be boiled very fast. **Carrots** and **turnips** should be cut into pieces in order that they may be equally cooked, and the size should be such as is convenient for serving at table. Potatoes should be put into boiling water, and boiled until it is found that they are soft throughout when pricked by a fork. All the water must then be poured away, and the potatoes be covered lightly with a cloth, and left drying near the fire, with the lid of the saucepan a little removed, for about five minutes. A potato is by no means an easy vegetable to cook properly. *Cooking a* *potato affords one of the most ready and effectual tests of the skill of the cook.* Different kinds of potatoes vary, from fifteen to thirty-five minutes, in the time which they require, but they must always be tried by the fork to ascertain their softness. Some cooks place them first in cold water, and then boil them gently until they become soft. But whichever of these methods be followed, the drawing away of the water at the right moment, and the allowing them to dry thoroughly by steaming off superfluous moisture, is indispensable to success. If the potato be left in the water after its proper softening has been ensured, it becomes waxy, or watery, instead of having the dry mealy state which constitutes its excellence.

LESSON XXVI.

MAKING BREAD, CAKES, AND PUDDINGS.

THE **making of bread,** although in appearance one of the simplest processes of cookery, involves in reality a series of considerations of great scientific interest. By means of this process a close compact paste, formed by soaking wheaten flour in warm water, is changed into an open spongy substance that is at once easy for grinding between the teeth, and easy to dissolve when mixed with the *saliva* in the mouth and with the **gastric juice** in the stomach.

The flour of wheat is most suitable for the production of bread because of the toughness and tenacity of its gluten. The gluten, which is procured when the starch of wheat-flour is washed away by streams of water, is so adhesive and firm that it can be pulled out into long strings without the breaking asunder of its substance. It is on this account that this substance is often termed vegetable fibrin.

When bread is made, advantage is taken of this adhesive tenacity of the gluten. The flour is mixed with water and worked or *kneaded*, either by the hand or by suitable machinery, until it is turned into a soft paste. In forming this paste, as the object in view is bread, the starch of the flour is not washed away, but left well mingled in with the **paste** or **dough**, as the soft substance is called. There is also mixed up with the dough a little salt, and a small quantity of either leaven, or yeast. **Leaven** is a piece of the paste made with flour and water which has been kept until its gluten has begun to decompose or decay. **Yeast** is gluten in the same decomposing state, but derived from beer that is in the process of fermentation.

The action of this ferment, whether it be leaven or yeast, after it has been mixed with the dough under suitable conditions, is that it immediately begins to change the dense tasteless and insoluble starch of the flour, into sweet soluble and less dense glucose, or grape sugar. But, as the less dense grape sugar contains less carbon than starch in its several molecules, the excess of the carbon has to escape from the paste as this change is brought about. It does escape in the state of carbonic acid gas, for the redundant carbon is seized upon by the ever-ready oxygen, and the escaping gas puffs out the glutinous mass into an open spongy state, by stretching it into bladder-like cavities. The bubbles of the carbonic acid are caught and imprisoned in the sticky dough, instead of being allowed to burst within it as they are formed.

In order, however, that this important change of starch into glucose, with the accompanying disengagement of bubbles of carbonic acid, may be properly effected, the dough, after it has been formed, has *to be left standing in a warm place.* Warmth as well as moisture is necessary for the transformation of starch into sugar. Where this process occurs naturally, as in the germination and sprouting of seeds, it takes place only when warmth is secured by the presence of genial sunshine. After the dough has stood some time in a moderately warm place it begins to swell up, or to **rise**, as the process is termed. This is due to the first escape into its substance of the carbonic acid gas. Then, when the dough is put in its still moist state into the yet hotter oven, still more carbonic acid is set free, and the bubbles become more abundant and of larger size. At last, by continued exposure to the heat of the oven, the gluten and the starch of the dough are dried into the less yielding condition of bread.

In order that good bread may be made, the circumstances which require to be carefully attended to are that the leaven, or the yeast, shall be in an active state and in proper quantity; that it shall be thoroughly mixed with the dough by most careful kneading, so that every part of the paste is penetrated by its transforming power; that a suitable temperature shall be provided for "raising the sponge;" and that the heat of the oven shall be carefully regulated with a view to the perfect baking of the dough. The heat of the oven needs to be a little more brisk than that which would be employed for cooking meat, but the floor of the oven should be covered with brick, where the loaves are to be placed upon it, because iron, at this high temperature, would be almost sure to burn the bread or to injure the quality of its crust.

The quantity of each ingredient that is required for making a *two pound loaf* is, twenty-four ounces and a half of wheaten flour, ten ounces of water, half an ounce of yeast, and from an eighth to a quarter of an ounce of salt. A mixture of leaven with yeast is sometimes advantageously employed. What is called *the quartern loaf properly weighs four pounds when it is new.* In that state it contains about 40 per cent. of water, about 8 per cent. of gluten, about 48 or 49 per cent., or nearly half its bulk, of a mixture of starch, sugar, and gum, and about $1\frac{1}{4}$ per cent. of salt and other mineral ingredients. The four pound loaf is, however, reduced in weight to something like three pounds, by the *continued evaporation of its water.*

The chief difference between wheaten flour and bread is the presence in the latter of the soluble glucose, which has taken the place of a considerable proportion of the starch. The sweet and agreeable flavour of good wheaten bread is due to the formation of this glucose, and the object of the fermentation of the dough is to produce this well tasting and soluble substance. Here again, however, this change is merely an anticipation by art of a transformation that would have naturally occurred in the stomach if unfermented flour, instead of fermented bread, had been used as food. One of the first actions of the stomach upon such food-substances as flour is the conversion of insoluble starch into soluble glucose. The making bread out of flour is therefore in this sense a lightening of the work of digestion.

Bread is not in the best state to be used as food until it has been made more than twenty-four hours. When new it is so sticky or doughy from the moisture still remaining in it that the teeth cannot chew it properly, and in consequence it is apt to prove difficult of digestion. On the other hand it is less palatable to the taste when it is so old as to have become dry and stale.

When **brown bread** is properly prepared by grinding up all the seed-coats or husks of the grain, and returning the ground substance to the flour, it is nutritious and excellent. But it is generally passed more quickly through the digestive organs than white bread, and, on that account, may not always yield all the nourishment that it contains. The advisability of employing brown bread or white bread as an article of habitual use depends very much upon whether, in any individual case, this more rapid passage of the food through the organs of digestion is desired or not.

There are some processes by which bread is made without changing the starch into glucose. The carbonic acid which is needed to form the bubbles of the sponge is then procured by some other expedient than that of converting the starch of the flour into glucose. Such, for instance, as the use of an acid that has a salt combined with it, like carbonate of soda, which contains carbonic acid in large quantity, or the mixing carbonate of ammonia with the dough, and setting free its gaseous constituents, carbonic acid and ammonia, by the simple influence of the heat of the oven. In all cases of unfermented, or as they are popularly termed **aërated,** breads, the product differs from true bread in the absence of glucose. It is more of the nature of unchanged flour than of bread, and upon that account may be found to be *less readily digestible than fermented bread*, although not less nutritious. The starch of the unchanged flour is in the end converted into glucose in the stomach, instead of the change being partly performed in the kneading trough and oven.

Flour of necessity loses a considerable amount of its weight when it is converted into bread, on account of the removal of a part of its carbon and oxygen, in the form of the gaseous bubbles that follow upon fermentation. It is generally considered that **280 pounds of flour** should yield **ninety-five quartern loaves** of nearly four pounds each, or **360 pounds of bread.** This 360 pounds is afterwards reduced to something like 260 pounds by the evaporation of moisture from the bread.

Biscuits differ from bread chiefly in being free from the bubbles of carbonic acid, produced by the fermentation of the starch, and in being baked until very nearly all their moisture is driven away. The word biscuit means properly *twice baked* or twice cooked, and was at first used because the drying of the biscuit was ensured by baking it a second time. As a general rule biscuits are more nutritious but less digestible than bread. When, however, they are not very dense, and are well browned in the baking, some part of the starch of their flour is turned into soluble sugar and gum.

Cakes and **puddings,** which are also made of wheaten flour, differ from bread chiefly in their starch not being changed by a ferment. Lightness is obtained by the use of eggs or of some kind of baking powder, and they are sweetened by the addition of sugar, and almost always moistened with milk instead of water. Richness is frequently given by the employment of butter as well as eggs, and spices or other flavourings are generally added. In making puddings various other farinaceous substances besides flour are used, the most serviceable amongst them being **rice, sago, cornflour, tapioca,** and **semolina,** which last is, however, a granulated preparation of flour. When properly made, puddings are as nutritious and wholesome as they are easy of digestion and pleasant to the taste. On account of the large range of ingredients that can be drawn upon for their composition they constitute a valuable and justly esteemed branch of food-supply, and of the cooking art. They are easily made, either by following the directions of the various receipts given in cookery books, or by learning the mode of preparing them from careful observation of the proceedings of a good cook.

LESSON XXVII.

DIGESTION.

All the more or less solid food-substances have, after they have been cooked, to be still further softened, and at last turned into an almost liquid state of pulp, before they can be employed to support the living operations of the animal body. This is accomplished within the body itself by the process which is termed **digestion.** The cooking, which is commenced by the kitchen fire, is continued in the stomach of the animal. The word digestion is derived from the Latin **digero,** which signifies to divide or to dissolve. By the act of digestion the several molecules of the food-substances are so loosened asunder, and so divided from their close connection with each other, that the whole is finally softened into pulp. In that sense the solid food-substance is dissolved into a liquid.

The first part of the process of digestion consists in the food, already somewhat softened by cooking, being broken up into fragments by the grinding operations of the teeth, and at the same time mixed with an abundance of warm saliva which is provided in the mouth. This saliva is itself a kind of ferment, and, as soon as it is mingled with the food, it begins to turn its starch into soluble glucose, very much as the starch of dough is turned into glucose, by yeast, in the process of bread-making. The pulp formed by the saliva and the broken up food is then swallowed, that is, it is carried down into the stomach by the muscular pressure, or squeezing action, of the gullet; and, in the interior of the stomach, the pulp is further mixed with a quantity of acid juice which exudes from the inner lining of this cavity. The stomach, which thus receives the pulped food, is a membranous bag, covered over with fleshy fibres that, by their alternate lengthening and shortening, can keep it moving about so as to churn together the substances contained in it.

The word **stomach** is derived from two Greek terms, signifying that this organ is the bag into which the pulped food is poured from the mouth. **Saliva** receives its name from the Latin word **sal**, which means salt, and is so called because it has a somewhat salt taste. The acid juice, which is poured into the stomach from its inner lining, is called **gastric juice**, or the juice of the stomach: the word **gaster** being the Greek name for stomach.

After the partially pulped food has remained soaking for some time in this acid juice of the stomach, the fibrous and glutinous parts are also loosened up into pulp by its influence. The warmth, the moisture, the acid, the constant churning movement, and the addition of another kind of powerful ferment, called **pepsin**, which is mingled with the gastric juice, all combine so to operate upon the food, already softened by the teeth and by the saliva, as to bring it into a yet more perfectly pulped and liquid state, in which it looks something like a mixture of thick gruel and cream. In this condition, it is called **chyme**, the word being derived from the Greek term **chumos**, which signified **moist juice**.

When the conversion of the pulped food into chyme is complete, this juice of the digested food is passed on from the stomach into the long coiled-up tube which lies beyond, and which is called the **bowel.** In it, the chyme is mingled with two other liquids formed within the body; one called the **bile,** which is manufactured in the liver, and conveyed from it to the bowel by a special channel, or tube; and the other the **pancreatic juice.** By these liquids, the oil and fat contained within the chyme are in their turn made soluble; and, over and above this, the digestion of the starch, which had been commenced by the influence of the saliva, is now finished and made complete. The chyme, then, after a little while, begins to separate itself into two parts; a white milk-like liquid, and a dark fibrous mass. The white liquid is the essence of the dissolved food; and contains its richest parts, the gluten, fibrin, sugar, and oil, all mingled up with water into a kind of emulsion. The milk-like liquid, or perfected essence of the digested food, is then called **chyle,** the word being derived from the Greek **chulos,** which signifies the liquid juice pressed out of any moist substance. The chyle is the liquid juice pressed out of the digested food.

The act of digestion thus consists, first, of grinding the food in a kind of mill; and then of macerating and soaking the ground food in a vat, where different solvents are provided to accomplish the softening of its various parts and ingredients. The nitrogen-containing, or glutinous and fibrinous ones are softened by the gastric juice; the starch and the fat by the saliva, the bile, and the pancreatic juice. The chyle is the remingling of the softened gluten, fibrin, starch, and fat, with a certain quantity of water.

The essence of the liquefied food, or chyle, when it has been thus separated from the coarser and less valuable parts of the food-mass, is drunk up, or absorbed, through the lining coats of the bowel. The inner surface of the bowel is covered all over by small projecting points or hairs which hang down into the interior of the tube, like the soft pile of velvet. These projecting points or processes are termed villi, the word being derived from the Latin villus, a tuft of hair. They are very small, and so numerous that some millions of them are contained within the bowel of a full-grown human being. From every one of these little villi, delicate tubes run upwards until they are collected together into the system of channels, or vessels. The points of the villi are covered over by a membrane so delicately fine that it allows the milky chyle to soak through and get into the tubes leading to the vessels, just as syrup soaks through blotting paper. The chyle-vessels, which collect the chyle from these myriads of absorbing points or hairs, all meet together at last in one common reservoir, or receptacle. From this a single duct, or tube, issues to convey the collected liquid on towards its final destination, which is one of the large veins leading to the heart. The liquefied and digested food that is gathered up from the villous coat of the bowel is there at last mixed in with the blood. The blood in the first instance is renewed and nourished by the fresh stores of food-substance brought to it through the process of digestion, and these fresh stores of nourishment are then afterwards carried on in it to all parts of the body.

LESSON XXVIII.

THE MIXED DIET OF MAN.

An almost infinite number of different kinds of substances are used by man as food. But, in order that as much nourishment may be procured out of these as is necessary for the support of the daily waste of a living human being, those different kinds must at least furnish due portions of all the distinct classes of foods, such as the nitrogen-containing gluten or fibrin, the sugar or starch, and the fat or oil.

The food and drink which are needed each day by a human being of average size and strength amount to nearly seven pounds by weight; but, of this quantity, five pounds and a half being water, only a trifle more than one pound and a quarter is *dry* food-substance.

Of that dry food-substance, eleven ounces and a quarter must be sugar, or starch; three ounces and three quarters fat or oil; four ounces and a quarter gluten, albumen, fibrin, or some kind of nitrogen-containing substance; three quarters of an ounce salt, and 170 grains other mineral ingredients. Whatever the nature of the food that is chosen for the daily meals, and however the different substances, such as meat, vegetables, bread, and the rest, are apportioned and mixed, so much at least of these several principles must be supplied in each day's diet.

As a matter of fact, a sufficient supply of these several ingredients is ensured by more food being consumed than is necessary for the renewal of waste. In order to secure 300 grains of nitrogen, more than 5000 grains of carbon are taken in; or, in order to secure 5000 grains of carbon, more than 300 grains of nitrogen are introduced into the body. When more of any one of the ingredients is received than can be turned to practical account, the superfluous quantity is rejected from the body unused. This is nature's way of making sure of a sufficient supply. More food on the whole is taken than is absolutely required, and the superfluity which is not wanted is rejected as waste.

This, however, as anyone can see, is not the most economical way of managing the matter. Under this plan some part of the food is not turned to useful account, and, what is perhaps of more importance than the mere waste, the excess is only got rid of at the cost of some strain upon those organs of the frame which are charged with the removal of superfluous substance. In extreme cases of over-feeding, disorder and illness of various kinds are actually caused by this strain.

If an adult human being were to live upon **bread** alone, and were to take as much every day as would yield the 300 grains of nitrogen required for the support of the body, sixty-one ounces, or nearly a **four pound loaf** of bread would have to be eaten; but these sixty-one ounces of bread would supply 7500 grains of carbon, instead of the requisite 5000; and so there would every day be 2500 grains of unused carbon to be got out of the way, unless that quantity were allowed to accumulate injuriously in the body. If, on the other hand, **beef** alone were taken, **nearly six pounds** and a half would have to be consumed to get 5000 grains of carbon, and that weight would yield 930 grains of nitrogen, or 630 grains more than can be used. If **potatoes** alone were taken as food, four times the weight that would be needed to furnish the 5000 grains of carbon, or **twenty-five pounds,** would have to be taken to furnish the 300 grains of nitrogen. This difficulty, however, at once disappears when a judicious mixture of the three kinds of food is eaten instead of any one alone. Thus, in *one pound of beef, one pound and a half of bread, and three pounds of potatoes*, there would be contained just about 5000 grains of carbon and a trifle more than 300 grains of nitrogen. Such an admixture of meat, bread, and potatoes would certainly prove both a more wholesome and a more economical arrangement of the diet than either meat, bread, or potatoes taken alone.

The quantities of the different kinds of food-substance that are needed to make up a sufficient and wholesome diet, and the least wasteful way of obtaining such a diet, have been ascertained by actual experiments made with soldiers, sailors, prisoners, and the inhabitants of workhouses. In the case of all these the food has of necessity to be measured out for each individual, and to be so planned that the health and strength of the body are effectually maintained, although no wasteful expenditure of food-substance is allowed. This is, at the present time, so successfully arranged, that in most of the prisons in England the inmates are more healthy than people who feed upon as much as they please.

Soldiers and sailors, who are regularly engaged in active work, receive, in their daily allowance of food, five ounces of fibrin, gluten, or other nitrogen-containing compound, and of starch, fats, or other unnitrogenized substance, enough to yield ten ounces of carbon. Prisoners, on full diet, receive four ounces of glutinous food, one ounce and a half of fat, and nearly nineteen ounces of starch and sugar. It is generally considered that labouring men engaged in hard work consume daily five ounces of glutinous food, three ounces of fat, and as much as twenty-two ounces of starch and sugar.

In one of the most instructive and carefully prepared books which has been written upon the subject of a good and economical dietary,* and which has been designed as a handbook to describe and explain the Food Collection of the Science and Art Department of the Government (now deposited in the Bethnal Green Museum), the following is given as a sample of what may be considered a standard selection of food-substances for one day's consumption :—

Bread	18 ounces.	Cheese	3½ ounces.
Butter	1 "	Sugar	1 "
Milk	4 "	Salt	¾ "
Bacon	2 "	Water, alone and in various forms of drink	66¼ "
Potatoes	8 "		
Cabbage	6 "		

In this assortment of food, all the different substances contain some water. But, if this be allowed for, the absolutely dry food-substance contained in the whole still amounts to not less than twenty-one and three-quarter ounces.

In the same excellent book, the following list is supplied of the quantity of the different kinds of food specified, which would have to be consumed, to get from each the 5000 grains of carbon required by an adult in a day :—

	lb.	oz.		lb.	oz.
Bacon	1	0	Bread	2	8
Oatmeal	1	9	Eggs, white and yolk ..	0	3
Dried peas	1	10	Potatoes	6	6
Rice	1	11	Beef	6	6
Cheese	1	11	Milk	8	11

The quantity of each kind of food that would be

* 'Some account of the Sources, Constituents, and Uses of Food,' by Prof. A. H. Church.

required in the day to obtain the 300 grains of nitrogen is given as

	lb.	oz.		lb.	oz.
Cheese..	0	15	Bacon	3	4
Peas	1	3	Rice	3	7
Oatmeal	1	10	Bread	3	13
Eggs	2	0	Milk	6	8
Beef	2	1	Potatoes	24	C

The admixture of different kinds of food-substances together in a meal, such as milk, oatmeal, and sugar; bread, vegetables, and meat; milk, eggs, and rice; bread and butter, bread and cheese, bread and meat, meat and potatoes, and meat with vegetables in every form, has arisen without design from the want of the different kinds of ingredients contained in the several substances. As a general rule, the natural craving of the appetite, and the natural inclination for different kinds of food ensures proper supplies of those different kinds being taken. If people be fed too exclusively upon meat, they soon feel a strong desire for vegetables and bread. Still, what the natural propensity accomplishes in a certain degree may be more thoroughly effected by forethought and design, when the reason for the admixture is understood; and this more especially when wholesome food has to be provided at the smallest possible expenditure, and with the least possible waste. It is then that the selection and varying of the articles of food for each day's consumption, and the cooking of those articles, become a very important branch of domestic economy, and one with which every manager of a household ought to be familiar.

IV.—Nature and Action of Drink.

LESSON XXIX.

DRINK.

Drink is no less essential to the maintenance of the life of animal bodies than food. There must be fresh supplies of drink furnished from time to time, as well as fresh supplies of nourishment. What happens if people are deprived of drink for days at a time is instanced when travellers across the dry deserts fail to reach wells after the exhaustion of their own stores of water, or when sailors are cast away at sea without proper supplies of it. They first faint with thirst, and then die from the stoppage of every action of life.

The drink provided by nature for all living creatures is water. The wild animals that roam free over some portions of the earth go down to the rivers and streams, so abundantly scattered about, to procure the drink which they need; and the rivers and streams of the earth do not run dry, because the clouds carry the water back to the hill tops as fast as it flows down the hill sides, and on to the sea through the valleys. The bountiful provision of uprising vapours, drifting clouds, and frequently recurring showers of rain, is made in part that there may be this natural drink diffused everywhere for animals.

The vast importance of this natural drink to human beings is at once expressed in the enormous amount of it that occurs in their bodies. **In a human body, which weighs 154 pounds, 109 of those pounds are water.** Of the six pounds and three-quarters of fresh food which must be furnished every day for the nourishment of that body and for the support of its life, five and a half pounds are water!

The reason why so abundant a supply of water is needed in the bodies of animals, and why fresh quantities of it have to be given as drink from time to time at frequent intervals, becomes manifest enough as soon as the use to which it is put is understood. Water is the great carrier of nature. All the food, which is taken into the body for the maintenance alike of its structure and of its living powers, is floated or washed into its interior chambers and cavities. It is poured into the places where its nourishing powers are to be turned to account, and that is simply everywhere. Every structure and texture of the frame is saturated and flushed with the liquefied nourishment.

In the first act of digestion, that, namely, which is performed in the mouth, the more solid food-substances are ground down and turned into a soft half-liquid paste. This is accomplished by mixing them up with a considerable quantity of water. The saliva, which is poured into the mouth as the food is in the process of mastication, is warm water having a comparatively small quantity of a ferment and of a mineral substance, or salt, dissolved in it. The white milky chyle, which is extracted in the bowel from the still further pulped food, or chyme, is water holding in suspension the glutinous, farinaceous, sugary, and oily essences of the food.

When the chyle is sucked up by the villous processes, or velvety pile of the inner lining of the bowel, it is carried along in an ever-gathering stream until it is at last contained in one long pipe, or vessel. This is called the **thoracic duct,** because it passes through the **thorax,** or chest, to get to the large vein which there enters the heart. All the dissolved essence of the digested food, or milk-like chyle, is poured along in a never-ceasing stream through this thoracic duct, just as the water supply of a house is poured through its main pipe to the cistern. All this pouring along, or streaming, of the liquefied essence of the digested food, is managed by the water with which it is so intimately mixed. The water of the chyle is the essential agent of its movement and transport.

But after the chyle has been poured into the great vein of the chest, it is immediately carried on into the heart, and is there blended with the blood. When the white milky chyle reaches the heart, it is turned into red blood. That is to say, the relatively small stream of white milky liquid which is pouring into the blood, is so mixed with that larger crimson stream as to be immediately lost in it. But that crimson stream, the blood, is renewed and maintained in its structure-building and life-giving powers by the newly-dissolved food, or chyle, being added to its current.

The digested and liquefied food, after having been first changed into chyle and then into blood, is poured out by the pumping, or squirting action of the heart, through a most beautiful system of supply-pipes, that are laid down in the body, as water-pipes are laid down to all the houses of a town, so as to reach every cavity, and fibre, and texture of the frame. A great vessel, or **artery** issues from the heart, and then branches out into smaller and smaller tubes, as the trunk of a tree branches out into its twigs, until at last every crevice and cranny, every film and fibre, of the living body is penetrated by a series of netted channels that are finer than the smallest hairs, and that are therefore called the **capillary**, or hair-like vessels of the body.

When the heart beats, or contracts, the blood is poured or flushed, by means of these capillary vessels, through the very substance of each texture. It flows everywhere. The point of the finest needle could not be thrust into any part of a living animal's body, excepting perhaps into the earthy substance of the bones, without an opening being made into some one of these delicate vessels, and red blood flowing from the wound. The capillary vessels are so universally spread throughout the frame, that if they were filled with some unyielding substance, such as red cement, instead of with flowing blood, and if all other parts were cut and picked away, still the general outline of the body, from head to foot and from skin to backbone, would be preserved in this hardened skeleton of branching vessels; just as the form of a leaf is preserved in its netted fibres when the skin and wood and pulpy flesh have been removed from them. There are, indeed, in some of the large museums of anatomy, such as that of the Royal College of Surgeons in London, specimens which have been prepared in this way from human bodies, and which are amongst the most wonderful things that can be looked at by curious and inquiring eyes. In these beautiful preparations, the red cement has been got into the interior of the capillary vessels by the simple and ingenious plan of squirting it in from the heart in a liquid state, and then leaving it to harden there into firmness. Wax, well mixed with red vermilion, is used in a hot melted state, and when the mixture has grown cold, it is firm enough to maintain the proper form of the vessels into which it has been poured, even to their minutest twigs and ramifications.

It is not possible to determine exactly how much blood is contained in a living human being, but in a full-grown person of average size it is probable that there are some twenty pounds of blood, or a little more. If, however, the quantity be estimated at twenty pounds, four-fifths of this, or sixteen pounds, would be water. In twenty pounds of human blood, about four pounds consist of the various nourishing matters, gluten, fibrin, starch, sugar, oil, and the rest, that have been extracted from the food, and sixteen pounds consist of the water that manages the washing along, or transport.

The direct services, therefore, which drink performs in the living animal body are these three :—

(1) It furnishes the moisture of the several juices that are mingled, in the mouth, stomach, and bowels, with the crushed food, to complete its digestion.

(2) It dissolves or suspends the nourishing essences extracted from the crushed food, and so enables them to be absorbed, or drawn in, by the small collecting vessels that cover the digesting cavity.

(3) And it then washes them along, through the branching vessels of the body, to all the organs and parts to which they require to be distributed. Having accomplished this all-important work, the drink still has some service to perform. But that will be best explained upon another occasion.

Water, the great drink-liquid of nature, is admirably fitted for the work of transporting nourishing substance into the interior parts of the body where vital actions have to be maintained ; first, because it has great power of reducing other materials to the liquid state by dissolving them into itself ; and then because it is unable to interfere with their composition even when it has so dissolved them. Sugar, gum, salt, albumen, and gelatin are all readily dissolved in water, and taken up into it for transport. But they are all unchanged in their essential natures by this close union with the liquid. They are all ready to be given up again as sugar, gum, salt, albumen, and gelatin, wherever those substances are needed for constructive operations. No chemical change is effected by the dissolving action of the water. In its work as a carrier, water is an incorruptible servant, giving up honestly at the end every molecule of each various substance that has been entrusted to its charge. It is on account, first of its great power of dissolving and rendering liquid so many other substances, and, then, of its disinclination to produce any *atomic*, or chemical change in their composition, that water is the very best drink which can be used by animals.

The quantity of water that requires to be taken in a day, as drink, for the effectual performance of this work of dissolving and transporting the food, varies to a certain extent with circumstances. More, for instance, is needed in hot weather than in cold, because the work of cooling the body by evaporation is then added to the other services that water performs. And again, as water is present to some extent in all kinds of food, less drink is required when moist food, such as fruit, vegetables, and soup are used, than when the food is of a drier character.

Allowing for all these circumstances, about **five pints and a half** may be considered the average quantity that must be supplied every day, in both drink and food, to full-grown human beings; and the proportion of this that is best taken as **drink** *will vary from two to four pints in the day*, accordingly as dry or moist food is used, and accordingly as the weather is cold or hot.

LESSON XXX.

THE COMPOSITION OF THE BLOOD.

When blood is drawn from a living animal body it is found to be made up of two distinct parts, namely, a clear, transparent liquid, and a vast number of opaque or untransparent granules floating therein. If a very small quantity of the freshly-drawn blood be placed under a microscope, these can be easily seen. The opaque granules, which are far too small to be discerned at all by the unaided eye, then appear as separate round bodies floating in the liquid. They can also be procured apart from this liquid by straining it off from them through blotting-paper. The granules are then left in a clustere mass upon the surface of the paper. Each one of them appears to be of a pale yellowish colour when looked at through the microscope. But it is really red. When many are seen closely packed together, they are of a bright crimson hue. The redness of the blood is entirely due to their presence. When they are all filtered away, the liquid which remains is nearly as transparent and colourless as water. The redness and opacity of the blood are therefore caused by a crowd of minute red granules suspended in its clear liquid part.

These opaque granules of the blood are called its red particles or **red corpuscles.** The word corpuscle merely means a little body. The red corpuscles of the blood are the little red bodies that float in its clear liquid. In twenty pounds of blood, three pounds are entirely made up of these red corpuscles. When all the red corpuscles of twenty pounds of blood are filtered, or strained away, the rest of the liquid weighs seventeen pounds.

The clear liquid of the blood, which is left after all the red corpuscles have been strained away, is called its **serum.** Serum is the Latin word for the *whey of milk* which remains after the curd has been removed. The serum of the blood is, indeed, almost of the same nature as the whey of milk. It contains, besides the material which is made into granules, all those parts of the dissolved food which are soluble in moderately warm water, that is, the albumen, sugar, and saline ingredients. In seventeen pounds of the serum of blood, nearly one pound is albumen held in solution in water.

There is, however, one other more highly elaborated product mingled in with the albumen of the serum of blood. If blood freshly drawn from the body of a living animal be left to stand in a basin until it grows cold, it separates into two parts: the thin liquid, or serum already described, and a kind of cake, clot, or **coagulum** of a more or less red colour, that floats upon the surface of the serum. This clot contains all the red corpuscles of the blood. But it contains something besides, for the red corpuscles are cemented together in the clot into a continuous cake-like mass. They in reality lie entangled in a loose web or net, of intermeshed "fibres" or strings. These strings are themselves made of the very same substance as the insoluble fibres of meat, and are indeed flesh beginning to be formed in the blood.

In living and warm blood this fibrin is in some mysterious way compelled to remain in solution with the albumen and salts, in order that it may be carried along the arteries in the rushing blood-streams to the places where flesh has to be formed. But the instant the living blood becomes dead and cold, in consequence of removal from the vessels of the body, the fibrin is condensed and thrown down out of the liquid in a compact insoluble state, and forms the coagulum or clot. This then consists of the fibres of the consolidating substance, the red corpuscles, and some little part of the liquid serum—which is retained in the porous mass, just as water is held in the pores of a sponge.

The fibrin, which is thus mingled in with the albumen of the blood, is that nourishing substance advanced one stage farther in its fitness to be made into organized structure. It is albumen rendered more plastic, or more organizable. Only as much fibrin, however, is made out of the albumen in the blood as is required for present use in constructive work. If more than that were made, the blood would become too thick and adhesive to flow freely, as it is required to do, through the delicate vessels and channels of the body. In ordinary circumstances, only a little more than half an ounce of the more plastic fibrin is found in each pound of the less plastic albumen.

The unnitrogenized or amyloid products contained in food—namely, the starch, sugar, and oil—are principally mingled in with the albumen in the blood, and then taken back out of its substance as they are required for constructive and living work. Small quantities both of sugar and of oil are found in the circulating blood. But the sugar and oil, like the fibrin, are prepared out of the albumen only as they are required for use. The sugar is dissolved in the serum. The oil is enclosed in little filmy bladders or sacs, which are constructed out of the albumen, and carried along in the general stream mingled in with the red corpuscles.

There is commonly very nearly the same quantity of oil and fibrin kept ready for use in the blood. In twenty pounds of blood there are also something like two ounces of salt and other analogous mineral ingredients. These are all dissolved in the serum.

The red corpuscles of the blood, which are so exceedingly minute that they cannot be seen at all by the naked eye, begin to become visible only when they have been magnified many times by powerful microscopes. They are so small that something more than three thousand of them can be ranged in single file within an inch. Upon a square inch as many as ten millions of them could be laid down side by side. In the blood of an adult human being of average stature, there must be at least two and a half millions of millions of them; or sixteen hundred times as many as there are living human creatures existing upon the earth.

These exquisitely minute little corpuscles are, nevertheless, very elaborate pieces of organization, constructed in the blood for an important purpose. They are, in fact, the first efforts of living organization. Each little body is a living organism, formed to accomplish work that no unliving agent can perform. Each one consists of a transparent skin, made of albumen obtained from the serum, which is plastered and hardened into a kind of horny coating, or shell. The corpuscle is flattened in one direction, instead of being round like a ball, so that it may be more easily able to increase and diminish in bulk, and may be capable of lying edgeways where close squeezing is required. In the inside of the filmy shell a rich red liquid is contained, which also is made out of the albumen, but which is of a more complex and elaborate character. New ingredients are added, as the albumen is drawn through the pores of the film, which turn the pale liquid into a crimson-coloured substance. That substance is a product of animal life, which has been manufactured out of the albuminous serum of the blood by the condensed, but still permeable, film of the corpuscle. Each pigmy corpuscle is a workman as well as a fabric; a living creature in some sense as well as a piece of construction. How it is that this minute organization manages to accomplish its work no one can say; but none the less certain is it that it does elaborate, or manufacture, this bright crimson liquid out of ingredients destitute of colour, and that this crimson liquid cannot possibly be prepared without its instrumentality. The red corpuscle is the first living thing that is made out of the plastic material of the blood, and it proves that it is a living thing by accomplishing vital work, such as no unliving thing could accomplish.

The bright crimson liquid, which is thus manufactured by the living corpuscles of the blood and closed up in the interior of their filmy shells, is the perfected and proper food of the moving and feeling parts of the animal body—of the muscle, the nerves, and the brain. The clear albuminous and fibrinous part of the blood, perfect as it is for the nourishment of the simpler and more lowly organized portions of the structure, is not elaborate and rich enough for the support of these higher fabrics. A vast staff of manufacturing vesicles is therefore commissioned to provide the more finished food that is required for them. These are the microscopic blood-corpuscles that exist in each human being in almost countless millions. The perfected muscle-food and nerve-food is the red liquid, or **hæmatin**, as it is then called, which is contained within the corpuscles. The word hæmatin, which has been adopted as a name for this most characteristic and finished product of the blood, is derived from **aima**, the Greek term for blood.

LESSON XXXI.

THE CIRCULATION OF THE BLOOD.

The plan which has been adopted to get the digested, or dissolved, food—in other words, the blood—to all parts of the body of a living animal, in order that each of those parts may receive its proper share for the nourishment of its substance and for the support of its actions, is a very beautiful and remarkable one. The liquefied food or blood is pumped along the series of branching tubes laid down through the body into every crevice and every fibre of the frame. The pump, or squirt, by which this forcing of the blood through the branching vessels is managed, is called the **heart.** The first great vessel, or tube, of the supply-pipes of the body issues from the heart. The heart is a hollow bag of muscular fibres, or flesh, filled with blood; and when the fibres contract upon the blood, it is squeezed out through the opening of the bag. If the hand be laid upon the left side of the chest, the action of the heart can be felt, pumping and pumping its blood forwards into the branching system of vessels.

This pumping action of the heart goes on without ceasing from the beginning to the end of life. It must not be stopped for more than the shortest instant, for if the beating or pumping of the heart be arrested, the blood ceases to flow, and if the blood ceases to flow, life stops as well as the blood. All the actions of life are maintained by the flow of the blood, and consequently all those actions are terminated when the flow comes to an end.

Seventy times or so every minute; four thousand two hundred times every hour; one hundred thousand times in a day; thirty-six millions of times in a year; 2555 millions of times in a life of seventy years—a human heart beats, on and on, before its wonderful activity and energy are stilled.

But as the heart of a living human creature beats in this way, it pumps, or forces out from its interior, at every stroke, some five or six ounces of the liquid blood. The entire amount of blood contained within a human being is thus pumped out from the heart in less than a minute. If, however, twenty fresh pounds of blood were pumped out every minute, this would mean that over 28,000 pounds, or more than 576 hogsheads by measure, were pumped out in twenty-four hours. If 576 hogsheads of blood were pumped out from the heart, it is clear that 576 hogsheads must be received into the heart to be so pumped out. But those 576 hogsheads are certainly not fresh hogsheads. No such amount of fresh liquid is supplied to the body in a day. The fresh substance that is introduced within twenty-four hours does not, at the most, exceed seven pounds, or pints. The inference, therefore, is plain. As twenty pounds of blood are pumped out from the heart every minute, and as certainly not more than the smallest fraction of an ounce of *fresh* substance is introduced in the same time, the same twenty pounds are used over and over again. The blood which issues from the heart is returned to the heart. It is pumped round and round through the system. In other words, the blood **circulates.** The same twenty pounds of blood, with slight changes from addition and loss, are pumped out from, and back into, the heart, many hundred times every day.

The circulation of the blood is managed in this way: the large vessel, or **artery,** which issues from the heart, is divided and branched into smaller and smaller tubes, and these small tubes are divided and branched again, until they form the network of minute, hair-fine vessels, or capillaries, spread through the interior of all the structures and textures of the body. These capillary vessels are at last so small that as many as 3000 of them could be laid side by side within an inch. They are so minute, indeed, that in their finest parts the red corpuscles of the blood can only just squeeze through. But the blood, which is forced into these vessels, does not stop there. It makes its way through them, and comes at last to other parts of the network, where vessels of increasing size begin to receive the blood-streams in their interiors. These larger vessels go on collecting into more and more capacious trunks, and at last all end in one main channel, which terminates in the heart, and so the circulation is complete. These collecting vessels, however, that lead the blood back from the capillaries to the heart are called **veins**, to distinguish them from the **arteries** which carry the blood out to the capillaries. The name "arteries" and "veins" were conferred upon the two sets of vessels before anything was known concerning the circulation of the blood, and therefore before anything had been ascertained concerning the uses to which they were put. It was merely observed that in the bodies of dead animals the arteries were always soft, flabby, empty tubes, and it was therefore conceived that their work was to carry air. The veins, on the other hand, were found to be filled with dark coagulated blood, which made them look like fibres, or strings. The word artery is derived from the Greek term "aer" or "air." The word vein is taken from the Greek "is," "ina," a sinew, or "fibre."

The stream of blood flows very quickly where it passes out from the heart. The fleshy bag contracts upon its liquid contents with a force that throws the blood along the large artery through as much as about twelve inches in a second. As, however, this main artery branches out into its numerous divisions, the space which has to be filled by the flowing blood gets larger and larger. In the extreme network of the capillaries the space is at least four hundred times as large again as the outlet from the heart, notwithstanding the minute size of each little vessel. The minuteness of each is compensated for four hundred fold by the vast number of the vessels there are to take the supply. The blood consequently flows more and more slowly as it reaches the larger space, until in the capillary channels themselves it gets through something like only an inch in a minute, instead of twelve inches in a second. It is this sluggish movement of the blood in the capillary channels which affords the opportunity for the various structures to select from the nourishing stream the ingredients that each requires for the renewal of its substance. The minute vessels themselves are made of a membrane so exquisitely fine as to be easily saturated and soaked by the loitering blood. In this way, therefore, it escapes to the surrounding parts and pores of the structures that have to be supplied from its stream.

The movement of the blood through the narrow channels of the capillary vessels is, however, as steady as it is slow. The crimson stream starts from the heart in successive jerks, as stroke after stroke is made by its expanding and contracting fibres. But the arterial vessels, into which it is driven, are as elastic as if they were made of india-rubber. Yielding to the stream when the stroke falls upon it, they expand; and then, when the stroke ceases, they contract upon the blood and press it onwards. As the blood gets farther and farther on into the narrower vessels, the original stroke of the heart is less and less marked, and the elastic contraction of the stretched vessels tells more and more, until at last, in the capillary vessels themselves, the stretched walls alone do the work of keeping up the movement. The intermitting strokes of the heart stretch the elastic tubes, and the elastic tubes in their efforts to contract then push on the blood in a gentle steady stream that has lost all trace of the primary jerks.

When the blood is sent out by the contraction of the heart, it is made to run on always in one direction by the simple contrivance of a series of trap-doors, or valves, which open inwards, to the cavity of the heart, where the inlet from the veins is placed, and outwards from the heart, where the passage to the artery is found. Under the action of these valves, the flow of the blood can only be in one and the same direction. It can only go forwards into the arteries, and it cannot go back into the veins.

Simple and obvious as is this beautiful process of the circulation of the blood, nothing whatever was known of it a little more than two centuries and a half ago. It was first detected by one of the physicians of King James the First, named William Harvey. He was convinced that the blood must flow in this way on account of the arrangement of the valves at the openings of the heart and at some other places in the great vessels. He, however, did not know anything about the capillary vessels, by which the circling current gets from the outward-trending supply-pipes, or arteries, to the inward-trending return-pipes, or veins, because in his day there were no microscopes strong enough to show structures so exquisitely small. These capillary vessels were discovered about half a century later by an Italian doctor, of Bologna, named Malpighi, and then the whole secret of the mystery was revealed.

The process, which was so dark and mysterious in those days, can actually be now seen by anyone. The web that unites the toes of a frog, in order to allow it to use its feet in swimming, is so thin and transparent that it can be seen through. If a small portion of this web be stretched under a properly arranged microscope, the streaming of the blood through the capillaries, supplied to it as they are to all other structures of the frog's body, becomes visible to the eye. The branching network of the delicate vessels appears spread out through the transparent web, and continuous streams of the blood-corpuscles can be observed hurrying along through the different channels, and passing out from the end of arteries into the commencement of veins. This spectacle, of the blood-streams running through the web connecting the toes of a living frog, is, perhaps, one of the most striking of the marvellous and interesting things that can be shown to human eyes by the microscope.

This, therefore, is what happens in the circulation of the blood: the digested and dissolved food, made portable by drink or water, is flushed through every portion of the body at each stroke of the heart, just as it is seen to be flushed through the transparent web of the frog's foot when looked at through the microscope. In every fibre and every film of the living frame, in nerve, brain, and flesh, in skin, gristle, and bone, in soft pulp, tough membrane, and built-up substance, those blood-streams flow continuously on and on. The whole living body is penetrated in every part with the moving flood of liquid nourishment. Sixty times every hour, more than 1400 times every day, the whole twenty pounds of the crimson blood are washed round and round in the ever-circling stream. Once at least in every minute the entire twenty pounds of the blood rushes out from the heart, streams through the expanded network of the capillary vessels, and returns to the heart; and this goes on from day to day, from year to year, and from birth until death, without any pause in the unceasing flow.

LESSON XXXII.

REMOVAL OF WASTE SUBSTANCE.

Water is the great natural agent of transport by which the dissolved and liquid food is conveyed throughout the body. The essence of the digested food is washed out of the stomach and bowels into the blood, and is then washed in the blood to all parts of the body, through the supply-pipes, or arteries, that are distributed everywhere. All this excellent service is performed by drink which is taken, like food, at frequent intervals.

But the drink, which is thus received at frequently recurring intervals into the body, must be got rid of again in some way. If four pints of drink are taken every day, that amounts to 112 pints in a month. But it is clear that 112 pints of liquid could not be added to the body, month after month, unless 112 pints were removed from it in the same time. The fact is that the drink is poured out from the body as well as being poured in. But as it has to be removed in this way, it is turned to still further account in the act. The opportunity is taken to make it wash out of the body a considerable portion of the waste food-substance which, having played its part, is no longer of use in the system.

Some portion of the waste is steamed away out of the mouth *with the breath*, being discharged from the blood into the air-chambers of the lungs. All the carbonic acid formed in the blood by the burning of the carbonaceous matters of the food is so got rid of. The air which comes out of the mouth after breathing contains 5 per cent. more carbonic acid gas than the air which goes in. As much as eighteen cubic feet of carbonic acid gas is discharged with the breath of an average-sized human being every twenty-four hours. A large portion of the waste carbon of the system is thus got rid of. The breath also contains a very large quantity of the **vapour of water,** which is simply some portion of the drink escaping from the mouth as steam. This vapour of water is at once seen coming out of the mouth on a cold day, because it is then chilled into the state of a visible cloud, by the cold air.

Another part of the waste water is carried away *through the pores of the skin.* The skin is everywhere pierced with little openings, which cannot be seen until they are magnified, but which exist nevertheless in vast numbers. There are millions of them upon the skin of every human being. The pores come from small tubes, covered with capillary blood-vessels, through the fine filmy walls of which the water transudes. In cold weather the pores are closed, but in warm weather they are relaxed and opened, and then the moist vapours pour out from them in what is called **perspiration.** The perspiration of the skin is formed of water drawn out of the blood, and bringing with it also a small quantity of more solid substance, which is waste matter being thus washed away. From *one pint to four pints* of water, accordingly as the surrounding air is cold or warm, are thus expelled out of the blood, through the pores of the skin, in twenty-four hours.

Yet another portion of the water gets back *into the bowels* and so escapes from the blood. The stomach and bowels are lined by a soft delicate skin which is called the **mucous membrane,** because it is bedewed with the escaping moisture. The mucous membrane of the stomach and bowels is, indeed, an extension of the outer skin into the interior of the body, and it has an abundant series of pores of a similar kind to the skin. There is a transudation of liquid mucus through the walls of the bowel, and this is a kind of internal perspiration, supplementing and helping the perspiration from the skin.

But a yet larger quantity of the waste water of the body drains away, drop by drop, *from the kidneys*, which are organs provided expressly for its removal. They are, indeed, very exquisitely formed to play the part of the sluice gates of the system, being amongst the most delicate and finished structures of the body. Each kidney is formed of a large artery, or supply-pipe, carrying bright scarlet blood, and branching out in the usual way into a network of capillary vessels. But in this case these capillary vessels are bundled up into a series of bunches, and these bunches are then packed away into the mouths of a number of funnels. Each bunch has its own funnel and its own venous outlet, or return pipe, running on towards the right side of the heart, so that a blood-stream may flow continuously on through its looped and meshed capillary vessels. The funnel, which contains the bunched-up mass of blood-vessels, is narrowed down, after the manner of funnels, into a pipe, and this pipe continues on into a collecting basin, hollowed out in the kidney; all the various pipes, coming in from the different funnels, join in this basin. Another pipe then empties the collecting basin into a larger store-bag or bladder, which serves as a temporary reservoir for both kidneys. The interior of the channels of the bunched-up blood-vessels and the cavities of the collecting funnels are only separated from each other by the thin delicate films of the vessels. Accordingly as the blood circulates through the vessels, some of its water exudes through the films and drips away into the funnels, and more water thus drips away when the system is full of liquid, so that increased pressure is put upon the films. More or less water is drained away accordingly as the pressure of the blood is great or small.

Through the two kidneys of a full-grown human being as much as 24,000 grains, or **fifty ounces**, of water drain away every twenty-four hours. But these fifty ounces are not pure water; they contain a considerable quantity of a peculiar substance called **urea**, which is a product of the living operations of the body. There are as much as 500 grains of urea in every fifty ounces of the liquid. There are also mingled in with the urea smaller quantities of other soluble substances, such as soda, potash, and salts, containing lime, magnesia, sulphur, and phosphorus.

All these soluble matters are in reality waste portions of the worn-up textures of the frame, and of such parts of the food as cannot be burned in the blood and removed in the form of vapour, as the carbonaceous compounds are, but which can be washed away in streams of flowing water on account of their ready solubility. The urea, which forms so large a part of this soluble waste, is, in reality, the product of the nitrogen-containing parts of the structures and of the food. It is itself very rich in nitrogen. The natural tendency of compounds which have been built up by the aid of nitrogen is to return, upon their dissolution or decomposition, first into the state of the ammonia from which they were formed, and then into that of the nitrogen and hydrogen gases, of which ammonia itself is composed. But ammonia is a very pungent and irritating substance, that could not be safely contained in the blood in any quantity, on account of the injurious influences it would there exert. The admirable expedient is therefore adopted of converting the decomposing nitrogenized waste of the frame into urea, which is a bland, unirritating and not pungent substance, and of then leaving the urea to be changed, in its turn, into ammonia, after it has been washed clear of the body. When urea has been thus removed from the living structures, it is further resolved into pungent ammonia and carbonic acid.

This, therefore, is how the waste portions of the structures of the body, and the food-substances which have been used for the production of activity and movement, or which are expelled unused because they are in excess of what is required for that purpose, are got rid of. They are partly burned away into invisible vapours, and poured out as such through the mouth and skin; and partly washed away in the steam of the breath and skin, and in the liquid stream which flows out through the kidneys.

All the most soluble parts of the body and of the blood are at all times in process of being slowly drained away through the kidneys. The albumen and fibrin of the blood and its corpuscles are the only parts that are kept back in the channels of the circulation, and not allowed to drain away through these organs. Their filtering funnels are so contrived as just to prevent those thicker and still valuable parts of the blood from passing through. In certain forms of disease, however, this restraining power is lost, and the rich stores of albumen, fibrin, and blood-corpuscles are filtered away, as well as the soluble waste, through the kidneys, to the grave injury of the health.

There is one other large organ in the body that plays an important part in the removal of waste substances, that, namely, which is called the **liver.** It prepares from certain portions of the blood a peculiar product termed **bile.** A large branch of an artery carries blood to the liver and then opens out in it into a vast expansion of capillary vessels, which pass on in the usual way into veins. But, closely connected and interlaced with the capillary vessels of the liver, are other delicate tubes, which draw out, or form, the bile from the blood, and then carry it on to a collecting channel of their own that ends in the lower part of the digestive cavity or bowel. A very considerable quantity of bile is thus made out of the blood every day.

The bile, which is thus formed out of the blood and poured into the interior cavity of the bowel in such abundant quantity, helps there, in the first instance, to complete the digestion of the food by turning its oily parts into a kind of soapy substance, such as can be floated back into the blood. The greater part of it is in that form taken back with the chyle, through the absorbing processes and pores of the bowel, and is afterwards burned in the blood for the production of heat. The bile is, really, a kind of oily emulsion, made from the waste carbonaceous substances of the system and from the amylaceous and fatty portions of the food, and well fitted to serve as a fuel for warming the body. It is kept in the condition of a kind of soap rather than of oil, on account of the greater convenience with which the soap can be transported and acted upon. The bile, being a thick and not altogether soluble substance, and being intended for burning as a fuel, is kept back in the blood with the albumen, fibrin, and corpuscles, and does not drain away through the filtering funnels of the kidneys with the soluble waste parts.

The drink taken in with the food thus plays the double part of washing that food into the body, and of then washing away out of the body all the waste portions that have done their work and require to be removed. In order, however, that it may accomplish this double service, it must first become part of the blood; and then make its escape from the chambers of the lungs, through the pores of the skin and by the funnels of the kidneys. It has to mingle with the blood, and with it to go circling round and round through all the textures of the frame, through the heart, and lungs, and flesh; through the nerves and brain. Every drop of drink that is taken into the stomach must mix with the blood, must circulate with it through the most delicate organs of the frame, and must remain circulating through them, again and again, for prolonged intervals of time, although its final destination is only to wash away waste refuse out of the body.

LESSON XXXIII.

THE NATURE OF FERMENTED DRINK.

Water is the all-important ingredient of drink. Animals that exist in the wild state in nature get nothing else but water for drink. Thousands upon thousands, also, of human beings take nothing else but water, and yet perform all the varied actions of their bodies with unfailing efficiency. It is therefore perfectly clear that nothing beyond water is absolutely required to maintain the liquid state of the blood, and to enable it to accomplish its nourishing, its force-giving, and its purifying offices.

In the somewhat artificial state in which man lives in civilized communities, he has however devised various ways of disguising the water which he employs as drink. In most instances he does this by adding to it something which gives it an agreeable flavour. Artificial drinks, prepared in this way, are in very general use. But, since thousands of people get through all the work of life without them at least quite as well as those do who employ them, they must be regarded as articles of luxury rather than of necessity. It therefore becomes a matter of some moment to reasonable people to determine how far they are either useful and harmless superfluities, or how far they are dangerous and hurtful substitutes for the natural drink which they are made to supersede.

The various kinds of artificial beverages in most common use are obtained by the fermentation of sweet vegetable infusions, or juices; and all agree in one circumstance which is common to the whole. They all contain a substance called **ardent spirit**, which is made out of sugar by the process of fermentation. This ardent spirit can be distilled from the liquid when it has once been formed, because it is more volatile, or, in other words, more easily raised into vapour, by heat, than the water with which it is mixed. In the process of distillation, the spirit is first driven off by heat, and is then condensed by cold, and is so caught again in another vessel, in a liquid state, but apart and more or less free from the water.

All the fermented drinks, known as beer, cider, wine, brandy, whisky, rum, and gin, contain more or less of this spirit. It is most commonly procured by distillation from wine, and is on that account called "spirit of wine." Another of its names is **alcohol.** This name was given to it by the old Arabian chemists who first examined its nature, and is still retained amongst scientific men as its most suitable denomination.

Alcohol, or spirit of wine, in its purest and strongest state, is a clear transparent liquid, looking like water, but very much lighter, bulk for bulk. The volume, which would weigh 1000 grains if it were water, weighs only 790 grains. Instead also of being tasteless and inodorous, like water, it has a very burning taste, and a very penetrating smell. Its burning nature is also marked even more strongly than its taste; for if a piece of burning paper or a burning match be brought near to it, it then bursts into a flame, and continues to blaze until the whole is consumed, and changed by the burning into invisible vapour. It is on account of this combustible character that the liquid is called "ardent" or "burning" spirit.

The heating power of spirit is also expressed in another remarkable way. It makes water warm merely by mixing with it. If thirty parts, by measure, of alcohol be mixed with seventy parts of water, the mixture contracts considerably in bulk, but becomes fifteen degrees hotter than either the spirit or the water were before they were mingled together.

Alcohol can be intimately mixed with water in any proportions. Either one drop of alcohol may be diffused through a pailful of water, or one drop of water may be diffused through a pailful of alcohol. The two fluids, indeed, have so strong an inclination towards each other, that it is hardly possible to procure them apart when they have once been mixed. The strongest alcohol that can be formed, which is termed "absolute alcohol," still contains 2 per cent. of water mingled with its substance. Strong alcohol of its own accord always attracts to itself water from moist substances, and it does this so powerfully that it has the effect of drying them in consequence of removing the water from them. Meat and organic substances of a similar kind are hardened and preserved from putrefaction when they are plunged into alcohol, on account of the drying influence which it exerts.

When spirit of wine is mingled with water, the liquid, which is formed by the admixture, is even thinner and lighter than water itself. This is a very important characteristic; because a mixture of spirit and water, when taken into the stomach of a living animal, is, on this account, at once conveyed from the stomach into the blood, as it would be if it were pure water alone. When fermented drinks are used, water and spirit pass into the blood instead of pure water.

The ardent spirit, which is formed in a sweet vegetable juice by fermentation, is produced by a change in the substance of the sugar. The sugar begins to be resolved into its elements, that is, into carbon, hydrogen, and oxygen, by the removal of a portion of the carbon in the state of carbonic acid gas, or vapour. This vapour is seen to escape from the liquid in the form of an abundance of bubbles which rise up during the fermentation. As this goes on, the liquid becomes progressively less and less sweet, more and more sugar being destroyed; but it becomes more and more spirituous, or hot, because ardent spirit takes the place of sugar.

When carbonic acid escapes from molecules of sugar, during the process of fermentation, the elements that remain behind are rearranged to constitute new molecules, which have a smaller amount of carbon in each of them. Those new molecules are molecules of spirit instead of being molecules of sugar. They have lost their sweet taste, and have acquired in its place a fiery taste and properties. The molecule of alcohol is in truth a molecule of sugar on its downward progress towards complete decomposition, but arrested half way. When the downward progress is renewed, the molecule of spirit is first changed into acetic acid, or vinegar, after that into carbonic acid and water, and then the destructive or decomposing process is complete. Alcohol, therefore, although still a complex substance, is a *product*, not of building up, but *of wasting down*. It is less complex than the substance out of which it is formed.

In **beer**, the ardent spirit is formed out of the "glucose" or grape sugar of the malt. In the finished product, or beer, from 80 to 90 per cent. is water, from 3 to 8 per cent., according to the strength, alcohol, and about 5 per cent. sugar and albumen, or gluten. Stout, porter, and pale ale all contain a little more than one ounce of spirits of wine in every pint. Very strong beers contain as much as two ounces in each pint. The 5 or 6 per cent. of glutinous material and sugar which beers contain is nourishing substance. But this quantity is relatively so unimportant, that a very small piece of bread added to the same quantity of water gives more nourishment. Beer is consequently a very extravagant and expensive kind of food, apart from all consideration as to what may be the nature and effect of the ardent spirit which is present in it. It has been ascertained that $2\frac{1}{4}$ pounds of bread give as much strength and force to the human body as nine bottles of pale ale. But the $2\frac{1}{4}$ pounds of bread cost only about $3\frac{1}{2}d.$, whilst the nine bottles of pale ale cost 4*s*. 6*d*.

In **wine**, the spirit is procured from the fermentation of the grape sugar, which constitutes the sweetness of the juice of the grape. There is also in wine a small quantity of albuminoid material and unchanged sugar capable of affording nourishment; but the amount is very much less even than that which is present in beer. The quantity is indeed so small as to be hardly worth consideration. The amount of ardent spirit, produced from the transformation of the sugar, is, on the other hand, much larger than in beer. There are three ounces and a half of ardent spirit in every pint of strong sherry and port; two ounces of spirit to the pint in Burgundy; and one ounce and a half, or one ounce and three-quarters, in the lighter wines, which are called champagne, claret, and hock. The colour, fragrance, and flavour of wines depend upon very minute quantities of other ingredients which are extracted from the grape, and retained with the spirit in the liquid, after fermentation. It is to these flavouring matters that the agreeable quality of all wines is due. But the seductive power of fermented drinks, even in the case of wines which are the most attractive to the taste, unfortunately depends more upon the influence of their ardent spirit than upon these comparatively harmless ingredients.

Grape juice contains a considerable quantity of tartaric acid, of which, however, the principal part is deposited from the wine after fermentation. When this is not effectually accomplished, the wine is unpleasantly acid to the taste. In what are termed home-made wines which are manufactured from English fruits, such as gooseberries and currants, various other acids are also present. These are not naturally thrown down from the wine as tartaric acid is, and, on this account, sugar is added until the acid is disguised in the sweetness. Such wines are, in consequence, even less wholesome than the wines made from the grape.

The **spirituous liquors** known as brandy, rum, gin and the rest, are all made by distilling off the spirit from sweet vegetable juices, or infusions which have already undergone fermentation, condensing and collecting the spirituous vapours, and then mixing them up with water and flavouring substances until they acquire a certain strength and taste. The whole of these compounds contain a terrible quantity of the ardent spirit.

In whisky, which is the strongest spirituous liquid used as drink, there is half a pint, or ten fluid ounces, of alcohol in each pint! In gin there are about eight ounces to the imperial pint; and in brandy and rum, nine ounces to the pint. Any person who drinks one glassful of brandy or whisky, drinks half a glassful of strong burning spirit.

The amount of money that is spent every year for fermented drinks is almost too large to be believed until it has been carefully estimated in figures. In Great Britain and Ireland alone, as much as 80,000,000 gallons of fiery alcohol are consumed every year in the various forms of fermented beverages. The value of the drinks thus consumed, in the British Islands, in a single year, is certainly more than 130,000,000*l.* of money. It thus costs the inhabitants of these islands, who are generally considered to be amongst the most civilized and intelligent of the nations of the earth, considerably more for their strong drink than it does for all the advantages of education and good government—police, the administration of justice, prisons and reformatories for offenders, and the army and navy for external defence all taken together. Yet those, who know best what the actual value of fermented drink is in supporting the strength of the body, are quite aware that almost the whole of this vast sum is expended in *waste*, because a very small part indeed of it, spent in such materials as bread and meat, would really give more nourishment and strength than the spirits can by any possibility furnish. There is also the still more sad knowledge that a very large quantity of the strong drink is consumed, not only to no good purpose, but to a very bad and a very hurtful one, as at once appears when the direct influence of the spirit upon the organs of the living body is taken into account.

LESSON XXXIV.

THE INTOXICATING POWER OF FERMENTED DRINK.

When spirituous liquors in their strongest state, as they exist in brandy and whisky, are drunk in considerable quantity, it at once appears what their real nature is. It is then seen that they are poisons of the most deadly power. Men have been frequently killed by drinking a large draught of strong spirit, just as they would have been by taking a strong dose of such poisons as arsenic or prussic acid.

When the spirit is mixed with considerable quantities of water, as it is in wine, beer, and most forms of undistilled fermented drinks, and is swallowed in that state, this is what happens. The spirit is first taken up with the water out of the stomach into the blood-vessels. Pure water does not need to go the roundabout way through the bowels and the chyle-ducts. On account of its great importance in the work of transport within the body, a large part of what is used as drink passes at once into the blood-vessels, or veins, which are running back from the internal lining of the stomach. When only a moderate quantity of ardent spirits is mingled with the water, as is the case in beer and the weaker wines, the spirit goes with the water into the blood. The water, spirit, and blood are then circulated together through the textures of the body. In other words, the spirit, as well as the blood, is flushed to all the interior recesses of the frame, to the flesh, to the nerves, and to the brain, and is kept streaming on round and round through them. The purifying organs of the body immediately become conscious of the presence of the unnatural spirituous ingredient in the blood, and begin to clear it away, with the other waste and useless substances, as fast as they can. Some part of it is distilled away out of the mouth with the breath, some is exhaled through the pores of the skin, some is removed with the liquid excretion of the kidneys and with the bile, and some part is broken up in the blood into its final elements, oxygen, hydrogen, and carbon. It takes some time to accomplish the clearance, but the whole is certainly removed, if the quantity which has been taken be not more than the purifying organs can grapple with. When anyone drinks a bottle of strong beer, or half a bottle of wine, spirit derived from that drink is circulating in the blood for two or three days at least, occasionally for as long a time again; but, after that interval, the whole is found to have been removed by nature's own beneficent care, provided always, of course, that no more of the same kind of liquid has been introduced in the meantime.

If, however, more be introduced, and if beer and wine be taken at frequent intervals, in quantities which are in excess of the amount that can be removed, then the burning liquid accumulates in the blood, until at length its poisonous powers begin to manifest themselves by the effect they exert upon the living textures.

The first organ to suffer is the one which is the most beautifully and delicately organized of the whole, the organ, namely, which is concerned in the production of feeling and thought, and which is called **the brain.** The brain consists of a soft pulp, permeated everywhere by capillary vessels, which bring to it its proper supply of blood. The brain, indeed, is so active and important an organ in the human being, that it has much more abundant blood-vessels, and receives a much larger amount of blood than any other part of the frame of the same size. When the blood, which comes to its pulp through the branching blood-vessels in this abundant way, is highly charged with ardent spirit, *the brain soon begins to lose its proper powers.* First, there is confusion of thought, for thought is one of the proper functions of the brain; then there is indistinctness of speech; and after that, loss of the power both of feeling and movement, so that the individual falls insensible to the ground. The state, which is thus produced by the action of burning spirit upon the brain, is very aptly called **intoxication.** The word really means **a poisoned condition.** Intoxication is derived from 'toxicum,' which is the Latin for venom, or poison. An intoxicated person is one who has been so far poisoned with alcohol that the brain has lost its proper powers of feeling, direction, and thought.

The reason why people generally recover from the insensibility of intoxication—when the effect is produced by the slow and gradual introduction of the poison into the blood—instead of dying of the poisoning, is, that as soon as they have become insensible from the quantity of spirit circulating through the brain, it is a necessary consequence of the powerless and helpless state that they cannot go on drinking more of the spirit-containing liquid. Nature immediately begins to clear the spirit away from the blood; and, after a few hours, so much of it has been removed that the brain is sufficiently relieved from the burning and pernicious presence to be once again able to resume its proper activity and work.

Of the ultimate evil effects of this poisoning of the brain by the intoxicating influence of ardent spirit, there can however, be no doubt. The protective powers of nature are so great, that they can remove the terrible mischief, if it be not renewed. But unfortunately it too often is renewed. People who once submit to the tyranny of drunkenness almost certainly repeat the excess again and again. Very grave disease then is sure to follow. The brain in the end becomes injured in its structure, so that it can never quite recover its healthy state; and, in addition to this, the purifying organs, the liver, the lungs, and the kidneys, which were not originally intended to deal with so pernicious an adversary as the burning spirit, break down under the unnatural and excessive work that is imposed upon them, and become injured in their structures also. Habitual drunkards suffer from various diseases brought about in this way, the most formidable amongst them being one called "trembling delirium," in which the powers of the intellect are almost entirely destroyed. Trembling delirium is simply a state in which the organization of the brain has been grievously injured by the poisonous action of alcohol, and is on the way to ultimate destruction.

It is a very remarkable fact that, although ardent spirit burns when it is set light to in the presence of air, and furnishes a hot flame, it does not necessarily appear to have heating power when it has been received into the blood. The portion dismissed through the mouth and skin as spirituous vapour, and through the liver and kidneys as liquid spirit, would of course yield no heat, because that portion is not burned. But it might very reasonably be expected that the part, which is split up in the blood into its original elements, would furnish some warmth. The opposite, however, seems to be the fact. The bodies of drunken men grow colder instead of warmer from the presence of the intoxicating spirit in the blood. In certain kinds of fever physicians employ alcohol as a medicine, because it reduces the heat of the sufferer, and makes the parched body cooler. The feeling of warmth, which follows when people drink a little spirit, wine, or beer on a cold day, appears to be due as much to the increased circulation of the blood that it causes, as to a true oxidation, or burning, of the spirit. When the blood flows more quickly through the various structures of the body, through the lungs, as well as the rest, other ingredients of the blood, such as the oil, sugar, and bile, are, for a short time, more rapidly consumed with the production of increase of warmth.

This effect, however, only lasts for a brief interval, and it is invariably found that the blood of persons who indulge habitually in strong drink becomes preternaturally dark from the accumulation within it of various carbonaceous matters that ought to be removed. This darkness is then due to the excess of black carbon, or charcoal, which the blood contains. In some well-marked instances it has been ascertained that blood contaminated from this cause really had in it 30 per cent. more carbon than there should be; and, in two or three cases, the blood was more like black oily pitch than blood. All this was virtually due to the fact that various carbonaceous ingredients, which had been supplied in the food to be turned to account in the blood in warming the body, had remained there unburned, in consequence of the disturbing presence of the alcohol. This dark carbonaceous and contaminated state of the blood, produced by the immoderate and habitual use of strong drink, goes very far to explain many of the diseases that are known to attack intemperate people.

LESSON XXXV.

THE FOOD-POWER OF ARDENT SPIRIT.

It appears scarcely possible to doubt that, at least, some part of the ardent spirit which is taken into the blood as fermented drink is there split up into its original elements and so ceases to be ardent spirit. The most careful observations of skilful investigators have tended to show that, when fermented drink is habitually and freely used, more spirit goes into the blood than comes out of it again in the spirituous state, in the vapours of the breath and skin, and through the kidneys. There, therefore, arises the question what becomes in the body of the remaining part; and this is not only an interesting, but also an important inquiry, because it is obvious that that part may possibly be turned to account either in building up its structures, or in supporting its strength and activity. Being so split up into the original elements as to cease to be spirit, its atoms and molecules may be used in connection with the ingredients of the food for the construction of organs and textures, or strength and support of some kind may be contributed by the act of change.

The opinions of scientific men differ as to what is the probable truth in regard to this particular point. Some believe that the spirituous part of fermented drinks does nourish and strengthen the body when they are judiciously and moderately employed; and that ardent spirit is, in itself, properly a food, as much, at least, as oil, sugar, and starch. Others, on the contrary, as fully believe, and strenuously maintain, that ardent spirit is in no sense a food; but at the very best, and when employed only in quantities too small to be capable of doing harm, is merely waste and useless substance that has to be got rid of. Both of these differing authorities have apparently some reason to give for the opinions they hold. Thus, it is certain that old people have been known, in some extreme cases of illness, or of confirmed habits of intemperance, to live for weeks at a time upon spirituous drink, without suffering any loss in the weight of their bodies, such as would certainly have occurred if they had remained entirely without food for the same period ; and, again, in cases of extreme weakness and the exhaustion ot severe fever of a certain kind, sick people are often kept alive by strong drink given as a medicine by their doctors.

On the other hand, it appears at the first glance inconsistent with the general order of nature's plans that alcohol should serve as a food, because it is a substance advancing towards decomposition and decay, and not one in the completeness of elaborate complexity, as all the proper food-substances are. Alcohol is a compound already corroded by the tooth of the wasting oxygen, and therefore, in this sense, unsuited to play the part of a food to the animal body. The rule of nature is that food-substances are complex bodies built up out of simpler elements, by the powers of vegetable life, in order that sustenance and strength may be obtained from them when they are pulled to pieces, or resolved in the animal frame. Alcohol is clearly not a substance built up out of simpler elements, but a complex organic substance broken down into a simpler state, and advancing to the condition of further decay.

In various other instances, complex substances, that are passing downwards through intermediate stages of decomposition, constitute very dangerous poisons, instead of being foods. Thus, both oxalic and prussic acid are poisons of this character. They are complex vegetable productions advanced one stage downwards in the process of resolution and decay. Alcohol, in its strongest and most concentrated state, certainly is as powerful and deadly a poison as either oxalic or prussic acid.

The truth appears to be that it is not as yet possible to say what is the actual destination of the alcohol which is consumed in the bodies of living animals. No one can tell what becomes within them of its elements. This, indeed, is one of the questions that has not yet been fathomed by human intelligence; one of the provinces of imperfect knowledge that has to be penetrated by the further investigations of science.

Certain considerations, however, in connection with this inquiry, are already clear enough, and should on no account be lost sight of. Unhappily a tendency is almost invariably produced, in persons who use fermented drinks, to take more and more of them day after day, and in the end to find that it is almost impossible to escape from the habit which has so been formed. A craving for the unnatural influence is set up, so that at the return of every meal and, too often, even more frequently, the seductive drink is looked for. This is one of the especial effects of the action of alcohol upon the nerves and the brain. It causes an almost irresistible desire for a renewal of the influence. Habitual drunkenness springs almost invariably, in the first instance, from this cause.

Even when people have the self-control and the proper moral sense to avoid actual intoxication, it still commonly happens that enough strong drink is taken, in consequence of this craving, to do harm in various ways; and this is more sure to occur with weak than with strong persons, and with old than with younger people. So long as the purifying organs of the body remain in vigorous action and in unimpaired strength, they are able to expel the unnatural intruder. But when those organs lose their power, the injurious effect of the spirit upon the textures begins to tell. Many of the most distressing diseases to which the human frame is subject can be distinctly traced to this cause. It appears from carefully conducted experiments that $1\frac{1}{2}$ ounce of alcohol (contained in 3 ounces of brandy, 6 ounces of strong wine, or $1\frac{1}{2}$ pint of pale ale) taken everyday is enough to keep the blood charged with the spirit, and is therefore in excess of the quantity which can be prudently taken.

As, therefore, it is perfectly clear that fermented drink is **not necessary** for the healthy action of the human frame; that it produces an **unnatural craving** which leads to more and more of it being consumed; that, when taken in quantities short of intoxicating excess, it is yet prone to **produce a dark state of the blood,** and to derange the proper balance of the economy; and that, when consumed to an intoxicating degree, it is a rapidly **destructive and dangerous poison,** it is simply a matter of self-defence to have as little to do with the treacherous agent as possible. So long as there remains any shadow of a doubt as regards its usefulness in the system, it must be the part of a wise ordering of the habits, as well as of a sound economy, to secure the benefit of the doubt, and to regard fermented drink as a thing to be avoided rather than sought. One of the best exercises in self-denial and self-control that can be conceived is, the habitual abstinence from strong drink, because it is known to be a dangerous agent to toy with, and because it is not known that even its most moderate consumption is an unalloyed good.

But, if this be the true state of the case, the keeping of so suspicious an influence and so seductive an enemy out of the hands of young people and children, becomes of even more momentous importance than that grown people should resist the temptation. To give strong drink to children, who can know nothing about these reasons for its avoidance, is a most cruel act. It is nearly certain to result in setting up the dangerous and almost irresistible craving before any power of self-control can have been established. Very few children, who have been used to beer and wine in their tenderest years, will ever be able to lay them aside in maturer life. Many cases of incurable intemperance can be distinctly traced to habits quite innocently and unconsciously acquired in early childhood. It is almost a rule with children that they dislike beer and wine when they first take them; but, after they have been induced to drink them a few times, they begin to like them, and then, after a while, cannot do without them. It is certainly a maxim of the soundest domestic economy to see that no child of the house ever has beer, wine, or spirituous liquor of any kind placed within its reach.

LESSON XXXVI.

TEA, COFFEE, AND COCOA.

The artificial drinks that are prepared from **tea, coffee,** and **cocoa**, are used for the same reason as fermented beverages; namely, on account of the pleasant flavours they communicate to the water, and of the agreeable sensations they produce. They are all, however, taken hot, being prepared at the time when they are used. Boiling water is poured over the dried leaves of the tea, or over the ground coffee or cocoa, and is then drunk when it has extracted from them the flavouring substances they contain.

There is no ingredient in these drinks that is so treacherous and hurtful as ardent spirit. But there is, nevertheless, something in them that is capable of exerting an injurious effect upon the delicate organization of the human body, when they are injudiciously and intemperately employed. This powerful ingredient can be easily made to reveal itself in the case of tea. If a small quantity of the leaves be put into a watch glass, and this be placed upon a hot iron plate, such as the top of a cooking range, and be lightly covered by paper, there soon begins to rise out from the tea a white vapour which collects both on the leaves and the paper, in the form of long shining crystals. This is a peculiar compound, manufactured by the leaves of the plant out of the four principal elements that are used in the formation of food-substances. Each molecule of the crystal contains in itself eight atoms of carbon, two atoms of nitrogen, five atoms of hydrogen, and three atoms of oxygen. This shining crystalline substance is the most important ingredient of the tea, and on that account is called **theine.**

The substance thus extracted from tea has a very powerful action upon the living animal body. It first lessens the force of the heart's stroke, and diminishes the speed of the circulation of the blood. It then produces a feeling of gentle and pleasant excitement, very similar to the effect caused by taking nourishing food. If only as much be used as produces this effect, no hurtful result appears to follow. If, however, larger quantities be taken, a somewhat distressing wakefulness is caused, and insensibility may even be produced. Still heavier doses lead to convulsions and death. In such quantities, therefore, theine is an actual poison. The essential nature of this white crystalline substance appears to be of somewhat the same character as the quinine which is extracted from Peruvian bark, and the morphia which is extracted from opium. About five grains of theine are enough to produce the full stimulant effects upon delicate organizations.

The quantity of theine contained in tea varies with its quality. In good ordinary tea there should be about *one hundred and seventy-five grains in each pound.* A teaspoonful of tea weighs something like seventy grains; consequently in each teaspoonful there would be from one to two, or possibly three, grains of theine. It will, therefore, be easily understood that if people drink strong tea, and take many cups of it, they may possibly get more of this energetic white salt than is altogether good for them.

Tea is the dried leaf of a shrub which belongs to the same natural family of plants as the camellia. It is a native of Bengal and probably of China, and is now cultivated for the sake of its leaf in Hindostan, China, and Japan. The leaf is plucked from the tree and dried by artificial heat.

The fragrance of tea is due to an essential oil, which, as well as the crystalline theine, is formed by the plant and retained in the dried leaf. This oil is pleasantly stimulating, and does not possess any of the poisonous powers of the crystals. When tea is made, about one teaspoonful of the dried leaf should be allowed for each person, so that each individual should get at the most not more than from one to two grains of theine. Other substances of inferior power to the theine and the essential oil are also extracted from tea. If one hundred grains of good tea be first crushed and afterwards boiled until nothing more can be extracted by the water, and the water be then boiled down until it has all evaporated, there should remain about thirty-five grains of dry solid substance which has been extracted from the tea.

Some of these solid matters are in all probability of a nutritious character, but it is only a very small portion of them that is taken up when tea is properly made; because the object is to extract only the more delicate parts and to leave the coarser matters behind. When tea is boiled long enough to extract from it all the soluble portions, the fragrance is entirely lost, having then been dispelled by the continued heat. The best plan for preparing tea is to pour boiling water over it, and to allow it to stand for from five to seven minutes, before using it as drink. This secures the flavour of the essential oil and of the most delicate parts of the tea, and leaves the coarser ingredients untouched. Tea, when of good quality, well made, and judiciously taken, is a very refreshing and altogether wholesome beverage. Its exact influence upon the body is not fully understood, but it certainly quickens the movement of breathing and gently stimulates the intellectual operations of the brain. Its pleasant action, when used in a reasonable and moderate way, is in all probability due to some subtle power that it possesses of sustaining the nerve-substance in its work. Like fermented drinks, however, it is *a luxury* rather than a *necessary of life.*

It is a curious and remarkable fact that both coffee and cocoa, which are the productions of plants in no way allied to the tea-shrub, nevertheless contain, amidst their other ingredients, a white crystalline substance that very closely resembles the theine of tea in appearance and chemical composition, and also in its influence upon the animal organization. This substance is called Caffeine in the case of coffee, and Theobromine in the case of cocoa. There are about forty-two grains of the crystals in each pound of coffee, and one hundred and five grains in each pound of cocoa. Both, therefore, contain much less of this active principle than tea; and coffee considerably less, one reason for which, probably, being that coffee is subjected to great heat in roasting, and that this drives off a considerable part of the volatile white crystal.

Coffee is the seed of a shrub belonging to the great natural family of plants that yields Peruvian bark and ipecacuanha. The shrub was originally a native of Abyssinia, but was introduced into Arabia about three centuries ago. It is now cultivated, on account of the valuable properties of its seed, in many tropical countries, especially in Ceylon, Java, Brazil, and the West Indies.

The seed, or bean, is contained in a pulpy fruit, and is principally composed of albumen. When this has been cleared of the outer pulp and of an inner dry husk, it is roasted in an iron pan over a hot fire, until the albumen is scorched into a crisp, brown substance. In this operation a fragrant oil is produced, which remains mingled with the albumen of the roasted bean, and becomes the immediate cause of the pleasant flavour of the beverage. As there is something more than two ounces of albuminoid substance in every pound of coffee, it is necessarily more nutritious than tea. But the fragrant oil tends somewhat to retard the digestive process, and coffee is, therefore, not always wholesome to persons of delicate digestion, especially if taken strong immediately after a meal.

Coffee needs to be freshly roasted and recently ground in order that it may be used at its best. It requires also to be made with judgment and skill, because the agreeable fragrance, which is its most valuable part, is easily dissipated by heat. One very good way of making coffee is simply to pass boiling water through the ground berry, placed upon a perforated strainer, over a suitable vessel. The boiling water then runs through the powder, and carries with it the fragrant oil and some part of the nutritious extract. Another excellent plan is to put half the ground coffee into cold water and bring it to the boil, to boil the other half in water for three minutes, and then to mix the two infusions. The first is found to contain the fragrance, and the second the bitter and nutritious extract. The one thing to be carefully avoided is boiling the infusion long and fiercely, because that effectually dissipates the fragrance.

The **cocoa** plant is a native of South America, and is now cultivated in Brazil, Guiana, and Trinidad. It is the seeds of the plant which are employed, as in the case of coffee. They are contained in a pulpy fruit, are first removed from the pulp, and then dried, roasted, freed from their husks, and broken into coarse fragments, which are termed "cocoa nibs." The nibs contain about the same quantity of albuminoid substance as coffee; that is, a little more than two ounces to the pound. But there is, mixed with this, four times as large a quantity of fixed oil or fat. One pound of the crude cocoa contains something more than half a pound of this fat, or "cocoa butter."

In the preparation sold as "soluble cocoa," some part of the butter has generally been removed, and the remaining part of the nib mixed with a certain quantity of starch. When boiling water is poured upon this mixture, the starch turns into a thick mucilage, in which the finely ground and oily cocoa is held suspended. The cocoa is not really soluble; it is only diffused through the gelatinized starch, so as to have the appearance of being so. **Chocolate** is cocoa ground up with sugar, vanilla, cinnamon, and occasionally with bitter almonds also.

The abundance of butter, or fat, contained in cocoa, makes it more nutritious than either coffee or tea. Many persons, however, can only use those preparations of it which have had much of the fat removed. The pleasant aroma of the nib is due to an essential oil, which is formed, as in the case of coffee, in the process of roasting the albumen. When well prepared, cocoa is a lighter and less stimulating beverage than either coffee or tea.

The best way to use tea, coffee, and cocoa, is to take them made fairly good, and to restrict the quantity to a couple of small cups at a time. Large quantities of very weak hot tea and coffee are often more unwholesome than small quantities of the stronger beverage. Two great excellences of this class of artificial drinks are, that they do not unconsciously lead those who indulge in them to increase the quantity used, as the spirituous beverages do; and that they do not produce any of the subtle and accumulative blood- and brain-poisoning which follows from the habitual use of fermented drinks. The distinguished chemist Liebig considered that tea and coffee are very analogous in their nature and powers to soup. It is a somewhat curious fact that iron, which in many instances is a valuable blood medicine, is contained in tea in some subtle form of combination that does not allow its presence to be detected in the usual way; namely, by being turned into black ink under the agency of ordinary astringents, such as tannin.

SECTION 3.—HEAT, CLOTHING, AND WASHING.

LESSON XXXVII.

SOURCE OF ANIMAL WARMTH.

The blood, which is returned *to* the heart after its journey through the capillary vessels that lie in all the textures of the body, is in a notably different state to that which is issued to the capillary vessels *from* the heart. It was of **a bright scarlet colour** when it started on its journey, but it is of **a dull purple hue** when it gets back again after its passage through the frame. This change can be clearly traced to the capillary vessels where the movement of the current is the most sluggish, and where the blood is brought into the most intimate contact with the various textures it has to nourish. The blood, which enters the capillary vessels of a bright scarlet hue, comes out from them at the commencement of the veins of a dull purple tint. This change indicates that the blood has been, to a certain extent, spoiled for its nourishing work during its passage through the narrow channels of those vessels.

The change produced in the blood when it acquires this dark purple tint, is due to two distinct causes. A large portion of its nourishing substance is removed from it for the work of construction and repair as it flows through the narrow, thin-walled tubes; but, besides this, the spoiled substance, which has accomplished its work of forming a part of the living textures, is at the same time drawn back into the blood. The blood, therefore, is altered both by the loss of some part of its useful ingredients, and by the reception or addition of waste and refuse material.

The waste substance, that is added to the blood as it streams through the narrow channels of the capillary part of the circulation, is of various kinds. All the several ingredients of the organized machinery that have done their work are thrown back into the current. But by far the largest part of the waste is composed of the solid element, carbon. The dark purple hue of the venous blood is merely this black element mingled in with the scarlet liquid in great abundance.

But the black carbon cannot get back from the worn textures into the streaming blood in its solid state. In that state its coarse molecules could no more pass through the fine films of the capillary vessels, than coarse sand could pass through the pores of blotting-paper. What, therefore, happens is this. Energetic oxygen is carried in the scarlet blood into the capillary network, and there seizes upon the carbon, converts it into the thin gaseous state of carbonic acid, as it is its nature to do; and this carbonic acid then passes through the films and mingles with the blood-streams. The dark purple blood is highly charged with a superabundant quantity of carbonic acid gas, whilst the bright scarlet blood is as heavily charged with an excessive quantity of pure oxygen. That this is really the cause of the change of colour in the blood can be readily shown by direct experiment. If a little bright scarlet blood be shaken up with some carbonic acid gas in a glass bottle, it immediately becomes of a dark purple hue; and if, then, the dark purple blood be shaken up with some pure oxygen in another glass bottle, it is turned back again to the bright scarlet colour.

Here, therefore, is one very good reason why as much as 5000 grains of carbon must be added to the blood every day by means of the food. The flowing blood-streams are continually taking the carbon molecules out of the textures of the body, and other carbon molecules have to be returned as fast as these are removed.

But one very remarkable consequence always results when carbon is united with oxygen to form carbonic acid gas. It is that result which is seen when a piece of carbon is burned in contact with the air; for the burning of carbon is nothing more than turning its dense substance into the invisible compound gas by the consuming touch of oxygen. The burning carbon sets free, or makes sensible, a considerable quantity of heat. The fierce heat which melts iron in a furnace is all extracted from the carbon of coal through the instrumentality of the air-blast that is blown in upon it. The black substance is flown away with by the oxygen supplied by the air, and the heat, which was hidden in the black substance, but which cannot be retained in the same way in the carbonic acid, is left behind. In a blast iron-furnace in full work, more than half a ton of the black coal has to be carried in this way up the chimney every hour, in the form of invisible vapour, in order that the requisite amount of heat may be procured; and, to carry away this half ton of the black charcoal, not less than six tons of air, which contain something more than one ton of oxygen, have to be blown in upon the fire of the furnace. Half a ton of carbon requires six tons of air for its conversion into carbonic acid vapour.

Exactly what occurs to the coal in the blast furnace of the iron foundry occurs also to some portion of the carbonaceous substance contained in the textures of the body. It is burned away under the blasts of oxygen that are conveyed to it in the bright scarlet blood. As much as *half a pound of black carbon* is burned up *in the streaming blood* of an adult human being in twenty-four hours. The only difference in the two cases is that, in the instance of the living body, the burning is slow instead of fast. Half a pound, instead of twelve tons, of the black fuel is consumed in the twenty-four hours. In order, however, to effect the burning of that half pound of carbon in the blood, eight pounds of air, or 90 cubic feet by measure, have to be furnished to fan the slow fire.

All the heat which is set free, in consequence of the burning of the half pound of carbon, is left in the blood. It is that which makes the body warm. Whatever may be the heat of the air outside, the body itself is kept at a steady temperature of 98° of Fahrenheit's heat-scale, which is called in consequence **blood heat.** This amount of warmth is essential to the actions of life, and is mainly kept up by the burning of carbon in the blood; and it is because carbon has this warming work to do, over and above its structure-building offices, that so much as 5000 grains of it per day have to be furnished in the food.

The carbonic acid vapour, which is generated in the blood by the burning of the combustible carbon, is carried on in the blood-streams, whose bright scarlet colour it has changed into the dull purple hue. But the spoiled blood thus laden with carbonaceous vapour is not fit for further work in nourishing the frame until it has been purified from these heavy fumes. It is, therefore, not returned to the bright-coloured pure blood in the heart, but conveyed to a separate chamber, and from that it is sent to the purifying organ called the lungs, where the carbon-vapour is exhaled away and fresh oxygen taken in in its place. The act of purification is brought about by the familiar operation known as **breathing.** Under the movements of the chest which accompany breathing, fresh, richly oxygenized air is drawn through the mouth to be mingled with the blood in the lungs, and impure, heavily carbonized air is poured out from the mouth.

The heart, therefore, consists of two distinct chambers, a right chamber and a left. The left side of the heart distributes bright scarlet and pure blood out to the capillary vessels of all parts of the frame; the right side of the heart sends dark purple and impure blood to the lungs, to be freed from its vapours and recharged with fresh air, or oxygen. The left side of the heart receives the purified blood back from the lungs; the right side receives the impure dark blood from all the structures of the frame. The mingling of the air with the blood in the lungs is managed by what is virtually a repetition of the process adopted throughout the structures of the body. The large pipe which leaves the heart branches out at last into a vast myriad of intermeshed capillary vessels that spread throughout the substance of the lungs, and these are then gathered up again into larger and larger tubes as they return to the heart. In the lungs, however, the capillary vessels are spread over the walls of puffed-out chambers, which are filled with air. As the blood-currents stream through the capillary vessels thus spread over the air-chambers, the blood in their channels is separated from the air by only the thinnest film of organized membrane. Through this film the air and the blood act freely upon each other. Oxygen passes through the film to the blood, and carbonic acid passes as freely from the blood into the air. The air, which goes into the mouth in breathing, is pure air laden with oxygen, but the air, which comes out of the mouth as the expiration, or outward breath, is impure air laden with carbonic acid vapour.

There are thus two distinct circulations of the blood; the circulation of **pure, brightly-coloured blood through all the structures** of the frame to do in them the work of nourishment and to be contaminated, or spoiled, in the act; and the circulation of **impure, dark-coloured blood through the lungs** to be there purified.

The oxygen which enters the blood in the lungs at once attaches itself to the little floating corpuscles, and changes their dark purple into a scarlet hue. As the colour of the blood is seated in the corpuscles, it is clear that in those corpuscles the oxygen must be placed. So, in the same way, the dense carbon-vapours are carried in the corpuscles, for it is in them that the dark purple colour is concentrated. The red corpuscles thus serve the important office of **carriers of gas.** They convey the ever-active oxygen from the lungs to all parts of the body, to blow up the gentle fires that depend upon the consumption of the carbon; and they carry back from those parts to the lungs the carbonized vapours that are the result of that consumption. The liquid blood which circulates through the capillary vessels of the frame always contains as much as half its own bulk of free vapour or gas. Fifty cubic inches of gas could at any time be extracted from 100 cubic inches of blood. But of those 50 cubic inches, it would be found that, about 15 cubic inches were made of pure oxygen, on its way to blow up the hidden and gentle fires of the system, whilst about 30 cubic inches are the heavy and suffocating carbonic acid vapours, produced by those fires, on their way back to the lungs to escape out of the body.

The red corpuscles which carry the oxygen from the lungs to the living structures are singularly well adapted for this particular work. The red liquid of the corpuscle, or hæmatin, can hold in itself very much more oxygen than even pure water can. But it nevertheless holds it so lightly that it is ready to give it up on the instant whenever required. As the red corpuscles have to return to the lungs after the delivery of their oxygen, the opportunity is seized to employ them to carry back a return load. But the load sent back is the heavy and waste carbonic acid which needs to be got rid of, and which, after reaching the lungs, is exhaled from them with the breath.

There is, of course, no direct communication between the two cavities of the heart to which the two distinct circulations belong. It is as if two hearts were placed side by side and beating together. They are two force-pumps acting with a single stroke. One single beat only is felt each time the heart drives out its blood, because the two separate sides act together at the same instant, or as if they were one. The sounds of the two different contractions can be heard, and distinguished from each other, but only by the most experienced ears.

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LESSON XXXVIII.

SOURCE OF ANIMAL ACTIVITY AND POWER.

The food which is consumed by a living human being is applied to two altogether distinct purposes. One portion of it is turned into the actual structure of the body, in order that the waste and the wear and tear due to its several movements and activities may be repaired. That part is applied to the mere building, or renewing operations, or, as is familiarly said, to nourishing the frame.

Another portion of the food is employed solely in giving movement and activity to the several parts that are formed and kept in repair by the nourishment. Out of this has arisen the commonly accepted division of the food-substances into what have been called **flesh-formers**, and **force-producers.** The term "flesh-formers," however, must be understood in a somewhat wide sense, because it refers not only to "flesh," or muscular fibre, but to all the other textures of the body which are built up by an elaborate and definite process of organization, such as gristle, bone, skin, nerve, and brain.

The quantity of the food used in mere building, or structural work, is very small in comparison with the amount consumed for the production of movement and activity. All the substances which are required for the building purposes of the frame are derived from the serum of the blood and from the red liquid of the little corpuscles. What appears to take place in the building up and maintenance of the structures of the body is that, as the blood is flushed through the capillary vessels channelled out in those structures, molecules are loosened from the built-up mass by a process of decomposition, or severing from the rest, and are thrown back into the liquid of the blood; and other fresh molecules are selected from the blood and packed into the place of those which have been removed. Each different kind of structure takes from the blood just those particular ingredients that are adapted to its special wants.

The term "flesh-formers" is convenient so long as it is understood to imply that it is the plastic and nitrogen-containing ingredients of the food and of the blood, such as the albumen and fibrin, which are *principally* drawn upon for the building work. But it is in some measure questionable on the ground of strict scientific accuracy, because the other kinds of ingredients of the food and blood, which have no nitrogen in their composition and which are not classed as flesh-formers, do in some degree also contribute to the building work. Thus, there is no doubt that oil, which has no trace of nitrogen in its composition and which is classed as a force-producer, is used in building up many of the structures of the frame. Some portions of the oil, or fat are themselves derived from the albuminous, nitrogen-containing ingredients of the food. Animals, like pigs, which are kept to be turned into food, cannot be fattened unless a considerable quantity of glutinous material is given to them with starch. So, in the same way, there is no doubt that even sugar itself is made in the living body out of albumen.

It is also equally clear that some portion of the flesh-forming, or plastic, ingredients of the food, is consumed for the mere production of force, or vital activity and power. The fact seems to be that the albuminous, or nitrogen-containing ingredients of the blood and of the body are split up into two classes of products when decomposed under the operations of life; of which one class is still a nitrogenized substance, whilst the other class contains only the more simple unnitrogenized products, such as sugar, starch, and oil, which are in the end burned, under further additions of oxygen, and so converted into carbonic acid and watery vapours.

The three principal ingredients of the food, namely, the albuminous, the amyloid, and the oleaginous, are in truth all of them composed of an easily oxidized material, that is, of substances prone to be burned by the addition of oxygen from the air. A small portion of all of them is first taken to be built up into structure before the burning is commenced; but the rest is entirely burned in the blood in order that *force* may be got out of the burning; as heat is got out of coal while it is burned in a furnace, or a fire, and as light is got out of oil that is burned in a lamp.

When these combustible food-substances are burned in the body through their combination with oxygen, the "force" which is produced may be manifested in three different ways. It may either reveal itself directly as heat, which then constitutes the warmth of the body. Or it may show itself in connection with the muscular texture as movement. Or it may appear in connection with the nerve-texture and brain-texture as feeling, voluntary impulse, and thought. These are all different forms assumed by the force that is set free by the consumption of food. The movement, again, which is manifested through the muscular texture, is of two distinct kinds. It is either internal movement, such as is shown in the beating of the heart and the play of the chest to keep up the breathing; or it is external movement, that is, the conveyance of the animal about from place to place upon its limbs and the employment of those limbs in mechanical work of any kind whatever.

The amount of work that is performed in the body of an animal, through the consumption of food, is surprisingly large, when the smallness of the material employed for the purpose is considered. Thus the heart of a man beats something more than one hundred thousand times in twenty-four hours, to drive twenty pounds, or so, of blood fourteen hundred times through the textures of the frame. The muscular effort which is exerted by the fibres of the heart to accomplish this circulation of the blood for twenty-four hours, if employed in lifting a weight instead of merely pumping a liquid, would be able to lift 121 tons of heavy material one foot high. The muscular movement which produces the action of breathing, if applied in a similar way, would also lift eleven tons one foot high. The heat which is developed in twenty-four hours in a human body of average strength and size, if employed as mechanical power, as it would be, for instance, if made to generate steam out of water in a steam engine, would be able to lift, according to some good authorities, nearly 3180 tons one foot high.

The external work which can be done by a man of average strength, that is, by walking about, digging the ground, or hammering iron, amounts to a force which, if employed in a different way, would be able to lift 350 tons one foot high. It will thus appear that the external work which is got out of a human machine from the consumption of its food, is but a small fraction compared with the work which is devoted to the internal actions of life and to the warming of the frame. It is, indeed, only as about one to nine. The amount of force which is expended in mere mental work, that is, in the work of the brain, is not easily estimated. But, for all practical purposes, it may be considered that the force capable of lifting 350 tons one foot high every twenty-four hours is really divided between external work and mental labour, and that for this reason people are seldom able to perform very heavy tasks both of intellectual labour and of muscular effort. The strength which is employed for the one ceases to be available for the other.

The result of these considerations is, therefore, this very marvellous fact. In the mechanical organization of the living human body, the mechanism is so skilfully and admirably contrived, that, by the consumption of merely one pound and a quarter of dry food substance, or fuel, as much active force is produced as would suffice to lift something more than 3000 tons one foot high, and, over and above this, all the substance is furnished which is required to keep the machine itself in good working order and in efficient repair.

It is, at the first glance, a somewhat startling circumstance that so very large a proportion of the food consumed by a human being should be used simply for warming the body. Wherever, in the interior recesses of the living frame, carbon is being united with oxygen and carbonic acid vapour produced, heat is generated. Each little loop of the capillary vessels that permeate the textures is, so to speak, a miniature fire-place. All the heat, however, which is developed in these fire-places, is communicated to the blood, and is carried on by it, as it circulates, through all parts of the system. The body is like a large manufactory warmed by hot-water pipes, the heat of which is generated in certain parts of the tubes, but is then carried on by the water, and equally diffused throughout the building. By this process the temperature of the body is steadily maintained everywhere at about 98° of Fahrenheit's scale.

For some considerable time it was supposed that the chief, if not exclusive, reason for the warmth of the body was that, at this temperature of 98°, all the various processes of change, such as the conversion of food-substance into blood, of blood into structure, and of structure into activity and force, were more easily accomplished. It is now, however, suspected that there is more than this in the large expenditure of food which is made for warming purposes.

Some few years ago Professor Tyndall, of the Royal Institution of London, wrote a book called "Heat a Mode of Motion," in which it was shown that, in the processes of nature, heat is the great store-supply of energy and force which can be changed into almost any kind of power, and which can be made to do work of almost any character.

This doctrine at once suggests that much of the heat, which is so abundantly produced in the living animal body, is turned to account by being converted into activity of some other kind, such as the movement of the fibres of the flesh, the transmission of the impulses of the nerves, and the production of feeling and thought. If this be the case, then heat is a "mode of motion" in the economy of the living frame as much as in the mechanical operations of unliving nature; and it becomes correct to speak of the "heat-producing" substances of the food, such as sugar, starch, and oil, as being, at the same time, "force-producers" in the operations of animal life. But, here again, what has been already said must be distinctly borne in mind, namely, that both the albuminous and carbonaceous ingredients of the food are burnt up in the body and the blood, and yield heat and force as they are resolved under the consuming tooth of oxygen into their simpler elements; and that both also contribute, each in its proper degree, to the work of building up and renewing the several textures of the frame.

LESSON XXXIX.

ARTIFICIAL FIRES AND FUEL.

The great natural fire of the earth is the sun. In the Torrid or burning Zone of the earth the sun shines down upon the terrestrial surface with such intensity of heat that, although the night is twelve hours long all the year round, there is nevertheless more warmth than human beings require for their comfort, without any help from artificial fires. The heat received by the earth from the sun in one year, if evenly spread over the entire surface, would be sufficient to melt a coating of ice 100 miles thick, encasing the globe like a shell. The heat which is given off from the sun every year is as much as would be produced by the burning of a layer of coals seventeen miles thick, and as large as the entire surface of the sun, and that is nearly twelve thousand times larger than the surface of the earth. So vast a fire is the sun!

But the heat from the sun is not evenly spread over the entire surface of the earth. On the contrary, by far the greater part of it falls on the torrid zone which lies, like a broad girdle, midway between the terrestrial poles. Around the poles themselves so small a portion of the solar heat is received, that ice and snow remain there all the year round. In the temperate regions, which lie between these frozen districts and the torrid zone, seasons of summer warmth and winter cold divide the year, and, during the winter's cold, men have learned to supplement the sun's heat by artificial fires, and so to keep, at least the interior of their dwellings, at such a pleasant temperature as does not allow the natural warmth of their bodies to be carried away too rapidly for the comfort and purposes of life.

The artificial fires that are used in winter time by all civilized people are made either of wood recently grown in the sunshine, or of wood of an older time which has been buried in beds in the earth, and which is dug up from the ground to be turned to account for purposes of heating, and then called coal.

Wood, it will be remembered, is made of carbon, hydrogen, and oxygen, which have been built into vegetable structure by the fabricating power of plants, and which have had stores of warm sunshine buried away amongst the molecules they have formed. The sunshine thus buried away in the wood is, indeed, the force which is used to keep the three elements bound together as wood. When dry wood is burned in the fire, more oxygen is taken from the air, and all the carbon and hydrogen of its texture, under the consuming touch of that oxygen, are changed into the compound gas, carbonic acid, and into the vapour of water, or steam. The wood disappears almost entirely, because it is transformed into these invisible vapours. But the warm sunshine, which had been stored away amidst the elements to keep them bound up in the complex woody state, being then no longer required to perform that work, is set free, and leaps back into sight as brilliant flame, which flame after all is therefore but an offshoot from nature's great fire, the blazing sun!

Coal, which is merely partially decayed wood that was grown on the surface of the earth, in sunshine, many thousand years ago, and that has since been buried deep in the ground, is composed almost entirely of the two combustible elements, carbon and hydrogen. When it is burned, the sunshine, which was buried in it thousands of years ago, is got back out of the black mass, and once more turned to account in producing useful heat.

When coal is burned in a fire, a strong blast of air is, in some way, blown in upon it, after it has been raised by means of flame to a high temperature. What then happens is that atoms of oxygen from the air seize upon atoms of the carbon of the coal and fly away with them as carbonic acid. Other atoms of oxygen seize upon the hydrogen of the coal and fly away with it as water. Both the carbonic acid and the water, thus produced, are in the state of invisible vapour, and are carried away up the chimney. Some small fragments of the coal are also hurried away with the ascending currents of the invisible vapours before they have had time to be burned. These unconsumed, but finely broken up, fragments of the coal are seen streaming away up the chimney, making with the ascending vapours dark masses of smoke.

Coke, which is also used as fuel for the production of artificial fires, is simply coal from which a portion of the carbon and all the hydrogen have already been removed, and which therefore turns entirely into carbonic acid gas when it is burned. Precisely in the same way **charcoal** is wood from which some of the carbon and all the hydrogen have already been removed. Whenever the fuel in a fire burns with a flame, it does so because hydrogen is there in the process of being consumed. Whenever it burns with a dull red heat, it is carbon alone that is undergoing combustion and being united with oxygen.

The current of air, which blows in upon a fire and helps to carry the carbonic acid and watery vapour up the chimney, is mainly caused by the difference of the density of the heated air, that is contained in the chimney over the fire, and of the cooler air contained in the room. The warm air in the chimney is light, and the cool air in the room is heavy. The cool heavy air presses in through the windows and doors of the room and even through the invisible pores of its walls, by mere virtue of its greater weight. It presses upon the air that is within the chimney as well as upon all parts of the inside of the room. But as the air in that chimney is hot, and therefore lighter, bulk for bulk, than the cold air of the room, it has to give way under the greater pressure and to flow before it in the only direction in which it can go, that is, up through the chimney and out at its open upper end. The hotter and lighter the air is in the chimney, the greater the speed with which it is pushed up out of the way by the heavier air pressing against it beneath. It is by this simple plan that an air-current is maintained to do the important work of fanning the fire.

In order that a steady current of air may be produced and sustained, the all-important need is that the throat of the chimney shall come closely down over the fire. All the upward moving air is then forced to rush through the burning fuel, to turn it into vapour, and so generate more heat. If the current of air be too strong and the fire too fierce, the proper remedy is to diminish the size of the chimney, so that there shall not be so much room for the current to force itself up. The down-draughts and unsteady movements of the air which cause *smoky chimneys* are almost always due to the *open space above the fire being too large*, and the proper remedy for that mischief is to lessen that space, and not to meddle with the chimney-pots above, as is so commonly done. The great secret of a steady draught for a fire is to have a low chimney-throat, and the chimney-shaft within of a properly adjusted size. When the chimney-shaft is too large the quickened draught carries away up the chimney much of the heat that ought to find its way into the room, and, then, although there is a good draught and bright fire, there is a wasteful and excessive consumption of fuel.

In the closed kitchener, which is now so commonly used for cooking, the excellence of the stove depends upon the efficient way in which these particular conditions of a strong steady draught and a limited chimney-space are provided for. The fire itself is almost enclosed in a square box, with no open space at all left between the burning fuel and the inlet into the chimney. The air, therefore, has to blow through the fire to get into the chimney. The passage beyond the fire, by which it flows into the chimney-shaft, is narrowed into a very small flue, and this turns round about the boiler and the ovens, in order to give up a large quantity of the heat that is passing through it to those parts of the range. At the same time this plan limits the consumption of fuel in proportion to the narrowness of the space that is left for the passage of the air into the chimney-shaft. The narrow flues of the kitchener have to be kept clear of soot, which is the loosened fragments of the unburnt fuel, because such deposits would prevent the already narrow passages from affording proper space for the current.

The one addition to the top of a chimney which does improve the draught of a fire, and tend to remove any inclination to smoke, is a tall chimney-pot, to increase the actual length of the shaft. Long chimneys cause stronger and steadier draughts than short ones, because with them there is a longer column of light heated air to be pressed up from below by the heavier column; that is, with a long chimney there is more difference between the weight of the air in the chimney and that in the room than there is with a short one, and the more difference there is in the weight of these two, the stronger must be the current which is forced up the chimney. A very light column of air gives way to the pressure of heavy air more rapidly and easily than one which is less light.

When, at any time, the draught is too strong, an unnecessarily large amount of fuel is consumed, and much of the heat generated is wastefully carried up the chimney with the ascending current. The proper remedy for this evil is to make the chimney itself narrower, either by the introduction of a damper into its shaft, or by some similar contrivance. The consumption of fuel and waste of heat are then lessened, but the upcast of the air continues to be steadily and efficiently maintained. Most fires can be made to draw well, and to burn economically, by the judicious application and adjustment of these two expedients.

LESSON XL.

THE NATURE OF HEAT.

It was for a long time conceived that **heat** was a kind of fluid substance which was capable of being poured in, and of being drawn away from, between the molecules of bodies. It is now, however, understood to be far more probable that it is an active movement in the very molecules of bodies themselves. When a solid body is made warm, the little molecules of which its substance is composed are caused to **vibrate**, or tremble. Each molecule pulsates, or beats, for a short distance, to and fro, amongst its neighbours, first striking to the right and then to the left. The greater the heat, the larger are these beats, until at last they become so large that the molecules fall apart under their own restless blows. The body is then changed from the solid into the gaseous state, on account of the wide separation, or sundering, of its elementary parts.

Since the molecules of bodies pulsate, or beat to and fro, to a wider extent when those bodies are hot than when they are cold, it follows that bodies must be of larger dimension, or occupy larger space, when hot than when cold ; more room must be required when the molecules make wider excursions to and fro amidst each other than when their movements are kept within narrower bounds.

When bodies are changed from the solid into the liquid state, the pulsating, or vibrating molecules are pushed just so far apart by their beating to and fro, that they are able to slip and slide about over each other without getting very far asunder. It is this condition of matters that constitutes the liquid state. When, however, in consequence of some stronger impulse, they are made to move farther and farther each way, they at last cease to be able to remain near together at all, but fly off from each other, until there are comparatively large interspaces, or intervals, between them. The liquid state is then converted into that of thin and wide diffusion which marks the gaseous condition.

In **gases** the pulsating, or to and fro beating of the molecules is changed into an altogether **forward movement**, in which the molecules dash off in straight lines as far as they can go. The greater the heat, the more energetic and rapid the forward rush of the molecules. Each molecule moves like a ball that is tossed into space, striking against any other molecules that lie in its course, and being made to rebound from them; striking also against solid surfaces that stand in the path, and rebounding thence in the same way. When a gas is contained in a glass bottle, or jar, it is conceived that the pressure it exerts upon the inside of the jar is caused by the energetic blows of the countless number of little clashing molecules imprisoned in the vessel, which are exerting themselves to get free. There is more internal pressure produced when the gas becomes hotter, because the rapidity and energy of the molecular blows, or, in other words, the speed of the molecular movement, is then quickened. Calculations have actually been made of the speed with which the clashing molecules of gases rush about. It is estimated, for instance, that, even at the temperature of ice, the molecules of the extremely light gas, hydrogen, move with a speed which carries any one of them through 6097 feet, or more than a mile—which contains 5280 feet—every second.

All nature is thus conceived to be in unceasing movement, so long as it has any warmth. As the warmth is withdrawn, the movements become less and less. But, only under the circumstance of the entire withdrawal of heat, could nature become altogether dead and still.

This explanation makes it very easy to understand why vapour rises up from the surface of liquid water. When any quantity of water is warmed, its molecules begin to vibrate, or dance to and fro, and, in the lower parts of the water, whichever way those molecules move, they are met by other molecules like themselves and are driven back. But, upon the immediate surface of the water, there will of necessity be a layer of molecules that have other water-molecules below them, but none above. These upper molecules, having then pressed downwards until they are met by the vibrating molecules below, are tossed off from them, and, finding no resistance from water-molecules above, they bound off in that direction into the air, and begin there the free roaming of vapour, or gas.

When *water is made to boil*, the molecules are rendered so active in their pulsating movements that they burst asunder into the state of vapour, or gas, even in the substance of the water, as well as upon its surface, and then rise up through that substance as bubbles of steam. In ascertaining whether water is boiling, it is necessary to make sure that the bubbles of steam are really rising through the liquid in this way, and that it is not merely hot vapour from the surface which is escaping. When a kettle *sings* before the water in it is boiling hot, this is due to small quantities of steam being formed near the bottom of the kettle, where the heat of the fire tells most, and rising up into the water. But, before this steam can get through the water, it is turned back into the liquid state, and does not escape. Steam can only escape rapidly from water when the whole substance of the water is as hot as the steam; then the steam can keep in the gaseous condition and is not turned back into a liquid, as it passes up through the water.

Different bodies expand to a different extent under the influence of heat. This affords a very convenient means for constructing instruments for measuring heat. Thus, the most common instrument of this class is that called a "thermometer," a word which is merely the Greek term for "heat measure." The thermometer is a small glass tube enlarged into a bulb at the bottom, and containing in its interior a certain quantity of either quicksilver or spirit of wine. The glass tube is entirely closed, or sealed up, and this is done in such a way that there is no air in the part of the tube not occupied by the quicksilver or spirit. When the thermometer, thus formed, is heated, it expands or grows larger; but the quicksilver contained in the interior expands more than the glass itself. Since it expands, it occupies more space, and must therefore be driven up farther into the narrow stem of the tube. When the quicksilver cools, it contracts and is drawn back in the stem towards the bulb. The distance to which it is either pushed up or drawn down in the tube thus shows the degree of heat or of cold to which it has been exposed.

In order to mark what the exact heat is that the instrument indicates, it is first put into melting ice, and when the quicksilver has been drawn in towards the bulb as far as it will go at that temperature, a scratch is made upon the stem of the glass tube. It thenceforth marks the position of the quicksilver for freezing water, and is called the **freezing point.** The instrument is next put into steam issuing from boiling water, and when the quicksilver has been pushed up as far as it will go under that heat, a scratch is made where the quicksilver-column then stands, and this fixes the position for the **boiling point.** The glass tube is then measured off between those two points into a certain number of equal spaces or degrees. Very commonly one hundred of these equal spaces are measured and marked, and the instrument is then called a "Centigrade" or "hundred step" thermometer. In such a thermometer, the degree for the freezing of water is called zero, or 0; and the degree for the boiling of water 100.

In the thermometer, which is most used in England, however, 180 steps, or degrees, are measured off between the freezing and the boiling points, and the freezing point is put at 32°, and the boiling point at 212°. The instrument marked in this way is called **Fahrenheit's** thermometer, because it was first contrived by a Dutch instrument-maker of that name living at Amsterdam about a century and a half ago. In the Fahrenheit's scale, 32° of precisely the same size are carried down below the freezing point, and the lowest one of those 32 is considered to be **zero**, or 0.

Thermometers are also sometimes marked with another kind of scale. The freezing point is made zero, or 0, and the boiling point 80, the intervening space on the tube being divided into 80 steps, or degrees. Thermometers with this kind of scale are called "Réaumur's," because they were first made in Paris by a scientific Frenchman of that name, also about a century and a half ago. Réaumur's thermometer was in reality constructed before the Centigrade, the latter being simply the improvement of using the more convenient number of 100, in the place of 80, as that of the intervening degrees. The Swedes and Danes still use the Réaumur scale in preference to either of the others.

Quicksilver and spirit of wine are used for charging the interior spaces of thermometers, because neither of these liquids freezes until exposed to cold very much greater than that which is sufficient for freezing water. Quicksilver does not freeze until the cold is 39° of Fahrenheit's scale lower than zero, or 71° colder than ice. At that temperature, which is one often met with in the Arctic regions of the earth, the quicksilver is turned into a solid metal, like lead. Strong spirit of wine cannot be frozen by any degree of cold that has been yet produced, although it has been exposed to temperatures 220° of Fahrenheit's scale lower than zero. Quicksilver is, however, preferred for the construction of thermometers when temperatures lower than 71° below zero, Fahrenheit, have not to be measured, because it has itself a low capacity for heat, and on that account does not absorb large quantities without being sensibly warmed by them, and also because changes of temperature pass very freely and rapidly through its entire mass.

The heat of the blood of a healthy human being, marked as **blood heat** on the scale, is 98°; 76° is called **summer heat**, because such is the temperature of the air in a warm summer day. 55° is marked **Temperate**, because when the air is of that warmth, people who are in exercise, or moving about, do not feel either hot or cold. "Temperate" is derived from the Latin word "temperatus," which signifies moderate, or mild. The highest natural air-temperature which has ever been experienced is 140° of Fahrenheit's scale, and the greatest natural cold ever experienced was not quite 74° below zero. The extreme degrees of air-temperature upon the earth are, therefore, thirty degrees farther apart than boiling and freezing water. The fiercest summer of India is about as much hotter than the greatest cold of the desolate ice-wastes of the Pole, as boiling water is hotter than ice. It is probable that the temperature at which all bodies on the earth would become solid, and all nature be fixed and dead, would be about 490 of Fahrenheit's degrees below zero.

LESSON XLI.

THE DIFFUSION OF HEAT.

In a strictly scientific sense there is no such thing as cold. Cold simply means deficiency of heat. When bodies in nature are of different temperatures, some more and some less hot, they immediately begin to make the division of heat among themselves more equal. Those which are the hottest begin to give some of their excess of heat to those which are less hot. The colder bodies begin to receive heat from those which are warmer. If the hand be placed upon a body hotter than itself, that body feels warm, because it gives some of its heat to the hand. But, if the hand be placed upon a body which is not so hot as itself, it gives some part of its heat to the body, and that body feels cold, because it takes heat from the hand. The idea of there being such an existence, or state, as cold comes merely from the living human body having a natural heat of its own of 98°. All objects that have less heat than this are capable of receiving heat from the human body, and of causing in it the sensation of cold, on account of their taking heat away. Cold objects are merely objects that have less heat in them than the living human body; and one object is said to be colder than another when it has less heat in it, and is therefore capable of taking some heat away.

Heat is communicated from one body to another by three different methods, which, for convenience sake, have received each a different name. The three different ways in which heat is scattered about, or communicated from body to body, are **conduction**, or leading; **convection**, or carrying; and **radiation**, or raying.

If the end of an iron poker be put into a fire, it soon becomes hot, and the heat which it receives from the fire travels along very slowly to the opposite end, until it can be felt by the hand that that end too is hot. This is an instance of the communication of heat by **conduction.** The heat is led along from one end of the poker to the other. The increased beating to and fro, or vibration, of the molecules, which constitutes the hotter state, is passed on step by step from neighbour to neighbour of those molecules, until at last it reaches the farther extremity of the iron bar. If the hand be then placed on that farther extremity, it feels the heat, because the vibration of the molecules of the iron travels on to the molecules of the hand. This is, however, still a case of communication by conduction. The heat is led on from the poker to the hand by direct contact.

The outer end of the poker never becomes so hot as the end which is in the fire. This is because that outer end gets rid of a great deal of the heat as fast as it receives it. All round that part of the poker which is not in contact with the burning fuel of the fire, there is air. The little particles of the air are everywhere packed closely round the poker, and touch its surface everywhere. Those particles of the air which touch the iron become hot. They receive heat from it by contact, that is, by conduction. But air is a movable, not a fixed substance, and therefore, as soon as the particles get heated by the iron, they fly away and allow other particles to take their place. But as they fly away, they carry some of the heat with them, and as fresh particles then press in close to the iron, more and more heat is being continually taken away. This is the method of diffusing heat by "carrying," or by **convection.** All liquid and gaseous substances, which are of a loose and movable nature, carry away heat from warmer bodies by this process. The heat carried away from the poker by the air is diffused all over the room, and serves to make it warm. The air moves in this way and carries off heat, simply because it expands when it gets hot, and because, when it expands, it becomes lighter, bulk for bulk. It is therefore driven out of the way by the pressure of the colder air, which, being of greater weight, forces itself into the place of the warmer and lighter portion.

But the outer end of the hot poker is also losing its heat in yet another way. It is shooting, or "raying," portions of it out through the air. When any person stands in front of a very fierce fire, the scorching of the fire is felt upon the face. That scorching is heat "shot off," or "rayed" from the burning coals. It shoots through without warming or moving the air, and produces no heating effect until it strikes upon the face. The outer end of the poker "shoots off" heat just in the same way, although in a less intense degree. This is the mode of communication of heat which is called **radiation.**

If the outer end of the poker did not lose some part of the heat it receives by conduction from the red-hot part, it would at last get red-hot too. It, however, does scatter a considerable portion of the heat led along to it from the fire both by convection and radiation. It thus never becomes as hot as the part which is in contact with the fire, and which receives its heat there by conduction. It does get something hotter by slow degrees, but only because it does not scatter the heat as fast as that is communicated to it by being led along the bar of metal.

All bodies do not conduct heat along with the same rapidity and ease. Some conduct it very quickly, and some at a very slow rate. Metals, for instance, are all of them, more or less, rapid conductors. Such things as wood and wool, on the other hand, are very slow conductors. This is why the copper handle of a boiling kettle is so hot that it cannot be touched by the hand without pain, and why when the handle is either made of wood, or is surrounded by a woollen cloth, it can be held without discomfort. It is also the reason why cold metal feels very cold when it is laid upon the skin, and why woollen clothes and blankets, placed round the body, keep it comfortable and warm.

Air, like wool, is a very slow conductor of heat. That is why double windows help to keep the inside of a room warm in winter time. The air which is shut between the outer and the inner panes of glass is so imprisoned that it cannot move and carry off the heat by convection; and it is of such slow conducting power in itself that it does not allow the heat to pass out from the room by being "led" or "conducted" through its substance. Even on a cold day, air, that is still, feels fairly warm, because the heat of the body is not led off through its substance by conduction. But the instant the wind blows, the same air feels cold, because the moving air then "carries" fresh and fresh supplies of heat away from the warm body.

When a cosey, or loose cloth-bag lined with flannel, or wool, is placed over a teapot filled with boiling water, it keeps the contents of the teapot hot for a considerable time, because it prevents the heat from being either led, rayed, or carried away. The air inside the bag is so shut up by it that it cannot get away from the teapot to "carry" off the heat, and it is itself so bad a conductor that only a small part of the heat can get through it to the bag. The bag too, being of wool, which is a slowly conducting substance, does not allow even that small portion of the heat to pass quickly through it.

If, however, the "cosey" were a piece of dark cloth fitted tightly to the teapot, it would not keep it warm in the same way. The tight cloth would then "radiate" or shoot off the heat through the air even more quickly than the teapot would do if left uncovered, and it would as quickly become cold. It is a very curious and noteworthy fact, however, that dark surfaces which shoot off, or "radiate" heat from warm bodies very quickly, also drink in, or **absorb**, heat from hotter bodies just as easily. A black, soot-covered kettle would rapidly radiate, or scatter the heat from boiling water, if it were hung up in the air; but the same kettle would make the water boil rapidly when placed on the fire, because it would "absorb" or draw in the heat rapidly and pass it on to the water.

Air is not at all warmed by heat that is merely "radiated" through it. It is only heated by contact with hot bodies or substances. Upon the top of a lofty mountain, the air itself is quite cold when the face and hands are blistered by the heat of the sunshine that falls upon them.

When, therefore, a fire is made in a room it warms the room *in three different ways*, acting by all of them at the same time. It communicates heat from the iron of the fire-grate to the walls of the room, by slow conduction. The heat of the burning coals, and of the hot iron grate and warm walls, is radiated, or shot off through the air to all the solid surfaces and substances of the room, and falling on them gradually makes them warm. The air which touches the grate, the walls, and the objects in the room, becomes warm by contact, and then floats away with its warmth, carrying or "conveying," it in all directions.

LESSON XLII.

THE NATURE AND USE OF CLOTHES.

The living animal body has a warmth of its own, generated by the slow burning of the food-substances in its interior, which acts like so many gentle fires in keeping up its heat. As soon, however, as a living body becomes from this cause warmer than the surrounding air, it begins to scatter its own heat into that colder substance. It radiates some of its heat out *through* the air, and it communicates some *to* the air which touches the skin; and the air itself carries away the portions which it receives.

But, when a warm animal body is placed in very cold air, the heat from the warm body is carried off so fast, in these ways, that it would not be possible to keep its warmth up to the requisite 98 degrees, unless some special expedient were used to arrest or diminish the loss. The plan adopted by nature for this purpose is covering the body over outside by a thick coating of fur, or wool, which are bad conductors of heat, very much as a teapot may be covered with a cosey of cloth and wool to prevent its heat from flying away. Fur, wool, or hair, is the natural clothing of animals, and it is made more thick and difficult for the heat to pass through in the case of such animals as live in very cold parts of the earth, and less thick in warmer places. The Polar bear has a thick soft fur that scarcely any heat can get through; the antelope, which lives upon the hot African plains, has only a thin covering of silky hair.

Man is intended to live in all parts of the earth, both where it is very hot and where it is very cold. On this account, he has been left without any natural covering to his skin. If he had had a thick warm fur upon his body, like that of the Polar bear, he would have found this very inconvenient and uncomfortable to wear in the fierce torrid regions of the earth; and if he had had only a thin covering of hair, that would not have been enough for even a climate like England, where there is ice and snow during one part of the year. The arrangement has, therefore, been made in his behalf of leaving him with a naked skin, and of conferring upon him the knowledge and the skill to provide clothes for himself, in such a way, that he may have them either as thick and warm, or as thin and cool, as circumstances require.

Man gets the substances which he turns into clothes partly from plants and partly from animals that have natural coverings to their skins. He takes the downy cotton from the seed of the cotton plant; the long flexible fibres from the stems of the flax and hemp plants; hair from the skin of the goat; wool from the skin of the sheep; and silk from the beautiful cocoon, or case, with which the silk-worm surrounds itself at the end of its caterpillar form of existence, to keep itself snug whilst changing into a winged moth. All these substances he spins into long threads, and then weaves the threads into cloth, and so manufactures clothing that is at once convenient and comfortable.

The cloth formed from cotton or **calico** is most used for under-garments that are worn next the skin for several reasons. It is fairly warm, without being too hot; it is smooth and soft; it readily takes up the moisture from the skin; it can be very easily washed, and it is cheap for its durability and strength. Calico, worth many millions of pounds sterling, is manufactured as clothing every year in this country alone, and is sent out all over the world, as well as being used by the people who live in England.

Flax and hemp are made into **linen** cloth, which is not so soft as calico; but smoother, stronger, and more durable. It wears longer than calico, and keeps its colour better when dyed. It also costs more money than calico, and is therefore less used by people to whom outlay of money is of great consequence.

Cloth, which is manufactured from the **wool** of the sheep, is the warmest of all kinds of woven goods, because it is of very slow conducting power, and therefore keeps the warmth well in the body. It is manufactured of all sorts of quality and thickness. It is most used for outer clothing, because it does not wash so readily as cotton. Cloth, flannel, camlet, serge, and worsted fabrics are all different kinds of manufactured goods made from wool.

Woollen cloth is, nevertheless, very suitable for under-garments next the skin, either in very cold seasons and places, or in circumstances where there are apt to be sudden changes from heat to cold. It is advantageous in such circumstances for two reasons. It prevents the sudden chill from affecting the body, because it is not an easy substance for the heat to travel through; and, at the same time, it helps to make the blood flow freely through the skin, by the rubbing which it gives it on account of its own roughness. It is almost indispensable that delicate and tender people should wear flannel next the skin in cold, damp, and changeable weather; and, therefore, all the year round in a climate like that of England. It should, however, be thin and fine in the warmer part of the year, and stout and thick in the winter.

Silk is very much the most beautiful and costly of the fabrics that are employed for clothes. It is so costly, indeed, that it should only be used for clothes by persons who have an abundance of money to spare. It is light, cool and pleasant to wear in hot weather; but by no means more so than cotton and linen of the lightest kind, and it has the great disadvantage that it cannot be washed, as these may over and over again.

Clothes of a dark colour, and of a rough surface such as woollen cloth has, are very warm in the summer, because they draw in the sun's rays, just as the black sooty bottom of a kettle draws in the heat of the fire. Clothes of a light colour, and such fabrics as white or grey calico, are cool in the summer, because they throw back, or reflect, the sun's rays, instead of drawing them in. Black hats are often covered over with white cloth when the sun is very blazing and hot, because it reflects the sun's rays before they get into the hat, and so prevents them from striking through injuriously upon the head and brain.

In hot countries, such as India, clothes are more required to screen the body from the high temperature which strikes upon it directly from the sun, than to keep it warm. On that account, they are there made as light and loose as possible, and white calico is the best of all materials that can be employed. In temperate climates, on the other hand, the warmth of the air is never so great as that of the body, and clothes are therefore needed in all seasons for the direct purpose of keeping it warm.

But in temperate and cold climates, it certainly is not advisable that one part of the body should be clothed, and another part left naked. When this is done, the naked part is almost certainly exposed to injury from sudden chill. In an uncertain and treacherous climate like that of England, it is as dangerous as it is absurd, that the throat, the side of the face and head, and the upper part of the chest of sensitive and delicate women and girls should be left almost without defence, whilst other parts of the frame, which are far less abundantly supplied with blood vessels and nerves, are huddled up in layer upon layer of thick covering, merely because an ignorant custom and false taste prescribe the unnecessary exposure of the more tender parts.

LESSON XLIII.

THE FITTING AND FASHIONING OF CLOTHES.

As clothes are intended especially for the protection of the body from external cold and external heat, they should be carefully **fitted to the frame** and thoughtfully adjusted for the work which they have to do, instead of being made upon some extraneous idea of what mere fashion requires. First, and before all things, they should be everywhere so loose and easy in their fit as not to embarrass or prevent the natural movements of the body, and especially those upon which some of the most important operations of life depend, such as the play of the lungs and the beating of the heart. In the fashioning of the body itself an altogether marvellous amount of care has been taken to guard against pressure of any kind that would hinder these movements. If the waist be laced in tightly by closely-fitting garments, all this beneficent care is made of no account, and weakness and deformity of various kinds are caused. It needs no very large exercise of wisdom and intelligence to comprehend that the noble and beautiful form which has been given to the human body by God is not very likely to be improved by the meddlesome artifices of vanity and fashion. But the argument which may be raised upon this ground is materially strengthened when it is also understood that such tampering with the provisions of nature can be shown to be actually the cause of derangement and disease, in the working organs of the living frame.

The dress should be so adjusted to the body that it fits everywhere. Not only should there be **no bonds** to hamper the free movement of the chest, but **no pressure** anywhere that can check the free coursing of the blood along the soft and elastic vessels that are laid down for its conveyance through the structures. The neck and the limbs are especially open to constriction of this kind, and should therefore be jealously guarded from such unfair and injurious interference. The clothes should be fashioned so as to keep the living body warm in the inclement periods of winter, and to protect it from undue heat in seasons of burning sunshine; but these ends should in all cases be secured without doing violence or damage to the exquisitely delicate and perfect organs that have been furnished for the working of its machinery. For the very reason that that machinery has had to be made of soft and yielding substance, in order to its being kept in the utmost perfection of repair, even whilst engaged upon its work, it needs to be tenderly and reverently handled, instead of being used as if it were fashioned out of levers and wheels of stubborn iron and brass, such as are employed in ordinary mechanism.

One other way in which injury may be done, by restricting the free movements of ingeniously and delicately fashioned parts of the living frame, and by transferring articles of clothing into barbarous and cruel implements of torture, is that which is very commonly exhibited in the particular of boots and shoes. The human foot is amongst the most admirably contrived instruments that are employed in the service of the body. It is made in the form of an arch, in order that the great weight of the body may be safely carried when, in stepping, this is thrown abruptly upon the top. That arch is composed of no less than twenty-seven separate pieces of bone, which are fitted together in such a way that they can move slightly upon each other and allow free and elastic play when the foot is shifted from one place to another. These separate bones are faced with smooth, shining gristle, and oiled where they touch each other.

In order that this very complicated instrument may be able to do properly the work for which it has been designed, it is indispensable that it should be left unconstrained in all its movements, and that it should preserve the form which has been naturally given to it. But when the foot is clothed with the intention of protecting it from external hurt, it is thrust violently into a case of thick, unyielding leather, one of the most obstinate of the materials that is drawn upon for clothing; and the boot or the shoe is scarcely ever shaped to the form of the foot, but some fanciful shape is given to it, supposed to be pleasing to the eye. The foot is then expected to take the form of its stubborn covering. The five toes are squeezed into a pointed space that is not properly calculated to accommodate three; the heel is galled by a stiff, straight board that stops its backward expansion when the foot receives its load, and is mounted upon a stilt that throws much of the weight it ought to receive upon the balls of the toes; and the instep, or front of the arch, is fixed in a sheath that is as tight as the bandage which is put upon a broken limb. Corns, bunions, and distortions too numerous and diversified to be named, are the frequent and natural consequences of this barbarous practice.

The foot, to be properly fitted for a boot or shoe, should be placed bare upon a sheet of paper, and when pressed fully down to its natural bearing under weight, should have its shape marked out all round by a pencil. That shape should then be taken as the pattern for the sole of the shoe. The upper leather should be cut so that there is not the slightest pressure anywhere during any of the varied movements of the foot. Tall heels should on no account be used, until a race of wild people have been discovered who are found to have similar pads provided within the skin by nature, and who are found to walk better with them than other wild races do without.

One of the purposes for which leather is used in the construction of boots and shoes is the protection of the foot from wet. All parts of the body require to be **defended from wet**, because wet is followed by evaporation and cold. Everyone knows how soon the warm hand feels cold when it is covered with a wet cloth. This is because the moisture is turned into vapour, or steam, which flies away into the air, and carries heat with it as it does so, by convection, as well as by taking it up for the conversion of the water into steam. But the feet are more liable to be kept wet than any other part, because in rainy weather their coverings are in contact with the soft, moist, sodden ground.

In rainy weather shoes that are thick enough in the soles to keep out the wet are essential to the maintenance of health, and damp shoes should always be changed as soon as the moist outside ground is left and a dry house entered. The indiarubber goloshes that are now so common and so cheap answer admirably so far as keeping the feet dry is concerned. But in order that they may be worn with comfort, the shoe that is used within should be thin, light, and roomy, and the golosh only just tight enough to hold on the foot. Tightly fitting shoes and goloshes are sure to make the feet tender and uncomfortable. A golosh should also be always put off from the foot the instant that walking in the wet is brought to an end. Stockings that are worn within boots and shoes should be soft and thick, and should always be changed as quickly as possible when they get damp or wet. Knitted woollen socks are the best kind that can be employed in damp cold weather, and when much hard walking has to be done. When such are used ample room must of course be provided for them within the boot or shoe, as well as for the foot.

All waterproof outer garments are good protections in wet weather. But they should be as loose as possible, and be put off as soon as their purpose is served. They are also most safe and most comfortable when it so happens that they can be worn with an abundance of other not waterproof clothing beneath them, because then the natural vapours from the skin are not prevented from escaping as freely as it is intended they should.

LESSON XLIV.

THE CHOOSING, BUYING, AND MAKING OF CLOTHES.

There are now so many different kinds of fabrics prepared for the making of clothes that a very large measure of choice can be exercised in selecting what may be deemed the best or most suitable. To most people there is a considerable amount of pleasure in using this opportunity of selection. But, in doing so, wise persons will never forget that the two most important things to be kept prominently in mind are, first, that the articles should be **durable** and strong, and then that they should be of **reasonable price.** Nothing is more easy than to make the serious mistake of spending money for look instead of for use. When a sound discretion has been employed by buying good, useful, and reasonably priced articles, it becomes quite a fair and a commendable task to consider next how they can be made to look most pleasant to the eyes of other people in the wearing. But everyone may rest assured that this task never is satisfactorily performed by attempting to run to the extreme of fashion and display. It is quite sad to see how ridiculous and unseemly many persons appear, who have taken the utmost pains and have made extravagant outlay, in order that they may be fashionably clothed. Such people fail entirely in the end at which they aim, and are more generally pitied for their ignorance and folly, and blamed for their extravagance, than they are admired for their peacock-like finery.

The only good argument that can possibly be urged in extenuation of extravagant outlay for dress, is that the large amount of money which is in that way expended is devoted to the encouragement of industry, and to the reward of ingenuity and skill. That argument, however, only applies in the case of persons who have an abundant superfluity to spare for the indulgence of such generous patronage of labour and art. Those who have no money to spare have no right to apply the little which they have in any wasteful and unproductive way. Indeed, it will always be a matter of considerable doubt to the most thoughtful and reasonable minds, whether even the abundantly rich might not find some better employment for their superfluity than the extravagant adornment of their persons, under a strained and fanciful acquiescence in the mere custom and passing fashion of the day. It is very difficult, indeed, for persons of independent and cultivated thought to understand how women can by any possibility be better because they do not wear the same dress more than three times, or because, at certain intervals, they change flowing skirts into narrow ones with abundance of tails, and transform sensible head-dresses into ungraceful monstrosities of bad millinery and tawdry artificial flowers.

In selecting material for clothes, perhaps the most important of all the conditions to be borne in mind is that it should be so chosen, in the matter of texture, quality, and colour, as to give good assurance that it will wear well, and will continue to present a good appearance to the end. On this account low priced goods should be avoided as a rule. Low costs almost invariably means that the material will not wear well, and that it will not look well either in the beginning or the end. When one dress will wear three times as long as another, on account of the strength and excellence of its texture, this means that in purchasing it there is a saving of the money which would be spent for two dresses out of three. Therefore, though twice as much money be spent for the material of the good dress, as would be given for the inferior one, there will still be a considerable saving in the end. Cheap goods are largely made in the present day from old rags torn to pieces, re-manufactured into various cloths, and then dressed up with a false face to make them look like better articles than they are. Cheap shops should, on this account, be regarded with suspicion and doubt by all good economists. It is a much wiser course to go to a respectable shop where it is known that only good materials are sold, and to save the excess of price that has to be paid for such materials, by making them up plainly and simply, and by wearing them as long as they will last. Above all things those shops should be especially avoided where great trouble is taken to persuade customers to buy what they are not seeking and do not want. It once happened to a young Englishman in India, who could never resist the temptation of buying a cheap bargain when he met with one, to purchase an old elephant which was past its work. When he had got his elephant, he found that no one else would buy it of him, because it was of no use, and that he must not kill it out of the way, because that would be deemed an act of cruelty. He accordingly had to keep the big beast, and then discovered that an elephant eats a great deal of food in the course of a day. Not being a man of ample means, he was nearly ruined by his cheap bargain before he got it off his hands. People who buy bargains of articles that they do not want, because they are persuaded to do so, for their own profit by cunning and smooth-tongued salesmen, are very much like the Englishman in India with his old elephant.

In recent years, very clever machines have come into use to help people who are engaged in making clothes to sew together the several pieces of which different garments are formed. These **sewing machines** are of great value in large families, where there are many individuals to be supplied with clothes, or in establishments where clothes making is a trade. Their chief excellence is that they afford relief to those who have to work long stretches at a time, and who get very weary over incessant stitching with the needle. The weak point in the machine is that it can only be employed with advantage in making long seams, or hems. But there is one sewing machine which is superior to all the rest, because it is not open to this disadvantage and reproach, namely, the machine that is comprised in a pair of deft and skilfully trained human hands. There is nothing in the way of needle-work which that machine cannot perform, and the wonders that it can accomplish, must be seen to be understood and appreciated at their proper value. A clever worker with the needle will make an article of clothing last as long again as it would do without such help as she can supply, and will make it pass through an incredible number of reappearances and transformations before its entire usefulness is brought to an end.

Of all the accomplishments that young girls are now systematically taught, none stands higher in the scale of usefulness than the art of fashioning clothes and **working with the needle.** It has been most wisely and judiciously arranged that formal instruction in these matters shall henceforth be made a part of the ordinary business of schools, and that it shall be more carefully and skilfully given than was ever thought of in olden times. It would certainly be an important step in advance towards a more satisfactory system of domestic economy that all women should be taught how to fashion and make their own clothes, so that they should be able to do so whenever the accidents and needs of life render it desirable for them to be independent of the costly, and often not altogether judicious, aid of the professional dressmaker. Few girls, who learn to make their own dresses and other garments, and to count the cost of the various steps of the process, will be so likely to continue the mistake of wasting their money about frivolous and tawdry display. For they will learn also how easy it is to make a better appearance before the eyes of the world by the exercise rather of sound thrift, thoughtful industry, good taste, and a little pleasant contrivance.

There is yet one other respect in which these particular remarks, upon the skilful and trained use of the needle, apply with scarcely inferior force. Clothes require to be mended as well as made. All articles of woven clothing should be strengthened by the needle as soon as they begin to show weakness from wear; and this process of continuous repair can only be efficiently carried on by the inmates of the house. This is, indeed, so important a part of true home-economy, that the thriftiness and capability of a woman may almost be told by an examination of her clothes. The article of all others, however, upon which the greatest stress of wear always falls, is the one which is chafed and pressed all day long between the full weight of the body and the tough unyielding leather of the shoe, that is, the stocking. The stocking must, therefore, be the object of the most assiduous care in this particular, or, it will probably be found that it is always falling into holes.

The kind of mending used for articles of clothing woven or knitted like stockings, is, of necessity performed by the hand. There is no machine yet invented to accomplish this work. It is clear that our ancestors, in the olden time, understood the importance of this kind of work, for the word "darn," which is universally used in speaking of it, is an old Anglo-Saxon term. The operation of "darning" is, nevertheless, one that requires some considerable amount both of judgment and practice to perform it properly. The process is less easy to master, and, until mastered, more tedious in the doing, than other kinds of needle-work. Experience alone can teach where the darning should begin, and where it should end. Nothing is easier, indeed, than so to mend a hole in a stocking as that two or more are formed in its stead. This is quite sure to be the result if the darning is not sufficiently extended beyond the hole or the worn part which has to be made good; or, again, if the loops between the rows of darning are drawn too tight, subsequent wear and washing will assuredly pull the stocking into holes.

Even when a hole has been mended, it may still be a very clumsy affair in the eyes of an experienced darner. The true method of good darning requires that the holes shall, in the first instance, be drawn together by threads of fine sewing cotton passed transversely on the outside, and that the darning shall then be well and sufficiently carried out by working across these on the inside. By this procedure the loops of the torn fabric are caught and prevented from running down, as dropped stitches in knitting do, and the thread passed through from side to side efficiently closes up the gash in the material. Without such previous sewing up every row of cotton or wool only separates the edges of the hole more and more.

Stockings that have been skilfully darned upon this proper plan will stand the close inspection of experienced eyes, as well as wear and tear. There will be in them no Jacob's ladders, and no drawn in and bulged out places loaded and strained with the mass of material used in the mending, but, instead, a good sound coating of well worked in thread, wherever the original fabric has required strengthening or renewal. The great stress of mending and darning falls upon the stocking. But the lesson which is learned, in consequence of the exacting demand of this weak article of the wardrobe, is fortunately one almost sure to be applied beyond the sphere to which it is primarily directed. When stockings are kept in good order and repair, it is quite certain that the other articles in the wardrobe will receive their fair share of care and attention. A good darner will most certainly be a good mender in all other departments and modes of repairing work.

LESSON XLV.

BATHING AND WASHING.

The natural warmth, or heat, of the living animal is kept up by the burning of the various combustible parts of the food-substances in the interior of its body. The heat which is thus generated is taken from the body by radiation into surrounding space, by convection currents of the air, by contact with colder substances, and by the evaporation of water from the skin and the lungs. The generation of heat by the internal fires, and the loss or scattering of the heat by the several processes of cooling which are in force, leave the internal temperature of the body fixed constantly at very nearly 98° of Fahrenheit's scale. The proper animal temperature of 98° is that which remains as the balance of gain and loss.

But when the air round the body is very warm, as it is in the hot season of summer, the body is less cooled by the influence of radiation, air-contact, and convection, than it is in the cold weather of winter. Consequently at that time, the heat would be accumulated in the body until it was more than 98°, if some special means were not contrived for keeping down the superfluous amount. Such means are therefore provided. The cooling of the body, in times of great heat, is accomplished by increased evaporation from the skin.

The moisture from the warm blood can transude out very slowly and gradually from all parts of the skin; but, in order that this transudation may be largely increased, beyond the ordinary and slight amount, when there is reason for bringing the cooling effect into play, small holes are pierced through the skin, which can be opened or closed. These holes, although not visible to the unaided eye, can be readily seen by magnifying glasses. There are more of them in some parts of the skin than in others; but, altogether, there are certainly not less then two millions and a half scattered over each human body.

Every little opening, or pore, leads into a small tube that dips down into the somewhat thick substance of the skin, and is then coiled up upon itself into a kind of knot, into which capillary blood-vessels pass in great abundance, somewhat as they do to the funnels of the kidneys. As the warm blood streams, in the process of circulation, through the capillary vessels, portions of its moisture pass out through the walls of those vessels into the knotted-up tubes, and, if the external pores at the ends of the tubes be open, are thence discharged into the air. If the external pores be not open, those portions of vapour are retained in the tubes. The pores, however, *are* opened widely when the body is getting too hot; and they are closed fast when it is getting too cold. In this way, the cooling of the body is kept in control, and regulated by the varying action of the pores of the skin.

The vapour which passes out through these pores when they are open, is called the **perspiration**, or "sweat." The word perspiration is derived from the Latin per and spiro, which means to "exhale" or "breathe out." The perspiration is the moisture which steams out from the blood through the openings in the skin. When this moisture passes out from the skin in only moderate amount, it flies away into the air as a thin, invisible vapour, which is not seen, and which is then called "insensible perspiration." When it is in great abundance, it collects upon the skin in liquid drops, or even pours down upon it in little streamlets, and is then called "sweat."

But the moisture which steams out from the pores of the skin is not moisture alone. It is heavily charged with various soluble substances that are brought with it out of the blood. The opportunity is taken, as it has to be driven out from the system for the reduction of its heat, to make it also the carrier of some of the waste matter which is waiting to be discharged. The skin really aids the lungs and the kidneys in their particular work of removing waste refuse and purifying the blood.

The perspiration which exhales through the skin is chiefly composed of water. In ordinary states about twice as much vapour of water is discharged through the skin as is passed out from the lungs with the breath. With very severe exertion, in extremely hot weather, as much as two or three pounds of perspiration may be passed out in an hour through the skin of a full-grown man.

The soluble matters which are mixed with the watery exhalations of the skin are carbonic acid, such as is removed by the lungs, and urea and mineral salts, such as are drained away by the kidneys. The watery parts exhaled in the perspiration amount to from 2 to even 30 ounces in the hour, according to circumstances. They vary to this very large extent. The solid ingredients carried off in the perspiration vary from 14 to 108 grains in the hour. The average amount of water that in twenty-four hours is removed from the blood, by the skin and the lungs, is about three pounds by weight; and of this, two pounds pass by the skin, and one pound by the lungs.

As a general rule scarcely less than 100 grains of nitrogen-containing substance, which is chiefly urea, are removed by the skin in a day; that is, one-fifth the amount which is removed by the kidneys. This solid part of the perspiration is also mixed with some carbonaceous, or fatty, matter that is likewise refuse of the food-substances and textures of the frame. Some portion of these solid substances is volatile, and escapes with the watery vapour into the air; but some portion remains upon the skin as a kind of soil, or adhesive deposit, until it is removed by water.

The skin and the kidneys are very close allies in the work of purification which they perform. When the skin is discharging profusely in warm weather, the kidneys are relieved of a corresponding part of their work and discharge less. On the other hand, when the pores of the skin are closed, and the perspiration is stopped by cold, the kidneys take upon themselves additional work and remove more water and waste substance. The fact that both the kidneys and skin are purifying organs, is remarkably manifested by the circumstance that, in the case of both, the blood, which is gathered up from their capillary vessels by the veins to be carried on towards the heart, is of a bright and scarlet colour and exceptionally fresh and pure.

The skin is, indeed, so important an organ of purification that, if it be entirely covered over by an impervious varnish so as to prevent all transpiration and exudation from its pores, the animal upon whom this operation is performed very soon dies, poisoned by the injurious accumulation of the imprisoned refuse in its blood.

In addition to the solid part of the perspiration, which is brought out from the interior of the body through the skin, there is also soil and dirt of various kinds deposited upon it from the air, where waste matter is always floating and blowing about. The soil of this character mingles with the moist exudation of the skin, and effectually covers and chokes the openings of the pores. The influence of this external dirt, in forming a kind of coating over the skin, is most strikingly shown in the case of the hands, which may be washed three or four times in the day, and still make the water that is used quite dark from their soil. The rest of the skin, although in some measure protected from external dirt by the clothes, has, nevertheless, a fair share of its own to deal with, a large part of which comes from within, and is left both upon the skin and the clothes, when the more volatile parts of the perspiration, or its thin vapours, escape into the air.

There is only one way in which this coating of soil can be removed from the skin, so as to leave the pores open and free to perform their further work of moderating the heat of the body, and helping to purify the blood from its load of refuse and worn-up material. It must be well washed and rubbed at least once every day. The most convenient way for managing this is to sit into a bath or tub, containing about a pailful of fresh water, and deluge the whole body with a sponge, and afterwards to wash the feet and legs, for which there is not room in the bath at first. The best time for doing this is the morning, on getting out of bed; and for all people in fairly good health the water should be cold all through the year, the skin being immediately wiped dry and briskly rubbed with a coarse towel until it is in a warm glow from reaction and friction. This process helps marvellously to produce a feeling of comfortable warmth. As a general rule, people feel warmer after a cold bath in winter time, if the bathing and dressing be quickly performed, than they do when no bath is taken. The sudden application of cold water to the skin, when it is warm in the morning from the bed, and when the body is refreshed by rest and sleep, serves also the excellent purpose of fortifying the system against accidental chills. People who regularly use a cold bath every morning are less liable to take cold from chill than those who avoid the touch of cold water. The feeling of comfort which the morning bath confers can only be appreciated at the proper value when it has been proved by experience.

When, for any reason, the morning sponge-bath cannot be enjoyed in this luxurious way, the skin should still be carefully and thoroughly washed every day. The best course to pursue, then, is to wash the whole body at night, before going to bed with soap and warm water applied with a piece of coarse flannel, and very quickly to repeat the washing on getting up in the morning, and then with flannel, and cold water, without soap. The washing in some form must absolutely be performed if the beautiful organization of the skin is to be kept in an efficient state for the blood-cleansing and blood-cooling work it is planned to perform, and if the body is to be maintained in its best condition of vigour and health. Sickness in various forms can be frequently traced to the habitual neglect of this very simple and easy duty.

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LESSON XLVI.

WASHING CLOTHES.

People who are not so careful in the cleaning of their skins by the daily use of water and bathing as they ought to be, are occasionally saved from the severest part of the penalty due for their laziness and neglect through the bountiful interference of nature. This kindness of nature, however, when it is once understood, has to be looked at in the light of an example and not of an excuse. As soon as people are warm from exercise and work, perspiration pours out from their skins, and the abundance of the moisture softens and melts the adhesive dirt which may be upon them. Both the perspiration and the old soil are then soaked up into the clothes, and so removed from the skin; and if the under-linen be forthwith changed, the most material part of the dirt is in that way got rid of. There can be no doubt that uncleanly people would suffer in their health much more than they actually do, if it were not for this influence of the clothes in absorbing and removing dirt and obstruction from the pores of the skin.

The under garments, whether of flannel or linen, that are worn next the skin, on this account soon become dirty with the soil, or thick refuse, of the perspiration which they absorb. If they are not cleansed from that soil, they may become at length sources of serious mischief. For the waste refuse, that is thrown out from the bodies of living animals, soon changes its nature and generates effluvia, which are even more energetic than itself in producing derangement and disorder in the living system, if they find their way back into the blood. Soiled clothes should, on this account, be removed and washed at frequent intervals, and clean linen be substituted in their place.

The ordinary method adopted for washing under-garments, and bed and house linen, is a troublesome and laborious one. The soil, which is taken up from the skin, is of an oily, adhesive nature, and can only be got out of the clothes again by the exertion of labour and skill. Still, the washing of clothes is not an affair of uncertain observance. It is performed everywhere. All people send their linen to be washed as certainly and regularly as they get up and go to bed. This general adoption of the troublesome, laborious, and very often, therefore, costly operation abundantly proves also the general recognition of its need and importance.

The most indispensable necessary, on the whole, for the performance of washing, is abundance of good water. But water alone is not enough, because of the oily character of the soil that adheres to linen. Water and oil will not mix. This difficulty, however, is readily got over by the employment of soap, which possesses the very useful power of causing oil and water to blend. Soap, itself, is oil of some kind, which has been acted upon by soda. When oil and soda are mixed and boiled together, the oil loses its greasy character, and becomes "*soapy*" instead—that is to say, it ceases to be repellent to water, and is changed into a substance which mixes readily with it, and which has the further excellent property, once it has been formed, of turning additional quantities of oil into the same soluble condition. In other words, both oil and water will mix with soap, and consequently soap has the power of making oil and water blend. But the water must be fairly soft and pure for this result to ensue. If it contain a considerable quantity of a salt of lime, or of any other mineral ingredient of a similar character, the soap then turns to a hard insoluble curd, and loses its power of mixing with grease and oil. Hence, rain-water, which is sure to be free from impurities and hardness of this character, is always used for washing in preference to river or spring water, which may have taken up these undesirable ingredients in running through the ground. When water that is in some measure hard has unavoidably to be employed, soda is added to it, to counteract the effect of the lime. This it effectually does, and it also of its own accord turns greasy matters contained in soiled clothes into soap, and is so useful in a double sense. It has, however, two drawbacks that have to be reckoned with on the other side. It is apt to make the hands of those who wash the clothes sore, and, if too strong, it even injures the texture of the clothes themselves. It has, therefore, to be employed with judgment and care.

When undyed clothes, such as shirts and other white under-garments, are about to be washed, the usual order of the proceeding is that a fair quantity of soap and a little soda are dissolved in warm water, and the articles are immersed in it one by one, and left to soak for some hours. This softens and loosens the finer portions of the dirt. Soap is then rubbed over one face of the cloth, and its different parts are well chafed against each other between the hands. The same process is next repeated with the other face of the cloth. This is the part of the operation which entails such heavy work. The rubbing has to be done very resolutely and thoroughly, in order to get the adhesive deposits upon the threads of the cloth to stir. After this the clothes are boiled in fresh water, being enclosed within a kind of bag when the vessel is of iron, to prevent the whiteness of the cloth from being injured by contact with the metal. A little soap and indigo, or blueing, are added, the latter being used to counteract a yellow tinge which is apt to be given by the soda and by the general process of washing. After boiling, the clothes are taken out from the copper and thoroughly rinsed in clean water, having also a little blueing in it, and are then wrung as dry as they can by the hands, and hung up on a stretched rope in the open air to be finished by the sun and wind. The rope and the pegs, which are used to fasten the clothes upon it, should be washed scrupulously clean before they are employed. In large establishments the drying is more expeditiously and conveniently managed in hot chambers provided for the purpose.

Clothes that have been coloured by dyeing, are not soaked before being washed, nor boiled afterwards, because that would be apt to weaken the colours too much; and they are often rinsed with water in which some salt has been dissolved. Woollen and flannel clothes are never boiled after washing, because that would cause them to shrink.

The manual labour of washing clothes is somewhat unpleasant and irksome on account of the hard rubbing which is required, and because this rubbing, continued long in hot water to which soda has been added, is very liable to make the hands sore until they have become well seasoned to the work. The labour, nevertheless, pays so well, and is so steady in its demand, that there are always a large number of persons prepared to make it the business of their lives. Those, however, to whom cost becomes a matter of consideration, have to manage to get through the periodical washing with their own hands, and, when the family is a large one, can only do so with some considerable strain upon their strength and time.

A good and orderly method goes some way towards the relief of this strain, and should, therefore, be adopted with thoughtfulness and care.

Very clever machines have been contrived to lessen the manual labour of this strength- and time taking process, and some of them successfully accomplish the object at which they aim. Unfortunately, however, like all machines, they are only of service when they are employed upon a somewhat large scale. They most of them consist of chambers which, after being filled with the dirty clothes, have soap and water forced through them in streams, by means of a wheel that requires the strength of a man or stout lad to turn it. When water is forced in this way through the clothes, as a matter of course, it at last washes away the dirt from them.

After the clean clothes have been dried, they are either ironed or mangled, to give them a smooth surface. Before, however, this is done, they are first sprinkled with water to make them slightly damp, and folded in a heap to allow the damp to spread equally through them. The mangling consists in passing weighted wooden rollers over them, and is used for such articles as table-linen, towels, and sheets. Wearing apparel has hot irons, instead of weighted rollers, pressed over it, to give the smooth pleasant gloss to the surface, because the garments of which it consists are of irregular shapes and too much encumbered with plaits and buttons, to allow of a long even roller doing its work upon them, as it can upon a broad and regular sheet. The irons are almost always now heated upon a stove, provided at the top with a hot plate upon which they can be conveniently placed, with a careful restriction of the heat to the temperature which is the best for the work, and with as little exposure to the dirt of the stove as possible.

Many parts of under-garments, such as the wristbands and fronts of shirts, are stiffened with starch before they are ironed, in order to enable them to keep their shape when worn, instead of falling into loose crumples. Starch, which is prepared either from potatoes or rice, is used for this purpose. When boiling water is poured upon starch, it is changed into a kind of thin jelly, which is really gum dissolved in water. Starch is turned into gum by boiling water, very much as, in the living plant, it is turned into sugar by sunshine and rain. Both processes are merely a different form of the same operation. When this solution of gum has been soaked into the clean linen and allowed to dry, it is found that it has filled all the pores lying between the threads, and converted the whole texture into a firm stiff material. Just the same kind of result is produced if a piece of paper is soaked in a thin solution of gum, and allowed to dry and become firm; only ordinary gum is not so beautifully white as the gum formed from starch. Great experience and care are required in ironing starched clothes to prevent the hot iron from sticking to the pasty fabric. Care is also required to prevent all linen, whether starched or not, from being scorched in the ironing.

In unskilful hands this may happen both from the iron being too hot, and from its not being passed briskly and deftly enough over the surface of the cloth. Scorching, however, is still more likely to occur when the linen has not been sufficiently rinsed in clean water after washing, because then some portion of the soda and soap may remain in the fibres of the cloth and be affected by the heat.

SECTION 4.—THE HEALTH, THE HOUSE, AND MONEY.

I.—Health and Disease.

LESSON XLVII.

THE NATURE AND CAUSE OF SICKNESS.

THE human body, although made up of a very considerable number of organs, or parts, which have each distinct offices to perform, and although framed of perishable material and delicate structures, has nevertheless within itself a power of orderly maintenance and endurance that is amongst the most wonderful of the arrangements of material nature. It is a notable and notorious fact in reference to one condition alone, that, namely, of temperature, or warmth, that although the interior structures of the human body, and the streams of the flowing and ever-circulating blood, require to be steadily maintained at a heat of 98° of Fahrenheit's scale, in order that the elaborate operations of the economy of life may be duly performed, people are nevertheless able to live for months at a time in places where the temperature of the air falls as much below that natural standard of animal heat as boiling water is above it. This was strikingly instanced in the recent expedition of the English explorers to the Arctic Sea, during which the temperature of the air at one period of the dark winter sank to a severity of cold 105° greater than that of ice, or freezing water. Direct experiments have also shown that human beings can live for considerable periods in ovens heated to very nearly the temperature of boiling water, provided care be taken not to allow the skin to be touched by any substance that can energetically, or quickly, communicate to it the great heat. All this is simply because the living human frame has a very considerable power of adapting itself to unusual circumstances, and of applying its own correction to unnatural conditions.

The fact of this self-correcting capacity of the human body, which is thus strikingly illustrated in the case of cold and heat, is not less remarkably instanced in reference to the other physical conditions by which its structures are affected. It can adapt itself, without suffering injury, to a very large range of unusual circumstances. It can set right by its own powers of resistance, and by its own perfection of compensation, a great many derangements that are injurious in their tendency, and that would be hurtful in their results if they were allowed to continue.

This indwelling power of preserving its proper adjustment of internal state is so strong in the human frame, that women and men are not unfrequently seen to live for more than threescore years and ten in the most varied circumstances of social existence, without at any time suffering more than a trifling derangement of the natural operations of their delicate organizations. When this is the case, however, it always is because their mode of life is so simple and natural that they give the inherent provisions for correction and compensation fair play, and allow the injurious derangements to be removed by nature itself as soon as they begin to be apparent.

With too many people, on the other hand; either because they are altogether ignorant of the circumstances that are bringing about the deranged operations in their bodies; or because they are too obstinate and wilful to deny themselves some passing enjoyment, or to refrain from some pleasurable excess; nature is not allowed fair play in this particular, but is oppressed and overwhelmed by a demand for an amount of correcting and compensating work which it is impossible for it to perform. The healthy and *easy* operations of life are then changed into unhealthy and *uneasy*, or **diseased**, operations. The proper and healthy actions of animal life are carried on for the most part without consciousness of the process. Deranged actions, on the other hand, almost always make themselves felt in some degree, and change the sense of comfort and ease into one of discomfort and DISEASE. The discomfort and uneasiness in this case are like the grating and friction of disordered machinery. They are indeed a palpable sign, intended to draw attention to the deranged condition, in order that the beneficent efforts of nature to remove the derangement may be aided, or, at any rate, not wilfully interfered with and opposed. The combination of this feeling of discomfort with disordered state is of such constant occurrence, that the word "disease" has been almost universally adopted as a term for wrong action in the living frame, and **disorder** and disease are now used as words that mean the same thing. The term **health**, employed on the other hand to express the state when all the various actions of the living body are easily and properly performed, and when no disease or discomfort of any kind is experienced, is an old Anglo-Saxon word. It was used by our ancestors to designate that indwelling power of correction possessed by the frame, which strives to remove disorder whenever it begins to present itself, and which, therefore, in that sense, **healeth**, or maketh whole, and so constitutes health.

A very large number of the diseases, or disorders, to which the living human body is subject, are most certainly due to circumstances that can be removed or avoided. A considerable proportion of them results from gross ignorance on the part of the sufferers. When people begin to feel the disease, or the discomfort of the deranged state, they do not know what it points to, and, on that account, make no effort themselves to give nature fair play, and to help it in its remedial operations. Too often, in their ignorance, they do exactly the other thing, and increase the force of the injurious agencies, until nature has small chance in the unequal conflict. The only efficient remedy for this fault is increase of enlightenment and improved knowledge. Young people need above all things to be taught at least so much concerning the structures of their frames, and the physical influences that act thereon both for good and ill, as will enable them in the advancing years of life to escape from this serious penalty.

Another and a considerable part of the preventible diseases must be ascribed to perverse wilfulness, quite as much as to ignorance. People refuse to bear in mind the unavoidable consequences that must follow upon some mere sensual indulgence, which, although it gives a brief enjoyment, entails afterwards derangement and discomfort, in consequence of the unnatural conditions in which it involves the delicate organization of some part of their frames. Excesses of various kinds in eating and drinking are the most frequent sources of this form of mischief. Highly flavoured and tempting dishes are used until the natural appetite for simple food is perverted into an unnatural craving for strong flavours, and until quantities of food are introduced into the stomach which are far beyond its assimilating powers, and so cannot be converted into healthy flesh and blood, or be turned to useful account in supporting the movements and actions of the system.

The injudicious use of strong drink is a still more fertile cause of derangement and disease amongst women and men than other forms of sensual indulgence. The excessive use of strongly flavoured or not easily digestible food ordinarily produces disinclination, or disgust, which limits the mischief. But unfortunately the habitual employment of strong drink has an exactly opposite effect. It creates an artificial want, and establishes a craving, which it is almost impossible to escape from when it has once been called into existence.

The unfortunate habit is also one which is most easily indulged under the circumstance of the too abundant provision that is made, almost everywhere, for its exercise. It is for these reasons that the use of strong drink needs to be watched and suspected before all things.

The diseases which are well known to be chiefly due to injudicious eating and drinking and to the habitual misuse of fermented drink, make up a formidable and terrible array. Rheumatism, gout, inflammation of an endless diversity of kinds, congestion and obstructed flow of blood, fever, headache, painful affections of the delicate and sensitive nervous structures, indigestion, and, above all things, those impairments of textures which are called organic, or structural, disease, and which, in plain language, are the destructive disorganization of the living substance of the frame, all belong to this group of disorders. The great excreting organs,—the liver, kidneys, and lungs,—whose especial work it is to remove from the body worn-out and useless material, are, as a matter of course, prone before all other organs to suffer from this cause, because they are, in the first instance, called upon to deal with the injurious excess, and so the brunt of the evil falls upon them.

The only efficient remedy for this source of mischief is increased strength of moral perception and purpose. In order to enable them to avoid the injurious indulgence of their mere sensual appetites, young people require not only to know clearly what is the exact nature of the evil they have to avoid, but also to be exercised in that discipline which gives them the power to refrain from mere passing indulgence when it can only be reaped at the cost of a subsequent penalty; and which also makes them incapable of doing, for the sake of any present or prospective gain, aught that they know upon higher grounds and principles to be wrong.

LESSON XLVIII.

INFECTIOUS DISEASE.

Errors and mistakes in the management of food and drink have, on the whole, more to do than anything else with the production of the most ordinary forms of disorder and disease. It necessarily is so on account of the large and important part which the continued supply of nourishment plays in the various arrangements of the living economy. The digestion and liquefaction of the food, the formation and circulation of the blood, the repair and support of the organized structures, the maintenance of the various kinds of vital movement and force, and the removal of useless excess, are all processes which are immediately affected and deranged by this influence.

The most general way in which derangements of this class begin to take effect, is that they lead to the injurious weakening of the reparative powers upon which nature depends for remedial work. All the purifying organs, which are concerned in the removal of useless or waste material out of the system and the blood, are embarrassed and oppressed by the additional labour that is thrown upon them; and so they become less efficacious for their purifying operations, just at the time when the unusual effort is required. The liver, the kidneys, the lungs, and the excreting apparatus of the skin and of the lining of the internal cavities of the body, are all very prone to be weakened and thrown out of their proper state of activity from this cause. There are other circumstances, besides the mere pressure of extra work, that produce similar effects upon these all-important organs; such, for instance, as the sudden application of cold at a time when the body is exhausted and fatigued, as well as heated, by exertion. As a simple fact, however, these additional causes of derangement are more easily dealt with by nature, and more easily rectified, than the errors of excess. They are *external* to the frame, and, for the most part, very soon cease to operate, in the ordinary progress of events; whilst, on the other hand, the influence of injurious excess is *internal* to the frame, indwelling in the body wherever it goes, and, under the ordinary arrangements of social life, almost certain to be frequently renewed and long sustained.

When the mischief is continued, in this way, until the purifying organs have been very materially injured in their efficiency and power, the blood gets more and more contaminated by the accumulation of the improper matters that are left in its streams. The impure blood being then carried to all parts of the living structures, they become sensible of the unnatural condition, and some of the most sensitive of the organs make strenuous efforts to rid themselves of it. The heart beats hurriedly and irregularly; the breathing becomes quick; the skin is alternately chilly and hot; the stomach acquires a loathing of food; sleep is prevented or disturbed; the mind is oppressed with weariness and fatigue; the secretions of the different parts are dried up, or become depraved, and the limbs are affected with aching and pain. In short, the usual and proper state of comfort and ease is exchanged for an unusual state, in which every part of the body is in discomfort and disease. This general state of all-pervading uneasiness is the condition which is known under the familiar designation of **fever**. The word has been selected for expressing this state of disease, because one of its most prominent indications is that the skin becomes preternaturally hot. The word fever is derived from the Latin **ferveo**, which signifies **to make hot.** Fever is, thus, simply that state of the living body in which every organ and texture are supplied with impure blood, and in which every excreting, or secreting, part is engaged in a more or less laborious and distressing effort to free itself from the oppression.

It is a particularly important fact, which has been learned through actual experience, that, when the blood becomes very deranged from this cause, it soon acquires an energetic power of communicating a similarly disturbed state to other blood by the conveyance to it of some minute portions of its own disordered substance. These often only consist in the vapour-emanations or effluvia, which issue from it into the air with the breath or with the exhalations of the skin, and which so find an entrance into other living bodies when the contaminated air is breathed by them. All fevers are not of this character; but all are apt to become so when the derangement is sufficiently advanced and severe. The fever is then said to be of an **infectious** nature, the term being intended to express that the disorder can be communicated from one person to another, by emanations generated in and issuing from the primarily diseased frame. The word **infection** is derived from the Latin term **inficio,** which means **to affect, or contaminate, with the same state or condition.**

There are some diseases of an infectious character in which this communication of the diseased state from one body to another can be traced as it occurs, by direct observation. Thus, in the particular kind of fever which is called small-pox, the most impure part of the disordered blood is thrown out through the skin, in the form of small pustules of matter, which lift the outer skin up where they appear. If a small portion of this matter is taken from the pustule, and inserted into a minute prick made in the skin of another person, who has not previously had the small-pox, or been protected against it by vaccination, small-pox within a few days almost certainly occurs in the individual who has been so treated.

In infectious diseases that are communicated by vaporous emanations from the skin, or by exhalations of the breath, the process, by which the result is brought about, cannot be as readily observed. But it is, nevertheless, of an altogether similar character. Some actual substance of an unnatural or disordered kind, that has been produced in the blood of one individual is introduced into that of another, and there, by its mere presence and contact, reproduces the same unnatural and disordered state.

The precise character of the disordered substance, which thus acquires the hurtful power of communicating a particular diseased state from one person to another, is not yet satisfactorily ascertained. This is one of the mysteries of life which is still being anxiously inquired into by men of scientific attainment and thoughtful minds.

The result is, however, in some way connected with the circumstance that the deranged substance of the blood and of the structures of the body becomes prone to rapid decomposition. Poisons of a very subtle nature are formed, by the regrouping of the elementary atoms as they pass from the state of organized structure into their primary and separated conditions; and, so long as they remain in this first stage of decomposition, they retain the mischievous power of infecting other blood with their own injurious and poisonous tendencies. But, as soon as they have passed from this intermediate and temporary state, into the advanced condition of decay in which their original elements are more perfectly separated from each other, they lose their infectious powers, and once again become harmless. It is on this account that infectious disease is liable to be produced wherever there is a great abundance of putrefying, organic substance, undergoing destructive change after the cessation of life; and it is also on this account that infectious disease very constantly disappears when such products of abundant putrefaction are hurried away into open spaces of fresh air as speedily as they are formed. In the free, open air, the subtle products of the putrefactive process are hastened on, by the disintegrating touch of the atmospheric oxygen, into the harmless state of final resolution into their primary elements.

Diseases of this more complex character are less under the control of human agency than the simpler states of disorder that can be more immediately traced to injurious and unnatural habits of life. They require for their avoidance or removal a clearer understanding and a wider knowledge of the conditions upon which they depend. It is, nevertheless, equally true, that in the first instance they are almost always generated by circumstances that could have been avoided; and that, even after they have been caused, they can be arrested in their mischievous career through the instrumentality of human intelligence.

It is assuredly the case that there are some diseases afflicting mankind, which in the present state of knowledge appear to be altogether beyond human control. These, however, happily are of less frequent occurrence than those which can be influenced and avoided; and there can scarcely be a doubt, that with the further advance of human intelligence and the further progress of science, many of such as yet uncontrollable diseases will be brought within the sphere of prevention and sanitary management.

In the meantime, there remain two great practical facts which it is important that everyone should be familiar with. First, disease is not a natural, but an unnatural state, brought about by a series of circumstances which ought not to exist, and which, at least to a very large extent, are capable of being avoided or removed; and, secondly, this unnatural state is itself removed, in most if not in all instances, by the operations of nature itself, if these be not perversely or ignorantly crossed and interfered with. The proper tendency of disease is to a natural cure, and the most important steps in the curative management of disease resolve themselves into helping and forwarding the beneficent operations of that process.

The great natural agencies for the removal of disease come less freely and readily into play in the artificial arrangements in which people live when they are crowded together in social communities. The fresh air, for instance, which is one of the chief curative influences, employed both for the removal of injurious excess from the body and for the speedy destruction of its infectious exhalations, has less ready access to people who live in cities and towns, than it has to those who dwell in the open country. The removal of waste decomposing matter, and of dirt of all kinds, is less easily ensured there; and so also is the prompt withdrawal of many forms of injurious excitement and excess. It thus unavoidably happens that nature needs more help in its reparative work in the circumstances of civilized existence, than where the arrangements of human life are more simple and rude.

The various conditions of derangement, upon which sickness and disease depend most, require, therefore, to be understood by civilized communities; savages may be left in such matters to the general provisions of nature; but civilized people need that those provisions, beneficent and marvellous as they are, shall be supplemented to a considerable extent by individual and intelligent action. Such, indeed, is a part of the price which man has to pay for the privileges he enjoys as a rational and responsible being. He is expected to employ, in his own behalf, the great gift of intelligence and reason which has been accorded to him; and it is in this sense, and from this point of view, that the art of nursing in sickness becomes an important characteristic in a well-ordered system of domestic economy.

LESSON XLIX.

NURSING IN SICKNESS.

In the large hospitals which are provided in cities and towns for the treatment of sick people, the nurses, who attend upon the inmates, are carefully taught and trained for the services which they have to render. Such nurses accordingly are very skilful and efficient in their work. As, however, many more have to be nursed through sickness at home than can be treated in such establishments, it falls to most persons to be called upon at some time or other to have to give help to their relatives and friends when disabled by illness. It is of great practical importance, therefore, that all women, at least, should know how they may best render such assistance in their homes. In cases of slight disease but very little help may be required. But, even then, it may make a difference of some hours or days of distress and of more or less prolonged incapacity for work, whether that help be readily and judiciously afforded, or the reverse. In more severe and protracted cases of disease, the same circumstance may possibly involve the difference between recovery of health and premature death.

In all instances of severe illness, the sufferer is confined more or less completely to bed, and is, therefore, dependent upon the attendance that is furnished by others. In such circumstances the entire arrangements within the sick room of necessity become the charge of the nurse.

In the care of a sick room, perhaps, the one thing that stands before all else in importance, is the securing of pure fresh air at all times within it. Fresh air is needed at all times by living human beings, in order that the purification of the blood may be efficiently maintained through the operation of breathing. But it is obviously even more urgently required when the blood is becoming unusually impure from the presence of disease; and when the sick person is confined to the narrow space of one room by day as well as by night. When the invalid is prevented by indisposition from going into the outer open spaces where the fresh wind blows. the sufficient purification of the air can only be secured by bringing in to such invalid that which he is incapable of going abroad to seek.

The means by which fresh air can be most readily admitted into a sick room is obviously by opening the windows. The door of the room communicates in most cases with the other interior spaces of the house; but the window invariably opens to the fresh external air. As a general rule, therefore, in chambers where sick people are confined to bed, the window should never be entirely closed. The sash should be drawn down a little from the top, so as to allow enough fresh air, for the needs of the case, to *flow* into the room. But, as air does not readily flow into a room unless provision is made for a current out as well as in, a second opening of similar extent must be provided in some other part of the room, and a careful examination be made from time to time to see that the current is both established and sustained. There is a very useful little instrument now constructed, called a ventilation-anemometer, which consists of a light flywheel turning before moving air in such a way that it indicates, by a revolving index, or hand, the amount of the movement. This is a valuable instrument for the scientific management of ventilation. But a rude and efficient substitute may be easily provided by tying a light feather, or some down, to the end of a piece of thin thread or silk. The drifting of the light object will at once show the movement of any current of air in which it is placed.

When there are two windows in a room, the requisite current of air may be generally secured by opening one window below whilst the second is opened to the same extent above. If there be not a second window, the current must be established by opening the single window both below and above, by leaving the door a little ajar, by an open chimney, or by some other expedient which will easily be thought of when the object that is required is known.

In providing, however, the current of fresh air that is essential to the good management of a sick room, it is of great consequence that no cold draught shall fall upon the invalid. This is easily prevented by the employment of a sufficient covering of bedclothes, and, if necessary, by the intervention of a curtain or screen. There is rarely anything to fear from even cold fresh air, when the warmth of the body is sufficiently preserved by proper covering. Open windows and warm bedclothes are prime necessaries in sickness.

The ventilation of a sick room is still more efficiently secured when the outlet for the air is provided by means of a chimney under which a fire is maintained. The combined influence of a fire burning in the grate, and of an open window, is about the most satisfactory provision that can be adopted for the due ventilation of a room; and it is only when the air is extremely cold, or extremely hot, that it may be undesirable to trust to this most excellent combination.

In ventilating a sick room, the object which has to be aimed at is mainly to keep the air, contained within the room, as nearly as possible in the same natural condition of freshness and purity as the atmosphere which floats and circulates in the open spaces outside and around the house.

The matter next needing the nurse's attention in a sick room, when the due admission of fresh air has been provided for, is to see that all materials which tend to contaminate the air are removed from the chamber as speedily as possible. The fresh air, which enters a sick room by the open window, can perform its purifying work but very imperfectly if it find within the room accumulations of dirty and decomposing substances. The most absolute and scrupulous cleanliness is therefore required in nursing the sick.

The substances which are most productive of mischief in the chamber of sickness, obviously are the emanations that issue from the patient's own body. Vapours are constantly pouring out with the breath, and through the pores of the skin, which are the products of the destructive decomposition of the disordered structures within the frame. The excretions which pass from the body from time to time in a more palpable form, being themselves in a state of putrefactive decay, pour out, on their part, unceasing streams of the same noxious vapours. The excretions of this class can fortunately be at once carried away, and always are removed out of the room without delay in all well-ordered nursing.

But the vapours which exhale from the lungs and, still more, from the skin, are not so easily dealt with. They are closely associated with moisture, and, in this moist state, they attach themselves to the clothes of the patient and of the bed, and to all soft porous matters that come within their reach. There they remain steaming out their subtle effluvia, unless they are removed by suitable and more searching expedients.

On this account, the linen of the patient requires to be very frequently changed, and of the bed also, so far as this can be done. The skin itself should be cleansed at least once every day. When the skin is thus cleansed, it is clear that the linen, both that which is worn upon the person and that which forms part of the furnishing of the bed, needs less frequent change than it would otherwise do, because the clean state of the skin prevents both from being as speedily soiled. The washing of the skin of sick people can always be accomplished without risk or discomfort, if it be managed in the proper way. The skin has to be gently sponged first with soap and warm water, and then with warm water alone, and after that should be quickly wiped dry with a soft warm towel. This washing is best done piecemeal, and to only a small portion of the body at a time. The clean linen should invariably be thoroughly dry and slightly warm when it is put upon the patient.

Soft and light woollen blankets are the only other bed-coverings, besides the sheets, that should be used in sickness. The linen, if changed often enough, goes far to preserve the blankets in a wholesome state; but the blankets should also be changed from time to time, and those which have been removed should be hung out in the open air and sunshine to get rid of any volatile and objectionable effluvia they may have imbibed.

All curtains and carpets should, from the first, be cleared away from the sick room. No hangings of any kind should be allowed to the bed when the illness is prolonged and severe. All such things serve to absorb and keep in the hurtful vapours which it is so desirable to get rid of; to prevent the ready and free circulation of fresh air; and to make it more difficult to preserve absolute cleanliness. In the absence of such obstacles and encumbrances, it becomes a very easy thing to wipe, at frequent intervals, the floor and other parts of the room, as well as some portion of the furniture with moist cloths, which readily take away dirt without causing dust.

The best bed that can be used in sickness is a soft well-made mattress of hair. But, in cases of prolonged and serious illness, even this should be changed, and well-turned and aired from time to time. The bedstead itself should be of iron, and fairly low, so that the moving and shifting of the patient can be conveniently managed.

The arrangement of the pillows in sickness is a matter of considerable importance to the comfort of the patient, and it is one that requires the exercise of both skill and intelligence on the part of the nurse. The object which has to be aimed at is to make sure that the body is supported in a natural and unconstrained position at as many points at once as possible, so as to prevent any tendency to slip and slide about under the influence of its own weight. The most perfect and comfortable bed that can be employed in cases of severe illness and great debility is that which was contrived by the late Dr. Neil Arnott, and which is known as his water-bed. In it the body of the patient floats upon water, with a smooth layer of waterproof cloth and warm dry blankets between; and so every part of its under surface is evenly sustained in whatever position the trunk and limbs may be placed. The liquid rises up everywhere into close contact with the weight that has to be supported. The water is held in a sort of trough, which is then covered at the top with waterproof cloth, made water-tight round the edge where it is joined to the wood. Mere water-tight pillows and bags filled with water, which are sometimes used in the place of this bed, but imperfectly answer the purpose that is in view. The body of the patient requires actually *to float*, evenly sustained everywhere, upon the surface of water, just as it does when a swimmer is immersed in the liquid.

These great rules, for providing an unstinted supply of fresh air, and for maintaining the utmost attainable cleanliness, require to be observed in all cases of sickness where the invalid is confined more or less to bed. They aid nature in its own efforts to bring about the cure of the disease, and so materially shorten the period of the illness. They contribute also in a very important degree to the comfort of the patient. When, however, illness has been so prolonged and severe, or is of such a nature that actual infection has been generated and come into play, the need for their observance is increased a hundred fold, for it is these very influences that are the destroyers of infectious power. No infection continues to operate where there is abundance of fresh air, unfailing and unqualified cleanliness, and unremitting attention to the wants and incapacity of the sufferer. It is well known that, in hospitals which are devoted to the treatment of the worst forms of fever, the disease is rarely communicated through the wide spaces of fresh air which are provided in the well-ventilated and well-kept wards.

In the slight attacks of indisposition which are of frequent occurrence amongst people in the ordinary circumstances of life, a little abstinence from food and drink and a little extra rest are generally all that is required to remove the derangement, because these afford the somewhat overtaxed and oppressed powers of nature the opportunity to recover their proper influence and state. When this is the case, the recovery is speedily marked by a return of the natural appetite, or the desire for simple and wholesome food, and by a restoration of the natural amount of activity and vigour.

But where the derangement is of a more serious kind this is not the result. A more prolonged continuance of care and nursing is required before the weakened and oppressed organs of the frame can resume their natural and healthy operations, and so efface the disease. Under such circumstances the regulation and management of the diet are matters of the utmost consequence. Food, which gives strength to persons in health, not unfrequently is seriously hurtful to invalids. The rule still obtains that abstinence of a certain kind is required, but it must only be abstinence from heavy and improper forms of nourishment, whilst better and more suitable kinds are furnished in their place. In prolonged sickness the body must be sustained at the same time that all unmanageable or oppressive food is withheld, and the accomplishment of this purpose is one of the services that the skilful nurse has to render.

The first step in the preparation of food in sickness is so to arrange that much of the effort and work, which are thrown upon the stomach in health, are performed by the preliminary operations of cooking. The employment of such readily digested foods as beef-tea, which is merely the diluted juice of the meat, simple broths, gruel, arrow-root, butter, cream, and the various lighter combinations of milk and eggs with flour or bread, rests mainly upon this ground. The diet in sickness needs to be light rather than strong, and to be given in small quantities at frequent intervals, instead of in large quantities at the usual period for meals. The good nurse has of necessity to discover by direct observation of the case, and by carefully feeling her way, what kind of food is best taken by the patient, and is most beneficial in its effects ; and also in what way it may be most advantageously administered. But, in doing this, it will always hold good that the food, whatever it may be, must be very carefully prepared, and that it must be in the freshest and most satisfactory condition. Such things as sour milk, stale eggs, and preparations of food half spoiled by long standing, must never, under any circumstances, be allowed to come within reach of the sick. Invalids are much more sensitive to offence of this character than persons in health, and very readily acquire a disinclination, or disgust for the nourishment which it is desirable they should be induced to take. As a general rule, it will be found that sweet things are neither suitable for, nor palatable to, invalids. The sick should be interfered with as little as possible whilst engaged in taking food; they should be kept at the time from having the attention drawn to other occupations or thoughts. It is one of the golden rules in well-managed hospitals that no other proceedings are allowed to go on in the wards when the patients are engaged at their meals.

The best of all drinks in cases of sickness are water and tea. Some other kinds, such as barley-water and lemonade, may be advantageously given at times. But pure fresh water is always the most acceptable of all beverages to the sick. Tea, when judiciously administered, is a supporting as well as a refreshing drink. Tea will often promote sleep in illness, where sleeplessness is due to nervous exhaustion. The tea, however, that is given to invalids should be of good quality, well made, mixed with a fair quantity of milk, and be allowed only in small quantities at a time. It is almost always found that small quantities of such restoratives as tea produce a more beneficial effect than large ones. As a general rule, tea should only be given to invalids in the earlier hours of the day, and not later than four or five o'clock in the evening, as, when taken after this, it is apt to render an invalid wakeful at night. Fermented drinks of all kinds should be entirely withheld in sickness, unless in such circumstances as require for some special reason the influence of alcohol upon the system. They then take the place of medicines rather than of food, and, on that account, should be dealt with by the doctor rather than the nurse.

Rest is scarcely less influential than judiciously administered food in the removal of disease, and the best and most perfect kind of rest is sleep. The nurse, who is aware of this, takes care that no accidental disturbance shall interfere with sleep, and especially at night. When the patient is, so to say, settled down for the night, no noise, abrupt movement, or flashings of strong light must be allowed in the room. It is more difficult in general for weak people to get to sleep again, if they be disturbed soon after the beginning of their rest, than it is when they are disturbed at a more advanced hour of the night. On this account, the earlier part of the night needs to be the most carefully provided for in the arrangements of the attendant. It is a remarkable fact that, in sickness, the more invalids sleep the more they appear to acquire the power of doing so, and of being benefited by the rest. The great difficulty in sickness is to get invalids to begin their sleep after long intervals of restlessness. The utmost care has, therefore, to be taken to do everything that can promote the inclination to sleep, and to avoid and foresee everything that can disturb or cross it.

But in cases of prolonged illness, where the powers of the mind as well as those of the body are weak, all sudden noise, hasty and purposeless movements, and unnecessary interference with the repose of the invalid, need to be avoided in periods of wakefulness, as much as in those of sleep. Sudden noise, when caused by some occurrence or circumstance that is not obvious to the eye, is at all times startling, and startling disturbance is of necessity distressing and hurtful to the sick. The movements of the nurse about the room of the invalid should be unhesitating, prompt, and directed at once to the object which is to be attained; but they should be at the same time gentle, quiet, without fuss or bustle, and not such as to draw unnecessary attention to what is going on, or to excite unnecessary effort on the part of the patient. Creaking shoes, rustling clothes, the swinging and banging of doors, fussy and purposeless movements of objects and articles in the room, sharp speaking, and, above all, meaningless gossip and babble, are all very objectionable, and often very injurious, in the chamber of sickness. In speaking to an invalid, or in reading, where that is necessary, the words should always be distinct and slow, ample time being given for the weakened powers of perception to follow their meaning without getting embarrassed or confused, or without having to incur the distressing effort of asking for a repetition or explanation of anything that has been said.

The punctual and faithful observance of the directions of the doctor in sickness is so manifest a duty on the part of the nurse that it scarcely needs to be named. The intelligent performance of this duty, however, implies that the nurse comprehends the immediate object which the doctor has in view, and forwards it by her own judicious interpretation of such instructions as she may have received. The administration of medicines is one very important way in which this rational obedience has to be shown. The nurse needs not only to be both punctual and exact in giving medicine, but also so far to understand the reason for which it is given, as to be able to draw the attention of the doctor to its operation and effect during the intervals that lie between his visits to the patient. It is in the power of the nurse in this way to render the most valuable and efficient aid to the doctor as well as to the invalid.

II.—The House and its Appliances.

LESSON L.

VENTILATION.

THE interior of the chest of a full-grown man, or woman, contains from 200 to 230 cubic inches of air diffused through its innumerable air-tubes and chambers. With each act of breathing about 30 of these cubic inches, or something like an eighth part of the whole, are changed—that is to say, 30 cubic inches are driven out from the chest through the mouth, by the drawing together of its walls, and by the diminution of its cavity; and then 30 cubic inches of fresh air from the outside are drawn in by the subsequent moving apart of its walls and increase of its cavity.

But the air, which comes out from the mouth after this operation, is in a notably different state from the condition it is in when it enters the chest. When it goes in, it is as cool as the external air, whatever that coolness may be. When it returns, it is at blood heat, or at a temperature of 98° of Fahrenheit. When it goes in it is moderately dry, but when it returns it is heavily laden with moist vapour. When it goes in it does not contain more than three parts, by volume, in each 10,000 parts of its own bulk, of the heavy vapour of carbonic acid; but it contains, when it returns, 470 parts in 10,000, or 5 per cent., of carbonic acid, and the same proportional quantity less of pure oxygen than it had when it went in; that quantity of the oxygen having been exchanged for the heavier compound gas. The expired air also contains small but important proportions of various volatile vapours, or effluvia, which result from the destructive decomposition of the complex substances within the body.

The immediate practical consequence of these changes, produced in the condition of the air by breathing, is that it is spoiled for the purposes of animal life. Air cannot be breathed over and over again without producing very serious disease, and, in the end, even death.

When a full-grown woman or man goes on steadily breathing fresh air in this way, pumping it in and out some fifteen times every minute, as much as nearly 400 cubic feet of fresh air is passed through the chest in twenty-four hours. But, in that time, 18 cubic feet of the oxygen which were contained in that air are removed, and 18 cubic feet of carbonic acid are added in their place, in order to generate which, not less than half a pound of actual black carbon is taken out of the body and from the blood. More than half a pint of water is also removed by the same path, to constitute the heavy load of moist vapour which escapes with the breath.

The fresh outer air, which blows about in the open spaces of nature, never contains more than three volumes of carbonic acid in each 10,000 volumes of itself, that is, thirty-three times less than 1 per cent. This is nature's own standard of purity.* If, at any time, the proper quantity of carbonic acid floating in air be doubled, that is, if 10,000 volumes of air contain six volumes of the heavy gas instead of three, that air is so far spoiled as to be no longer capable of being breathed without producing disorder of some kind. If the quantity of carbonic acid be increased 40 times, or to 240 volumes in 10,000 volumes of air, that air becomes unable to sustain either flame or the breathing of animals. The 5 per cent. which is contained in air that has been breathed, is,

* See page 64.

however, more than double this amount. It is manifest, therefore, that it cannot go on sustaining the operations of life.

But the air which has been breathed by a living animal is injurious, or, in other words, poisonous to other living beings, in consequence of the combination of three circumstances. First, because a considerable portion of oxygen has been removed; secondly, because a considerable amount of carbonic acid has been added in its place; and, thirdly, because other injurious emanations, resulting from the decomposition of complex organized substances, have also been added. The mischief is not merely the consequence of the direct poisonous influence of the heavy carbonic acid vapour itself. For if 5 per cent. of pure oxygen be added to air that has in it 5 per cent. of carbonic acid, generated in the process of breathing, then such air *can* continue to support animal life, although still charged with the excessive proportion of carbonic acid.

The increased quantity of carbonic acid, however, in the circumstances of ordinary life is at all times associated with the other causes of mischief, namely, the reduction of the vital air, or oxygen, and the production of the volatile and poisonous effluvia. Its presence, therefore, for all practical purposes, may always be taken as a proof, or sign, that the air is to that extent of a dangerous and unwholesome character.

Carbonic acid is produced in the air by the burning of fires, and of lamps, candles, and gas, quite as abundantly as it is by the breathing of animals. Thus, two ordinary sperm candles do as much to spoil the air in which they are burning, as the breathing of a woman, or a man; they produce half a cubic foot of carbonic acid in less than an hour. An ordinary gas-burner consuming 3 cubic feet of gas in the hour, will produce 2 cubic feet of carbonic acid from its flame in that time. In the case of a fire, the carbonic acid is almost entirely carried away up the chimney with the smoke. But, in the case of the candles and gas, it is left within the room, either to be removed by other expedients, or to produce injurious effects in its atmosphere.

When coal, charcoal, or coke is burned in a fire, another kind of compound gas, besides carbonic acid, is formed by the union of the charcoal and oxygen. This gas is distinguished by being light instead of heavy, and by being able itself to burn with the production of a blue-coloured flame, when it is further united with oxygen. It is named carbonic oxide, and only contains half as much oxygen in each of its molecules as carbonic acid has. The blue flame, which is often seen flickering about the red embers of a coal fire, is due, first, to the production, and then to the burning of this gas. It is converted into true carbonic acid gas when it is burned, being, in that way, united with an additional quantity of oxygen.

Carbonic oxide is generated in the burning of candles, lamps, and ordinary house-gas, as well as in fires. Its blue flame may commonly be observed mingled with the yellow and white flames of candles, lamps, and gas. This carbonic oxide gas is a very much more injurious and deadly poison than the heavy carbonic acid.* It produces, first, insensibility, and then suffocation, when even minute quantities are intermingled with the air which is breathed. In the various instances in which people have been suffocated whilst sleeping in small, close, badly ventilated rooms where charcoal or coke fires are burning, the result has been generally due to the gradual mingling of carbonic oxide with the air. This gas is especially dangerous on account of the subtle and insidious way in

* Faraday believed it to be one hundred times more deadly.

which it produces insensibility before it chokes. It first deepens the sleep, and then kills whilst the sleeper is quite unconscious.

The air needs to be continually changed in rooms in which people dwell, both on account of the accumulation in it of carbonic acid, carbonic oxide, and other noxious vapours and exhalations produced by the process of breathing and by artificial combustion, and of the removal at the same time of an important part of its vitalizing oxygen. Such changing of the air in houses and rooms, in order that it may be preserved as fresh and pure within as it is without, is the process which is familiarly termed **ventilation.** The word is derived from the Latin **ventilo,** which signifies **to blow.** The air which is in this way changed is **blown** along through the room very much as the wind blows in the open outside spaces of the atmosphere. In other words, in the process of ventilation a gentle wind or current of air is artificially produced in the interior of houses, where the air would be still and stagnant if such influence were not brought into play.

In the free open spaces of the country, the air is kept pure by the combined operation of the rain, the wind, and vegetable life. The rain washes all soluble vapours, such as carbonic acid and ammonia, out of the air, and carries them down to the ground. Living plants absorb into their leaves and roots the same soluble vapours, and work them up into vegetable structures, such as wood, starch, gum, and the various food-substances elsewhere enumerated. When impure exhalations and vapours are generated in any one spot in rapid abundance, as happens in the case of the decomposition or putrefaction of dead organic substances, they are caught by the wind, and drifted off by its moving currents until they are thinly spread through very large spaces, where they can be beneficially dealt with by the rain and vegetable life. In this way it happens, that although there are some of these vapours floating in the free open air of the country, they never amount there to more than three volumes of carbonic acid in 10,000 volumes, and 3½ volumes of ammonia in 10,000,000 volumes, of air.

In the close rooms of cities and towns, where many people live crowded together, and where artificial fires and lights are in use, the carbonic acid is sometimes increased to as much as eight volumes of the gas in 10,000 volumes of air. This would be a very injurious quantity if the air containing it were continuously breathed. In very crowded buildings, such as theatres, where bright gas is burned, and where inadequate means are employed to secure good ventilation, the quantity of carbonic acid sometimes increases to as much as 25 volumes in 10,000 volumes of air, or eight times as much as there is in a wholesome and natural state of the atmosphere.

C The first and, upon the whole, the most important influence by which the good ventilation of the inside of houses is brought about, is the action of the outside wind. On account of the fluidity and great mobility of the air, the movement of its outside currents, or the wind, is always more or less communicated to the interior spaces of dwellings. The wind presses in through some of the chinks and crevices of the windows and doors, even when they are closed as much as they can be, and so sets up a current. This current may be impeded and made insufficient by the narrowness of such chinks. But the instant the windows and doors are thrown open, the wind begins to blow freely through the house, and then the ventilation of its inside spaces is abundant and complete.

The opening of windows and doors is always the most satisfactory way of producing ventilation, when it can be done without making the inside of the house too cold.

When fires are burning in the open fire-places that are continually in use in England in the season of greatest cold, the ventilation is secured without opening the doors and windows, because then a new and very energetic power is brought into play in aid of the influence of the wind. The column of air, contained within the chimney over the burning fire, becomes so expanded and light, from the heat to which it is exposed, that it yields before the pressure of the heavier and denser air which is pushing against the crevices of the windows and doors. It is driven, in consequence, as a rapid stream up the chimney, before the fresh and heavier air from the outside which comes in to occupy its place. When a fire is burning in a room, the air contained within the room may be looked upon as being in the position of a kind of elastic cushion, pressed upon through all the openings into the room by the weight of the outside air. Some of that weight tells through the open chimney, and some through the chinks of the windows and doors. The cushion within the room, of course, yields before the greater rather than the smaller weight, and being itself formed of a fluid and movable substance, immediately begins to be squeezed out in a stream up the chimney. Thus it is *not* that the light air moves up the chimney to allow the heavy air to come into the room and take its place; but it is, that the light air is driven up the chimney by the greater weight and superior force of the heavier air which is pressing in, and which, in virtue of its weight, is able to overcome a resistance less than its own pressure.

From this cause, namely, the different density of the inside and outside air, a moving current is, to a certain extent, set up within the interior of a house, even when no fire is burning, if only the inside of the house be warmer than the outside, as is almost sure to be the case. This influence, indeed, is so marvellously strong that it operates not only through the chinks of the doors and windows, but also through the unseen pores of the walls themselves. It has been found that as much as eight cubic feet of air per hour pass through each square yard of an ordinary brick wall, when the air within the house or room is four degrees warmer than that outside. When the difference between the temperatures of the inside and outside is larger, the passage of air through the walls is even greater than this. In one experiment, which was very carefully made, it was found that more than one thousand cubic feet of air per hour were driven through the walls of a room of ordinary size, when the temperature of the air was 32° outside and 66° within, that is, when there was as much as 34° difference between the inside and outside air-temperature.

A full-grown healthy man passes as much fresh air through his lungs, in the process of breathing, in the course of twenty-four hours, as would be contained in a room 7 feet square all ways. If it were possible for anyone to live in such a room without changing the air contained in it, there would be 5 per cent., by volume, of carbonic acid everywhere at the end of that time. But human beings cannot continue to live with comfort and safety where there is as much as 1 per cent. of carbonic acid, with equivalent diminution of the proper quantity of oxygen; therefore, if there were no change of air, or ventilation, a single person could not remain continuously for even as much as a fifth part of twenty-four hours, or five hours, in such a room.

In order to secure an altogether wholesome and fresh condition of the air inside a house, it is found that every individual living within it should, in the first instance, have as much as 800 cubic feet of air-space for himself or herself, that is, as much as is furnished by a room 10 feet broad and long, and 8 feet high. In such a room, as a matter of fact, the entire air-contents require to be changed as frequently as three or four times in an hour, to preserve the air at anything like its natural purity. At least 2000 cubic feet of fresh air every hour should be supplied for every pair of lungs breathing within the room.

But, in cold and temperate climates, it is essential that the fresh air thus introduced into a room should not be moving at a higher rate of speed than 100 feet per minute. Any air-movement faster than this would produce the feeling of a cold draught, which would not only be uncomfortable to most persons within the room, but dangerous to some, on account of the difficulty of preserving the proper warmth of the skin where such a cause for the rapid removal of heat was in operation. An opening 1 foot square would receive in an hour 6000 cubic feet of air streaming into it at the rate of 100 feet per minute. An opening one-third such a size, that is, 12 inches long and 4 inches wide, or, if square, of 7 inches each way, would, therefore, receive the 2000 feet requisite for one person, and be sufficient to allow the proper ventilation of the room, if no air whatever passed by any other means than through the opening. Since, however, in actual fact a large quantity does pass in by other means, as through the chinks and crevices of the floor, doors, and windows, and even through the pores of the walls, a considerably less opening, such as a space 12 inches long by 1 or 2 inches broad. would, in most circumstances, be enough for all practical purposes. There must, however, be quite as much open space for outlet in one direction as for inlet in the other, or no efficient current can be secured, and the opening must be smaller or larger accordingly as there is a very great or a comparatively small difference between the temperatures of the internal and external air, or accordingly as the wind itself, moving on the outside of the house, is strong or gentle. An ordinary window-sash drawn down something less than 1 inch, it will be observed, is quite equal to an opening 12 inches long and 2 inches wide.

LESSON LI.

WATER-SUPPLY.

An unstinted supply of good water is of as much consequence to the maintenance of health as an abundant supply of fresh air. It, consequently, too becomes the object of artificial provision in cities and towns; and water, which is collected from rivers and from the rain outside the town, is brought into the houses by pipes, so that it can be drawn from those pipes, or from cisterns connected with them, whenever and wherever it is required for use.

One of the leading characteristics of water, which makes it so serviceable for the office it has to perform in its relations to living beings, namely, its power of dissolving and carrying in its streams various substances that are of a soluble nature, acts in a less desirable way where purity of water-supply is concerned. Water is of necessity collected after it has fallen upon the ground, and, for the most part, after it has soaked and drained through portions of the soil and coursed along in the channels of the rivers, which are themselves scooped out in the soil. It is consequently nearly always charged with various soluble matters that it has taken up during this progress.

Some part of the soluble matters which water takes up from the soil, are simply of a mineral character, and of that part lime is one of the most abundant ingredients. Water, when highly charged with lime, becomes what is termed **hard**, that particular state in which it is less serviceable for the purposes of cleansing and cooking, because it turns soap into an insoluble curd that cannot combine with oily and greasy substances in the process of washing, and is itself less capable of dissolving such other things as the most valuable principles of tea and meat.

Pure water will only take up a very small quantity of lime; so small a quantity, indeed, that the amount dissolved has not the power to render the water actually hard. As soon, however, as the water is charged with carbonic acid, a very much larger quantity of lime is dissolved, and river-water nearly always has in it enough carbonic acid, derived from the air and the soil, to produce this effect. In ordinary river-water, every gallon of the liquid contains six or seven cubic inches of carbonic acid; and water, charged with carbonic acid to that extent, can contain as much as fourteen grains of lime, or chalk, in every gallon, although rain-water, devoid of carbonic acid, would not hold as much as two grains of the same mineral substance. Some well-waters contain even as much as eighty grains of lime in each gallon, and on that account are entirely unfit for domestic use.

The circumstance, however, that it is the carbonic acid which enables the water to dissolve the large quantity of the lime, happily furnishes a very simple and ready means for the removal of the evil. When water is boiled, the carbonic acid is driven off by the effect of the heat, and when it is so driven off, the lime cannot be any longer held in solution, but is thrown down out of the water as a solid, and no longer soluble, substance. The thick fur, which so commonly collects on the inside of kettles, is entirely due to this cause. It is the lime which was at first held suspended in the vessel by the carbonic acid, but which was no longer able to be so sustained when the carbonic acid was driven away by boiling.

When hard water has unavoidably to be used for cooking, or washing, it should hence be first boiled to get rid of its hardness, and be afterwards poured away from its fixed deposits. It will then be found to be sufficiently soft for all practical purposes.

Water takes up from the earth various soluble organic impurities, as well as mineral principles; and, as these are all derived from decaying and putrefying matters that have been recently deprived of life, they are at all times objectionable in water which is used for drink, and, in some circumstances, may be dangerous and injurious in a very serious degree. Some diseases, such as cholera and typhoid fever, are unquestionably communicated by the presence of such substances in water that is taken as drink.

A considerable amount of trouble and pains is incurred to avoid impurities of this class in water that is supplied for the use of large towns. The water is brought from the purest sources from which it can be obtained, and it is filtered through basins and reservoirs to get rid of the grosser particles that can be thrown down by settling, or strained away. The best of the waters that are supplied for the use of the great town of London, on this account do not contain more than two grains of inorganic substance in each gallon, and in that state are quite satisfactory, so far as purity is concerned, for all purposes.

In order, however, that any such degree of purity may be maintained in towns, it is indispensable that the cisterns, into which the water is received before it is distributed in the house for domestic use, shall be looked carefully after, and be thoroughly cleaned out from time to time. If this is not done, the pure water that comes from the mains of the original supply, will be sure to get contaminated by the filth which collects in the cistern, and will be rendered by that means unfit for use.

When water is boiled, the organic impurities which it may contain are either driven off or destroyed by the heat. Wherever there is any reason to doubt the purity of the water, it should, therefore, for this reason also, be boiled before it is employed either as drink, or in the preparation of food.

It is also a very advisable step, in the management of this matter, to have all the water, that is not subjected to boiling and that is yet used as drink, passed through a filter *immediately before it is employed.* As a general rule, soluble matters, that is, such substances as are actually dissolved in water, are not removed from it by filtering. In their dissolved state they pass quite readily through the pores of the filter with the water. But the filters which are now made for domestic use, are constructed of charcoal packed closely within the chamber through which the water has to find its way; and it fortunately happens that charcoal has the property of absorbing organic impurities, and of neutralizing their hurtful powers. If a dead mouse be placed in a wide-mouthed glass jar, and be covered up, or buried in it, in broken charcoal, the jar may be left standing open-mouthed in a room that is ordinarily inhabited without the slightest smell being ever perceived.

In using the filters which are furnished by the manufacturers for domestic use, the water that is passed through should first be allowed to clear itself from all coarser impurities by settling. It is important that as little of cleansing work as possible should be left for the charcoal to do; because, the more actual work of that kind it has to perform, the sooner its pores become choked up by the accumulating impurities which it removes, and the sooner it is in that way deprived of its active powers of purification.

Of the charcoal-filters which are in general use, there are two different forms that are both good in their way. In one, the charcoal is packed into a closed interior chamber, where it cannot be seen, and the water is admitted into this inner chamber through a piece of fine sponge pressed firmly into a round hole, or opening. In this form of filter, the sponge is designed to catch and keep the first and coarser portion of the impurities, and, in that way, to lessen the choking of the pores of the charcoal. In order, however, that this object may be properly secured, the sponge requires to be itself kept very clean. It needs to be taken out every few days and well washed; and to be then carefully replaced in its proper position.

In the other kind of charcoal-filter, the charcoal stands up where it can be seen, in the midst of the water, as a solid black cake, and the water finds its way through the charcoal-block to a glass tube at the bottom. The tube then carries the water down into the closed chamber from which it is drawn for use. In this filter, the choking of the charcoal-pores occurs principally on the outer surface of the block. The block can consequently be kept for a long time in a good acting state, if it be occasionally taken out from its place and well brushed, with a brush that is not too hard, as it is held under the stream of a flowing tap. It is also a good point in connection with this filter that the charcoal-block itself can be changed from time to time, an old worn-out block being readily replaced by a new one. The glass tube at the bottom of the block is fixed in the charcoal, and the block is adjusted into its place, by firmly pressing the lower end of this glass tube into the open socket that is prepared in the earthenware part of the filter, to receive it.

LESSON LII.

HOUSE SEWERS AND DRAINS.

All waste and refuse substance, that remains as the residue of the operations of life, needs to be carried away from towns where people are very much crowded together. In the broad open spaces of the country, in which comparatively few people dwell in one spot, all such matters are very much left to be dealt with by the ordinary processes of nature and by spontaneous decay. The superabundance of fresh air and of vegetable life there suffice to remove the noxious products of such decay as rapidly as they are formed. But in crowded towns this is not the case; and if artificial means were not provided for the prompt removal of decaying substances, the hurtful vapours and effluvia arising from their decomposition would very soon gather to such an extent as to cause disease in the people who had to breathe the air in which they were suspended. Even when such artificial means for their removal are provided, but not to a sufficient extent, it is found that these injurious results do follow, and that diseases of various kinds appear.

The waste substance in towns is carried away by the contrivance which is known as **drainage.** Brick or earthenware channels are made sloping down, under the ground, away from the houses. Pipes from each house lead into these underground channels, or sewers, and the channels themselves run on until they can be made to open out into the stream of some river. Water is employed to wash the waste substance from each house down through the pipes and drains, until it reaches the natural outfall of the rivers, and is by them hurried along towards the still wider basins of the sea, in which all products of decomposition are in the end harmlessly swallowed up by the immense mass of water with which they are made to mingle. The water-supply of towns has on this account to be rendered abundant enough to efficiently perform the cleansing work of washing waste substance through the drains, as well as to fulfil other requirements, such as those of drink and cooking.

It necessarily happens, however, that the mixed liquid and solid substances, which are washed along in the underground sewers, are at all times giving off the noxious vapours and effluvia of putrefaction and decay even as they are being hurried along. The sewers themselves are consequently filled partly by the running stream of liquid, and partly by the poisonous vapours which steam up from it.

If no contrivance were employed to prevent the return of these noxious vapours, it is manifest that the pipes which go down to the sewers out of the house would at all times be charged with them, and would serve as ready passages for their conveyance back. The light vapours would flow up the open pipes to the house as readily as the heavy liquids flow down through them to the drains.

The plan, which is almost universally adopted to prevent this streaming back, or regurgitation into the house of the noxious effluvia of the drains, is the ready expedient of dipping the end of the descending waste-pipes into a small basin or reservoir of standing water, sunk to a lower level than the entrance of the sewers so that the water can only run away into them from its upper surface. The water then acts as a sort of plug, barring the free return of light vapours into the pipe, although it does not prevent the ready outflow of heavy liquid from the pipe into the drain. This arrangement is technically termed **a trap.** When the outlet of the waste water-pipes, soil-pipes, and drain-pipes of a house is furnished with this contrivance they are said to be **trapped.**

But the water-traps, formed where the waste house-pipes enter the underground drains, do not efficiently perform the office of protection for which they are intended, unless there is no backward pressure of any kind acting upon the foul air in the channels of the drains. If, for instance, a strong wind be blowing up the system of drains in the opposite direction to that in which the water is flowing down, the foul gases may be driven back so strongly by the blast that they are forced through the water of the trap, and made to bubble up into the pipes of the house, so as ultimately to mingle with the air which is breathed by the inmates. Or, yet again, if it so happen that the free outflow of the drain itself is impeded and choked, then, when water is poured down any pipe into the choked drain, an equal quantity of the foul air must be forced back from the drain, up through the water-trap and into the house. It is impossible for the choked drain to receive the additional quantity of descending water unless room is made for it by the driving out of an equal volume of the lighter vapour, or gas, from the drain. Very serious, and even deadly disease has been produced in towns and in some crowded districts of London from this very cause.

The effectual protection against the possibility of this form of mischief is what is called **the ventilation of the drain**, that is, the furnishing in the drain itself some secondary opening for the outflow of vapours, which allows them to escape by it more readily than they can by the water-trap. When, with such an arrangement, backward pressure is applied to the vapour, it rushes away through the easiest or least resisting channel that is open to it.

The ventilation of drains is best managed by carrying a pipe of sufficient size from the drain up into the air to a height above that of the neighbouring housetops. Any escape of the noxious effluvia of the drain then takes place into the free, open region of the air, where it is caught and carried away by the wind and destroyed by the oxygen, before it can be breathed by living beings.

The drains of each separate house may be efficiently ventilated by placing an escape-pipe of this character along the side wall of the house in such a way that it stands up, with an open mouth, above the roof. But the discharge-pipes of the house must then have water-traps, both where they leave the rooms of the house and where they enter the sewers or drains, and the ventilation-pipe must be inserted into some suitable part of the system of outflow-pipes between the two traps. In the case of any return of foul gas from the sewer, it then bubbles up through the outer trap, and afterwards streams out of the high, open mouth of the ventilating tube, instead of being forced through the inner water-traps also, and into the house.

One of the most important of the drain-pipes of a house, and also the one that commonly falls most under the management of servants, is the sink-drain, which carries off the waste water from the sink of the back kitchen, or scullery, into the sewer.

The sink-drain almost always has a brass plate, or cap, perforated with small holes, placed over the opening from the sink into the waste-pipe; and under this plate there is a water-trap formed by the dipping of the lower edge of a kind of bell of brass into a cup of water. When this trap is in operation, the waste water has to find its way through the holes of the plate, down the outside of the inverted bell and under its edge, into the cup which leads directly to the outflow. The water, standing in the cup higher than the lower rim of the inverted bell, then acts as the trap for preventing the return of disagreeable effluvia from the sewer into the scullery.

The brass plate with the holes is furnished to prevent large masses of refuse, such as the parings of potatoes, from being washed down into the drain-pipe. All such bulky substances require to be removed from the sink by the hand, or to be got rid of in some other way. If the attempt be made to force such matters down through the sink-pipe, the result must be that its channel will very soon get choked, and unable to carry even the liquid waste for which it is purposely designed, until the drain below has been opened, cleared, and its free passage restored.

It rarely happens, however, in ordinary households, that the perforated cap is not habitually removed from its proper place, and that all kinds of coarse substances are not forced into the drain-pipes. The natural result then follows that the sink-drain gets choked and out of order.

The outflow of the sink-drain is very generally made smaller than it ought to be. But, in consequence of this, more, and not less, care is needed to keep it from choking up. The *perforated cap should never be removed at all*, unless for the purpose of cleaning and examining the water-trap. If at any time the sink-drain begin to act with diminished efficiency, it is the drain beneath, and not the cap above, that is at fault, and nothing whatever can be gained by the removal of the cap.

The choking of an insufficiently roomy sink-drain is often produced by the accumulation in the outflow of the pipe of greasy matters derived from the refuse of food-substances. This cause of choking of the drain may be for the most part avoided by the simple expedient of pouring down into the drain about once a week a pailful of very hot water, in which a good quantity of common washing soda has been dissolved. The soda and the hot water then liquefy and carry off the oily fragments and settlings that are prone to cause obstruction.

The drainage of houses is planned and provided by the builders. But it is commonly carried out in such an imperfect and unsatisfactory way that nothing is more frequently productive of derangement and annoyance in a household than defective action of the drains. On this account, everyone who has to do with the management of a household should have a very clear conception of the cause of such mischief when it occurs, and of the best method of setting about its *permanent* removal. In the case of house-drains, knowledge of this class is also of great practical importance for another reason. Defective action in the drains is a circumstance that may lead to most serious disease amongst the inmates of a house. But it is also a circumstance that very commonly escapes notice until the mischief is done, and until attention is drawn to the evil only by its baneful results. It is most desirable, therefore, that those who dwell in crowded towns, and especially those who concern themselves with the ordering of domestic affairs, should have a ready and keen perception of the presence of such defects, and a clear understanding both of the nature of their cause and of the best expedients for their remedy.

Amongst the scattered population of country districts no organized system can be pursued, either for the supply of water, or for the removal of waste refuse. The inhabitants in such districts have therefore to rely upon other and simpler contrivances.

The water for domestic use is chiefly procured in such circumstances from wells, that is, from circular pits, or shafts, hollowed out more or less deeply into the ground, so that the moisture contained in the surrounding soil may drain into them and become collections of water, which can be thence pumped up for use.

In very deep wells, the water is generally hard, in consequence of having drained into them only after it has percolated through strata of the ground which contain lime and other such mineral ingredients. In shallow wells, on the other hand, the water is more prone to be contaminated with organic impurities, because it is principally derived from the superficial portions of the ground, where vegetable mould and decaying organized matters are abundant. In both instances, however, the same methods as those which have been described in reference to the water of towns may be adopted for the purification of the liquid.

In the removal of the waste refuse from houses in the country, it is chiefly necessary to see that everything which can be the subject of decomposition and decay is at once transported from the immediate vicinity of the house, where the effluvia arising from the process might possibly get mingled with the air that is breathed. In the case of large houses in the country, covered pits or cesspools are prepared in the ground a little distance away from the dwelling, and drains are made from the house into these cesspools, along which the refuse is washed by water. When this plan is adopted, all the precautions for trapping and ventilating the drains, which have been already described in the case of town sewers, must be adopted, and with even an increased amount of thoughtfulness and care, because under this arrangement the vapours generated by the process of putrefaction are imprisoned in the cesspools, and retained there until their disintegration and decomposition are complete. In such cases, also, an additional source of danger is incurred, because the liquid and foul contents of the cesspool are very prone to drain to some extent into the neighbouring ground, and may so even find their way through it into the wells of the water-supply, if these be at all near to the cesspool. Instances have actually occurred in which fatal and obstinate disease has been caused by the contamination of water in wells from a neighbouring cesspool, and in which the cause of the mischief has only been discovered after some of the inmates of the house have fallen a sacrifice. The most scrupulous care must, therefore, at all times be taken to make sure that cesspools are formed only where it is an absolute impossibility that the liquids they contain can in any way pass from them to the well which yields the water for domestic uses.

The natural process by which the decomposition of complex organic bodies is harmlessly effected in the open country, is that they are turned into mouldering substances in the ground; and that the gaseous products, which in that state arise from their decay, are absorbed into the earthy and carbonaceous part of the mould, and held imprisoned there until they are taken back by the rootlets of living plants and elaborated into vegetable structure. When cesspools are formed for the temporary reception of refuse substance from houses, they have to be cleared out from time to time, and the residual and still undecomposed portion of their contents is then spread upon the ground, where it can in this natural way be converted into, or mingled with, the mould, and so be turned to its proper account by the agency of vegetable life.

Precisely the same care that is taken in reference to the contents of the cesspool must be observed in regard to any heaps of dry refuse or manure that are deposited upon the ground. Rain falling upon such heaps soon gets impregnated with organic impurities as it percolates through them, and then it necessarily carries those impurities with it. If, consequently, it find its way into the water of a well, before there has been time for it to give up such noxious vapours to the earthy part of the soil, it necessarily interferes with the purity and wholesomeness of the water. It is for this reason that it becomes a golden rule for the management of houses in the country that the immediate vicinity of such houses shall be kept free from all such accumulations.

LESSON LIII.

BEDS, BEDDING, AND FURNITURE.

Until recent years the bedsteads, or frames which are used for the support of beds, were invariably made of wood, and had sacking-bottoms kept tight by a lacing of rope. The sacking-support of a bed is pleasant to lie upon, but it has the great disadvantage and drawback that it affords ready lurking-places for insects and dirt. Whenever it is employed, it requires constant watching and cleanliness, and to have its corners and edges frequently brushed and wiped.

Bedsteads are now much more generally made of iron, with cross laths of wood, or broad strips of iron, instead of sacking, for the support of the bed. Such bedsteads are of comparatively reasonable cost, are easily kept clean, and have, therefore, a well-deserved reputation. They are not, however, by any means proof against harbouring insect-pests, as is sometimes supposed. Their advantage over wood in that particular is that they are more easily taken to pieces for examination and cleansing.

Brass, which is also now much used for the construction of bedsteads, possesses all the good qualities of iron, with the additional recommendation that it does not require painting, as iron does, to preserve it from rusting. The natural surface of smooth brass is pleasant to the eye, enduring against corrosion, and little prone to cause stain in woven fabrics that are placed in close contact with it. Brass bedsteads are also, generally, stronger and of a more solid construction than iron ones, and, therefore, better bear pulling about.

The best kind of bed that can be placed upon a bedstead, is the **hair-mattress** now generally in use. It is more elastic, and keeps longer in good condition than any other kind of bed, but it is somewhat costly in the first instance, especially when made of horse-hair, the best kind of hair for the purpose. The cheaper forms of mattress have a great deal of cows'-hair in their composition, which does not wear so well. Wool-mattresses are of lower price, and are at first even softer and warmer than hair, but they soon lose their springiness, more easily contract dirt, and get more quickly out of condition, so as to require to be re-made. Flock-mattresses, which are cheaper again than those of wool, are formed of little "flocks," or small bundles of refuse cotton. They are harder and less elastic, or springy than mattresses of either wool or hair, and very soon get into irregular lumps when lain upon. Their only recommendation is their cheapness. Yet another kind of cheap mattress, which is called a palliasse, is stuffed with straw, and is commonly used under a hair-mattress to protect it from the iron laths of the bedstead. Some defence of this kind is indispensable; indeed, the bottom of an iron bedstead should always be provided with a cover of some sort, as otherwise it is apt to stain and injure the ticking of the mattress that lies upon it.

Whatever may be the kind of mattress that is used for the bed, the same handling and management are required to keep it in a good and wholesome state. It should be well aired and turned every day; aired, so that the heat and moisture, communicated to it by the last night's use, may be got rid of, and turned, so that the side which was then next to the bedstead may be brought uppermost. The airing should be managed in the actual sunshine whenever this is possible. Without frequent airing and sunning, mattresses are almost sure to acquire an unpleasant smell from the exhalations they imbibe from the body whilst in use. Nothing removes this so speedily and certainly as sunshine. When this cannot be secured, the next best substitute is a bright fire, combined with exposure to fresh air. Besides the daily airing and turning of mattresses, it is an excellent plan to have them well brushed once a week, with a brush kept for the purpose, along the edges or binding, and in the creases and folds. This is one of the most efficient protections against the lodgment of insects.

Bolsters and pillows are almost exclusively made of feathers, and all articles that are composed of feathers require even more care for their good keeping and preservation than such as are formed of wool or hair. They must be sunned and aired exactly in the same way as mattresses, but, in addition to this, they require to be well kneaded and shaken. When feather-beds are used, this remark applies with even greater force to them. They need to be shaken and worked about thoroughly, as well as aired whenever the bed is made.

Blankets should always be of the best quality that can be afforded, because such last longer, and are much warmer than those of an inferior kind. The better they are, of course, the more carefully they should be used to avoid unnecessary soiling. A good blanket may be kept in use without washing for a considerable time if it be sunned and aired in the same way as the mattresses and pillows, and occasionally shaken in the outer air as well. When blankets are not in constant use during the summer, they must be opened and examined from time to time to make sure they are not attacked by moths. The quilt or counterpane, which is employed outside a bed as a covering to the blankets and sheets, should be as light as is consistent with warmth, and of some substance that will readily wash, because one of the offices of the quilt is to look neat and smooth to the eye, at the same time that it preserves the blankets beneath from being soiled.

The bed-linen employed within the blankets must, of course, be changed and renewed at frequent intervals. The better this is attended to the more easy it becomes to air and purify the rest of the bedding, because the linen of necessity first gets the soil from the body, and only passes it on to the blankets and mattress in the form of vapour and moisture.

The principal parts of the hard furniture of a house, such as chairs, tables, couches, sideboards, presses, drawers and wash-stands, are made of wood. The great thing to be desired in regard to all these is that they should be strong and good, rather than merely *good-looking*. There is no worse economy than the purchase of articles of this class which will not bear the strain of use, and unfortunately this is a thing which can easily be done, because furniture of bad quality can be made to look good to inexperienced eyes by means of mere varnish and paint. The only available protection against being deceived in this way by false appearances is that which may be found in competent advice, caution, and experience.

Such articles of furniture as carpets should be especially chosen with regard to enduring qualities, for carpets must be exposed to great wear however well they are used and cared for. There is no actual economy in the purchase of a cheap carpet when one of a better quality can be obtained, and no more reprehensible instance of the foolish preference of show to use, than when a carpet of inferior quality is bought because it is pretty and gay, although one less attractive to the eye, but of a stouter kind, could be had for the same money.

In rooms where much soiling work has to be carried on, such as kitchens and store-rooms, it is best to avoid the use of carpets altogether. In such situations they can only serve to increase the difficulty of removing the dirt which is unavoidably caused. If a carpet is ever used in such circumstances, it should only be a movable piece, readily taken up when the work is going on, and laid down again when its stress is over and when quieter occupations are pursued.

Curtains add very much to the comfort, as well as to the adornment, of a room. In some cases they are quite necessary additions to a window, from the service they render either in softening strong light, or in screening the interior of the room from intrusive observation. Drapery of all kinds, that is not needed for actual use, or that is not in sufficiently good taste to serve as ornament, is however, more to be shunned than desired. Curtains, like carpets, are quite out of place wherever house-work of a dirty or soiling nature has to be performed. Neat muslin blinds that admit of easy removal for washing, and well-fitting roller-blinds of some dark-coloured material, suitable alike for softening the glare of sunshine and for forming a covering to the window in the evening, when the room is lit from within, are in such circumstances very much to be preferred to more pretensious but less serviceable drapery.

LESSON LIV.

KITCHEN UTENSILS AND EARTHENWARE.

The kitchen appliances are an important part of the furniture of a house, because they are all, more or less, directly connected with the preparation of food. The cooking of necessity suffers from inadequate provision in this department.

Cooking utensils are, almost without exception, made of metal, because they have to bear exposure to great heat. The two kinds of metal principally in use for their construction are copper and iron. Copper is preferred for kettles, saucepans, stew-pans and frying-pans in all cases where its greater cost is not of importance, and where adequate care can be given to keep it in a fit condition for use. It is more durable and more easily polished bright than iron.

Both copper and iron cooking utensils are tinned on the inside to preserve them from corrosion. It fortunately happens that tin is not easily acted upon by water and air at moderate heats, and that it is easily kept bright and clean. It is also readily attached to surfaces of both copper and iron, by an intimate kind of adhesion which amounts to the actual molecular joining together of the two metals where they touch. All that is necessary to produce this union is the placing of the melted tin in direct contact with the copper or iron made very clean and hot. This is readily done, because tin melts at a temperature which is only a trifle more than as hot again as boiling water. Tinned vessels, however, gradually deteriorate from the wearing away of the tin lining, and on that account they need to be tinned over again from time to time. If this be not carefully attended to, a poisonous compound, called verdegris, is apt to be formed in the case of copper, from the corrosion of that metal under the combined influence of air, moisture, and heat; and if any trace of this poisonous compound be left in the vessel when it is used in the preparation of food, it may be productive of great injury to the health of a household. The similar compound that is formed from the corrosion of uncoated portions of iron, is not poisonous in the same way. But it is also soluble in hot liquids, and communicates to them a metallic, ink-like taste, and, in many instances, an undesirable, dark colour. The interior tinned surfaces of cooking utensils are liable to be spoiled by the running of the tin into irregular patches and ridges, if the vessels are exposed to great heat when not containing water, or some other kind of liquid. When this has occurred, it is impossible for the irregularly ridged and wrinkled surface to be kept properly bright and clean.

The cheaper kinds of saucepans and kettles, which are spoken of as made of tin and which have the colour and gloss of tin inside and out, are in reality constructed of thin plate-iron, which is tinned on both surfaces. They are very cleanly and serviceable, but are easily injured by careless exposure to dry heat. They take the heat more quickly and also part with it more speedily than utensils of thicker metal.

The best iron saucepans are such as are lined with a kind of enamel, because this is even a more perfect and enduring protection against the corrosion of the iron by the moisture of the food, than tin. These enamelled linings are so beautifully hard and smooth that their surfaces can be washed as easily and perfectly as a plate of glazed earthenware. The enamelled saucepan, however, requires more judicious and tender handling than tinned vessels, because the enamel is apt to be cracked by a careless exposure to great heat, and, when it is cracked, it cannot be renewed as inside tinning can.

With all kinds of cooking utensils, it is essential to proper management that they should be cleaned as soon as they have been used. The soil which they acquire from the combined influence of the oily and other sticky constituents of the food, and of heat, is very much more easily removed if it be attacked at once than if it be left to dry and harden upon the metal before the cleaning is carried into effect.

Some of the utensils used for cooking, such as paste-and meat-boards, rolling pins, and spoons employed for certain purposes, are made of wood. With these, prompt and unintermitting cleanliness is even more important than it is with utensils of metal, because grease and soil can soak into the actual substance of wood, and, when they do so, may go so far that they cannot easily be got back again. Implements of wood should always be washed with soap, or soda and water, directly after they have been in use, and, if this is properly done, they are easily kept in good order.

The most perfect, in point of cleanliness, of the utensils provided for domestic use unquestionably are those which are made of earthenware and glass. In both, the surface is formed of a hard glazed substance, which is quite impervious to water or grease, and which, therefore, can be washed thoroughly clean with the utmost ease. Both are, however, unfortunately brittle, and can be broken by rough and careless handling; and neither can bear great heat, or even sudden change from heat to cold, such as is produced by pouring cold water into a vessel directly after it has been filled with hot, without risk of fracture. Earthenware, however, is a perfect material for all those cooking processes which are performed before the fire is brought into play; such as the mixing of sauces, puddings, cakes, and other food-preparations. If wood were used for these processes instead of earthenware, it would be almost impossible to prevent the flavour which hung about the wood, after it had been employed for one mixture, from finding its way into the next. The impenetrable glaze of earthenware is also unassailable by any of the acids which are used in preparing food, and which are especially prone to corrode metals.

Earthenware, in some of its forms, is made capable of withstanding a considerable amount of heat. This is illustrated in the case of pie- and tart-dishes, which have to remain in hot ovens during the baking of their contents. The glaze of these dishes in the end gets discoloured by the heat, but it even then continues to perform its work of keeping the ware itself impervious to liquids, so long as its own substance is not actually cracked.

The finer kinds of earthenware, of which are made the plates, dishes, cups, and saucers that are employed in the serving of food and drink after they have been prepared, and glass which is so universally seen upon the dinner table, are amongst the most beautiful and serviceable of the substances employed for the construction of household utensils. In both of them, the object of cleanliness is as perfectly obtained as it is possible for the most fastidious and exacting taste to desire. Everybody is aware how very easily all articles of china and glass are washed after they have been used, and what an irresistible charm well-kept china and glass have when they are set out for a meal upon the table. The brittleness is the chief defect with either ware, and this is unhappily increased in proportion to the delicacy and excellence of the articles: with the notable exception that thin glass bears the sudden application of heat, such as is caused by the pouring in of a stream of hot water, better than the thicker kinds do. The thick kinds crack when hot water is suddenly poured into them, because the thick substance expands unequally as the heat slowly finds its way in, and the parts which are most expanded by the heat are then apt to be actually torn asunder from those that are so acted upon in a less degree. In thin glass, the heat gets through the entire thickness at once, and then all expands equally, without disrupture of the particles. On this account utensils of glass which are intended for heating, such as the retorts used by chemists, are always made very thin.

In the washing up of china and glass, deliberation and care are necessary; and the habit should be acquired of handling in this way articles that are at once so slippery and brittle. Such a habit must of necessity be formed by the exercise of thought and method, but is easily acquired when it is set earnestly and resolutely about.

Knives are, on the whole, the most difficult to keep in good order of all the hardware utensils of the house. They require to be very carefully cleaned whenever they have been used; and, in order to keep the easily corrodable surface of the steel polished and bright, they have to be rubbed with firmness and strength against a knife-board, furnished with a dressing of emery. If, however, the strength be not applied in the right way, very much of it is expended in turning and blunting the edges, and in bending and twisting the half-worn, thin ends of the blades, instead of in polishing their surfaces. The practical result of such clumsy handling is, not only that the knives are unduly worn away and destroyed, but, over and above this, that they are never fit at any time for convenient or comfortable use. It requires a very skilful hand indeed to cut a slice of bread with a knife whose edge is bent at right angles to the general direction of the blade, or to separate a mouthful of meat from a piece upon the plate, when the end of the knife turns up into the form of a bow under the slightest pressure.

Yet, all that is necessary for the avoidance of this annoying form of mischief is that the knife should be held quite flat upon the cleaning board whilst it is moved backwards and forwards, and that it should not be lifted up with a sudden flourish and sweep when it is taken from the board. The movement, by which the metallic surface of the blade is carried along the board, should be firm and smooth, rather than violent, and as little abrupt as possible. The good habit, by which such handling becomes unconsciously, and as a matter of course, practised, is quite as easy to acquire as the vicious and uneconomical one which is more generally adopted, if the object to be aimed at be understood, and if attention be given to the attainment of the right method. As a general rule, however, both explanation and looking after must be expected to be required where a bad habit has to be superseded by a good one.

Knives should never be left wet, or soiled with moist substances, but should be at once wiped dry after they have been used. If this be not attended to, the blade soon gets eaten into with rust, and is then proportionally more difficult to get bright again. The handles of knives also need to be washed and wiped with some care, if they are to look well upon the table, or to be fit for a clean hand to touch.

Various contrivances of a mechanical kind have been devised to facilitate the cleaning of knives. In these the knives are thrust into suitable holdfasts and then rubbed with revolving brushes. It unfortunately happens, however, that all machines require to be carefully and somewhat skilfully handled, if the mechanism itself is not to be put out of gear and deranged. The person who cannot be taught to clean a knife properly in a simple way, would rarely be capable of using a piece of somewhat complicated machinery properly. The real advantage of such machinery is that it enables a larger number of knives to be cleaned in a given time, when it is skilfully employed. Knives are, upon the whole, less likely to have their edges notched and turned and their points bent awry, when cleaned in a machine, than when rubbed by an unskilful hand upon a board. But they are by no means less liable to be worn up quickly, and, with the machine, there is, it will be remembered, the additional risk that it, as well as the knives, may be injured by unskilful management.

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LESSON LV.

CANDLES AND LAMPS.

In the equinoctial region of the earth, the part which lies midway between the poles, or fixed points of its rotation, the terrestrial surface moves round the axis in such a way that it is half the time in sunshine or daylight, and half the time away from the sun and out of daylight. In such situations the night is, therefore, approximately equal in length to the day, and it is also equal in length, or of about twelve hours' duration, all the year round. This part of the earth is therefore called the district of equal nights, or the "equinoctial" region. In actual fact the day is a little longer than the night, because after the sun is below the horizon, light from it is still brought round to the earth's surface, for a brief period, by the refracting or bending power of the atmosphere. That, however, makes only a small and not very important difference in the result.

As human beings do not need to sleep anything like twelve hours out of the twenty-four, it becomes, even in such situations, important that there should be some expedient by which artificial light may be provided to supplement the natural allowance of sunlight. In temperate parts of the earth, this becomes even of more consequence, because there, although the entire year is still equally divided between daylight and darkness, the distribution is unequally made at different seasons, so that at one period the night would be yet more seriously and tediously long if its darkness were not artificially relieved. Thus, in England, at mid-winter, the night is sixteen hours, and the day not more than eight hours, long; artificial light at that season, therefore, becomes almost as important as daylight for the various occupations of civilized life.

Candles, lamps, and gas are the three contrivances by means of which artificial light is supplied. These all depend upon the burning of a combustible fuel in such a way that it gives off brilliant light, in addition to heat, as a product of the combustion.

Candles were, in the first instance, made of animal fat, or tallow. Animal fat is a kind of firm oil, composed, it will be remembered, almost entirely of the two elements, carbon and hydrogen. The constituent molecule, in all kinds of fixed oils and fats, is a complex one, containing in itself several elementary atoms, of which by far the larger number are atoms of carbon and hydrogen, although in each molecule a few atoms of oxygen are mingled as it were incidentally with the carbon and hydrogen.

In all oily or fatty matter there are, however, two distinct kinds of hydro-carbon molecules which can be separated from each other by appropriate processes. The one of these constitutes a firm and almost solid substance, when it is thus procured apart, on account of the tendency of its molecules to cling strongly together. The other constitutes a thin liquid, on account of the absence of such tendency. The firm, almost solid, ingredient of tallow, or fat, is called **stearine**, a word derived from **stear**, the Greek term for suet. The liquid ingredient is called **oleine**, which is derived from **elaion**, the Greek term for oil. In all oils, however, which are fluid at ordinary temperatures, such as olive and sperm oil, as a matter of fact both these ingredients are present. There is more or less stearine dissolved in the oleine; as, in the firmer fats, the stearine is softened by the mingling in with it of a certain amount of oleine. The white sediment, which appears in olive oil in cold weather, is stearine, separated from the oleine by cold. The very thin oil, employed by watchmakers because it is not readily made solid even by cold, is oleine which has had all the stearine taken away from it.

But the solid stearine melts and becomes liquid at 144° of Fahrenheit. Being composed almost entirely of carbon and hydrogen, it readily burns when raised to a yet higher temperature, and it fortunately happens that it burns with the production of a brilliant flame, and that it is, therefore, well fitted for the making of candles. The qualities which render it especially valuable for this purpose, are, first, that it is solid and hardly ever greasy at a temperature of less than 144°; next, that it melts at a heat higher than 144°; and lastly, that it burns at still higher temperatures with an exceedingly brilliant flame. Various other substances, besides stearine, are also used for candles, such as paraffin, spermaceti, and wax. They are all, however, bodies composed in the same way, of carbon and hydrogen, and which, in other particulars, so closely resemble stearine, that, whatever is true in regard to it, is more or less true in reference to them. The stearine which is used in the manufacture of candles, is procured from tallow by first boiling it with quicklime, and then treating it with oil of vitriol to neutralize the lime. By this process all other ingredients of the tallow are got rid of, and the stearine is left virtually pure.

When the wick of a stearine candle is set light to, the small quantity of the inflammable substance, which has been already soaked into the wick, is converted into a vapour by the heat of the flame, and catches fire. The flame then runs down the wick until it comes into communication with the solid stearine at the top of the candle. This it melts, until a small liquid pool is formed, which is retained in the middle, as in a little cup, in consequence of an outer edge, or rim, being kept cool and still hard by the rising up of the air all round to feed the flame above. The flame itself is stopped where it comes into direct contact with the pool of liquid.

The liquid stearine in the meantime is drawn up out of the pool into the wick, as water is drawn up into the pores of a sponge, and, when it reaches the flame, is first turned into vapour by its heat, and then set fire to. In this way it feeds the flame and maintains the burning of the candle.

The flame of the candle consists of an inner, cone-shaped space, which is filled with the as yet unburned vapour distilled out of the wick by the heat, and of an outer shining film or coat. The flame is, in fact, a thin, hollow shell, formed where the inner vapour comes into contact with the outer air. Where the outer air and the heated vapour touch, the oxygen of the air combines with the carbon and hydrogen of the vaporized combustible, and intense heat is developed to appear as flame. The flame, which is thus produced by the union of the oxygen of the air with the combustible vapour, has the form of a cone, rising up to a point at the top, because the heated, and therefore light vapour ascends in its efforts to escape, and because the current of air, which sets in from below, blows and fashions it into that shape as it does so.

But the film of the flame, where the oxygen and the combustible vapours are in the process of union, is shining and bright as well as hot. There is a cause for this, which is one of the most noteworthy and beautiful peculiarities of the process, and the real reason why such combustibles as stearine can be employed for artificial illumination.

The surface of the heated vapour, where it comes into contact with the rising and surrounding current of air, is formed of two things, namely, light and very inflammable hydrogen gas and minute particles of carbon. The carbon, however, being a solid element which is incapable of conversion into the gaseous or vaporous state by mere heat, has, on the instant when it is first separated from the hydrogen, to float in that gas like a fine powder of solid particles scattered through it. The hydrogen gas, being much the most inflammable of the two, catches fire, and, as soon as it does so, the carbon-powder floating in it is made red hot by its burning. The carbon-powder then becomes an infinite number of shining sparks, crowded so closely together that they form a continuous film. The light which is given out from the flame, is in reality the shining of these sparks. The bright flame is thus a layer of exceedingly minute particles of carbon, just separated from their union with the hydrogen, and made so intensely hot by the burning of that gas that they begin to shine before they have the opportunity of mingling with the oxygen. The instant after they come in contact with the air, this mingling takes place. Then they are themselves converted into carbonic acid gas, and cease to shine; but more shining particles come from the decomposing vapour to take their place, and to keep up the flame. The carbonic acid and watery vapour, formed from the union of the oxygen with the carbon-sparks and the hydrogen gas, rise up from the top of the candle in an invisible stream, and scatter themselves through the air.

It is an unvarying rule that it is solid bodies only, and not true vapours, or gases, which give out bright light as well as heat when they burn. Pure hydrogen gas burns with a flame that is so dull it can scarcely be seen. Carbon becomes a bright spark when it is hot enough to burn. Platinum-wire shines with a brilliant, white lustre when made exceedingly hot by the passage through it of a current of electricity from a galvanic battery, even without burning in the slightest degree itself. The lime-light, which is one of the most brilliant artificial lights known, is the shining spark caused in lime when it is made very hot by a burning combustible gas. The electric light is a small fragment of charcoal kept in the same shining hot state by the influence of a current of electricity.

But, of all the solids that can be made to shine as sparks, carbon is the most convenient for the purposes of artificial illumination, because in many abundant compounds, such as tallow, stearine, oil, and gas, it is already mixed with just the due proportion of inflammable hydrogen gas which serves to keep it at a shining heat whilst burning.

In the excellent composite, or stearine, candles which are now made, fine wires of metal are so woven in with the wick as to cause it to turn its end out to the side of the flame as the candle burns. The end is then kept cut off short, by being corroded away where it touches the current of air passing into the film of the hot flame. Candles are convenient to use chiefly on account of their lightness, and the readiness with which they can be carried about. They suffer, however, from the disadvantage that they "gutter" when carelessly carried, or when left in a current of air or draught. This guttering is caused by the firm, cool rim, which constitutes the cup at the top of a burning candle, being broken down, when the flame is driven too much on one side of it by a draught. A gap is made in the rim through which the melted stearine is apt to flow down, until it forms an unsightly and wasteful ridge along the outside of the candle.

The shining hot state into which solid particles can be thrown by great intensity of heat, is technically called incandescence, a word that is derived from the Latin term incandesco, which means to wax very *hot*.

OIL-LAMPS.

There is a very inflammable liquid, composed like stearine of hydrogen and carbon, which is called rectified oil of turpentine, or camphine. If a small piece of cane be put end downwards into a little saucer of this, the liquid not being able to get out sideways through the hard, flinty skin of the cane, is sucked up through its pores to the top; just as the melted stearine is sucked up through the wick of a candle when it is alight. The vapour of the inflammable camphine may then be set light to, where it issues from the top of the cane, and will go on burning like the flame of a candle.

But the rude piece of illuminating apparatus thus formed is a lamp, and not a candle. Whenever an inflammable substance, that is liquid at ordinary temperatures, and therefore does not require to be melted, is sucked or forced up through a wick and burned at the top, the arrangement constitutes what is called a lamp. The lamp only differs from the candle in the fact that it is a liquid substance in the first instance, instead of a solid, that is burned, and that the necessity for melting it at the time of the burning is thus got rid of.

The chief difficulty that had to be contended with in the case of lamps when they were first used, was the getting the liquid combustible sucked up to the top of the wick in sufficient quantity to prevent the wick itself from being burned in its stead. If this occur, the wick gets so hardened and charred at its extreme end that the vapour of the oil can no longer pass out freely to maintain a bright flame. In the improved modern lamps, this difficulty is entirely got rid of by special ingenious and admirable contrivances.

In the best oil-lamps, the combustible oil is no longer left to be sucked up to the top of the wick, as water is sucked up in a sponge, but it is forced up, either within a hair's breadth, or so, of the top of the wick, or above the top, so that it overflows and runs down. There is always, then, such an abundance of the combustible liquid at the edge of the wick that it alone burns, appropriating the entire supply of oxygen, and leaving the wick no opportunity to do so at the cost of a charring.

In the form of oil-lamp which is known as the Queen's reading lamp, and which is very simple and good, the oil-reservoir is placed higher than the wick, so that the oil can flow down to it by its own weight. The oil-reservoir, or cistern, stands at one side of the stem, or foot, and the burner apart, at the opposite side; the two being connected by a transverse tube which carries the oil. In order to prevent the overflow of oil from its high cistern, there is a self-regulating outflow at the bottom of an inner part that fits into an outer cylindrical case, or open cup. There is a small hole there, which only allows oil to flow out of the inner case so long as air can bubble up through it, in consequence of its being left uncovered by the sinking oil, as this is consumed by the lamp from the outer case. When enough oil has flowed down from the inner reservoir to cover that opening air can no longer get in, and on that account the oil ceases to run out until the hole is once again left free by the wasting of the outer oil. Oil can only run out from the inner reservoir so long as air is free to go in to occupy the vacated place. When the reservoir has to be charged with oil, the inner part is lifted from the outer cup and turned upside down; the hole then opens of its own accord, to allow the oil to be poured in, and can be closed by a stop, as the inner vessel is again turned over to be replaced in the case. In this lamp, if the height of the hole, at the bottom of the can, and of the wick be not carefully adjusted, so that the latter stands a trifle higher than the former, the oil will overflow from the wick, and may at length fill the bulb which is placed beneath the tube of the burner to catch such as escapes.

The best of all the forms of oil-lamps is, however, the Moderator. This consists of a cylindrical oil-reservoir, in which a piston-rod carrying a leather plunger can move up and down. The piston-rod and plunger are lifted by turning a toothed wheel acting upon a ratchet, and, when they are so lifted, they push against a spiral spring above, and bring its elastic resistance into play. At the same time the oil contained in the reservoir runs down under the edges of the leather plunger as this is raised. When the winding is finished, the wound-up spring presses upon the leather, the leather presses upon the oil, and the oil under this pressure is squeezed up through a very fine tube which leads to the burner and the wick. The size of the can and tube, and the strength of the spring are so adjusted to each other that it takes four or five hours for all the oil to get squeezed out through the tube. As it is squeezed, it flows gently to the wick, and, having fed it with as much oil as is necessary for the burning, overflows and drips down the outside of the burner. But the drip is caught beneath and carried back to the reservoir, where it can be used over again, when the lamp is once more wound up. As much oil is poured into the reservoir every day as serves to replace the quantity consumed in the last burning. In the Carcel Lamp, which was much used before the Moderator was introduced, the overflow of oil through the wick was maintained by a small pump driven by clockwork.

The principal care required in using the Moderator Lamp is to see that pieces of solid refuse, or dirt of any kind, do not get into the oil in the reservoir, because the tube, through which the oil is driven thence to the burner, is of necessity so small that it can easily be choked up. This tube is so contrived that, by the insertion of a long pin of a tapering form into its interior, the internal and effective diameter is increased, for the passage of the oil, in proportion as the pressure of the wound-up spring becomes exhausted and weak. This is the peculiarity from which the lamp derives its name. The lamp is so planned that the flow of oil, under the pressure of a varying spring, is so moderated, or regulated, as to be steady and unvarying.

With both these excellent forms of oil-lamps, it is indispensable that only oil of a good quality should be used. If impure oil be employed, the lamp will certainly burn badly, however good may be its own form and construction. In impure oils, various materials, not entirely composed of the combustible elements, carbon and hydrogen, are mingled in with them. When used in a lamp, the consumption of these coarser and less combustible ingredients leads to dullness in the flame, in the place of brightness, and very soon also chokes with thick deposits the tubes and pores which need to be open for the free passage of the oil.

All oil-lamps are, however, indebted for their perfection and usefulness to an invention which was made—now nearly a century ago, that is, in the year 1782—by a physician and chemist of Geneva, named Aimé Argand. He constructed a burner, in which a ring-shaped wick was employed, and in which air was allowed to pass to the inside as well as to the outside of the circular film of flame. Very shortly after the invention of this burner, the younger brother of Aimé added to it the tall, circular, glass chimney with which it is now universally used. This chimney causes a very powerful current of air to pass up both inside and outside of the flame; and, under the blast which is so sustained, the combustion is made very brilliant and perfect, all the hydrogen generated by the heat being at once consumed, and all the carbon being turned into bright, shining sparks. The value of the invention is at once seen, if the passage of air, to the inside of the flame, be temporarily interrupted by inserting a plug in the hole at the bottom of the burner. Black smoke or unconsumed carbon immediately rises from the flame.

The chimney which is used with the argand burner, is often arranged to be raised and lowered at will, so as to regulate the stream of air supplied to the flame. In order to get the best results, the size of the burner, the breadth and height of the chimney, and the supply of oil to the wick, require to be all carefully adjusted to each other. In the best Moderator Lamps, this adjustment is now made in such a way that no further alteration can be effected. With a burner which is 1 inch across, the glass chimney needs to be 9 inches high, $1\frac{3}{4}$ inch in diameter at the bottom, and $1\frac{1}{2}$ inch at the top, and to have its contracted shoulder 1 inch above the upper edge of the wick.

The oil most commonly used with the Moderator Lamp is that which is known as colza. This oil is expressed from the seed of the rape, a variety of the Brassica campestris, which is a near relative of the wild turnip and cabbage. The colza-oil plant is very extensively cultivated in France for the manufacture of this oil. The word colza is simply a corruption of **cole seed**, which is another name for rape seed.

A stearine candle, of the size known as six to the pound, consumes 120 grains of stearine in the hour, and should burn from nine to ten hours. The Moderator Lamp, with an argand burner one inch in diameter, gives the light of seven such candles, and consumes in full burning 728 grains of oil per hour. The Moderator then costs three times as much as the candle, but gives seven times its light.

PARAFFIN LAMPS.

The Paraffin Lamps, which are also now in general use, burn an oil that is procured from the distillation of coal-tar, and some other kinds of bituminous substance. This liquid is not properly **paraffin**, as it is sometimes called. It is **paraffin oil**, or tar-oil, which is another name for the same thing. Paraffin itself is a solid substance which can be extracted from the oil, and which is of a very similar nature to stearine. The combustible mineral oils employed for lamps are all very rich in paraffin, and their high illuminating power in the main depends upon its presence. The name is derived from the important peculiarity that this substance is comparatively indolent in its chemical energy, or tendency to combine with other bodies. The word is a modification of the Latin **parum affinis**, which means **small affinity**; affinity being the scientifically accepted term for chemical energy.

The crude oil, procured from coal and bitumen, consists of four distinct substances, which are, however, readily procured apart from each other, because some are driven off into vapour at lower degrees of heat than the rest. The first product which is separated as vapour when heat is applied, is called *paraffin naphtha*, after it has been again condensed into a liquid. It is very inflammable, and its vapour will burn in the objectionable form of a sudden explosion like that of gunpowder. The next liquid produced is the true *paraffin oil*, which is employed for purposes of illumination. A third product is a heavy oil, used only for lubricating machinery; and the fourth and last constituent, which remains when the other three ingredients have been removed, is the solid *paraffin* already spoken of. All tarry and bituminous substances, as well as coal, are primarily derived from the slow and impeded decomposition of vegetable substances, and it is therefore not a surprising matter that in their nature they should so nearly resemble oil, which is also a vegetable product.

Paraffin oil and paraffin contain a larger proportion of hydrogen than most other hydro-carbon compounds; and they both give a whiter and brighter light in burning than other oils, or than stearine. The great recommendation of paraffin oil is its being so limpid and thin that it flows up readily into wicks, by the mere influence of suction, and that, on account of its great inflammability it burns without charring the wick itself. It requires a temperature of 150 degrees to convert it into vapour, and it does not inflame until raised to a slightly higher degree of heat than that.

The danger which attends the use of paraffin oil in lamps is mainly due to the fact that it is sometimes mixed with the highly volatile and explosive paraffin naphtha, because that is a cheaper product than the oil. When this is the case, the vapour is liable to be suddenly generated at temperatures lower than 150°, and to cause a dangerous explosion. There is, however, a very simple and easy way of testing whether the oil has been properly deprived of the naphtha, and is safe for use. If a teacupful of boiling water be mixed with a teacupful of water having something like 60° of heat, its temperature will be lowered to 136°. One teaspoonful of the oil, being floated upon this, will be at once brought to the same temperature, and will then take fire, on the application of a lighted match, if it contain the volatile naphtha, but will not burn at all if it be pure paraffin oil properly prepared for use in lamps.

Paraffin oil is burned in lamps with a flat wick furnished with a brass cap, that has a narrow slit in it only a little wider than the wick. This slit directs a strong blast of air upon the sides of the flame, and secures a clear combustion without smoke. When the lamp is first lit, the flame should be turned down by lowering the wick until it is only just alight along its entire length, and the glass chimney should then be put on. The wick may afterwards be turned up very gradually until the flame assumes its best aspect of clearness and brightness.

In using paraffin lamps, the lamp should invariably be trimmed and replenished with oil in daylight. The reservoir should never be quite filled, and the oil on no account be allowed to come up so high as the metal part of the burner. Any overflow of the oil to the outside of the lamp must be at once very carefully wiped away, so that there may not be any disagreeable smell; and, when the lamp is not in use, the wick should be turned down as far as it can be into the tube of the burner. Paraffin oil is about one-fourth part cheaper to burn, for producing artificial light, than colza oil, when equal quantities are consumed; but in reality gives the same brilliancy of light with less consumption.

LESSON LVI.

GAS.

THE **gas** which is used for the lighting of houses and streets, exactly resembles the combustible vapour formed in the interior of the flames of candles and lamps. It is composed entirely of hydrogen gas and carbon, and is distilled, as a vapour, by heat out of a combustible substance. It is formed out of coal exposed to strong heat under the entire exclusion of air, in the retorts and furnaces of the gas factory.

But there is this important difference in the two cases. The gas which is distilled out of coal, is not set light to and turned into flame as soon as it is driven off from the combustible substance that yields it. It is in the first instance stored away in large reservoirs or gasometers; and is then pressed out from these through pipes, and distributed to the houses and streets in which it is to be finally turned, by burning, into illuminating flame. The coal gas which is thus generated, consists however of four distinct kinds of combustible vapours mingled together; that is to say, four different gases are simultaneously distilled out of the coal.

Quite one-half, or 50 per cent., of the coal gas is pure **hydrogen,** which burns, it will be remembered, almost without giving light. More than another quarter, or 36 per cent., is the compound gas called **carburetted hydrogen.** This is formed by the union of carbon and hydrogen, and yields a comparatively dull, yellow flame, of a very inferior intensity to that which is furnished by street- and house-gas. Another 8 per cent. is a gas which burns with a dull-blue flame. This is **carbonic**

oxide, the compoun l formed when carbon is made to unite with oxygen in circumstances in which only a limited quantity is supplied. These three gases, hydrogen, carburetted hydrogen, and carbonic oxide, taken together, make up as much as 94 per cent. of coal gas. Yet if these three so abundant ingredients are mixed together in the proportions that have been named, the mixture burns with only a dull and useless flame. The brightness of gas-light is hence obviously due to whatever substance it is that constitutes the remaining 6 per cent. of the mixture.

The fourth ingredient of coal gas, upon which the brilliancy of its flame depends, is called **olefiant gas.** It is composed entirely of carbon and hydrogen, and is therefore a compound gas comprising the same actual elements as carburetted hydrogen. But there is a larger proportion of carbon to the hydrogen in it. Each molecule of carburetted hydrogen contains two atoms of hydrogen combined with each atom of carbon. In olefiant gas, there are two atoms of carbon as well as two atoms of hydrogen in each molecule.

Olefiant gas, in its pure and separated state, burns with an intensely white and brilliant flame. Its light-giving power indeed is so great, that when it is diluted with nineteen times its own volume of its less brilliant allies, the hydrogen, carburetted hydrogen, and carbonic oxide, the mixture still burns with more brilliancy than even the paraffin oils. If the four gases, hydrogen, carburetted hydrogen, carbonic oxide, and olefiant gas, be made separately, and then mixed together in the proportion of 50, 36, 8, and 6 measures or parts, respectively of each, they burn, in that state, exactly like coal gas. Coal gas may thus be made by putting together its several ingredients.

The brightly burning olefiant gas is of a very similar nature to the inflammable liquid oil of turpentine and to the solid paraffin. It is composed of the same elements, combined together in nearly the same proportion. A very pure form of paraffin called naphthalin, oil of turpentine, and olefiant gas, are now generally looked upon as being scarcely more than three different forms of the same substance. They are considered to be very nearly the same thing in the solid, the liquid, and the gaseous states.

The argand burner is quite as useful in the case of coal gas, as it is in that of the oil-lamp. Gas is burned to more advantage with it than in any other way. The gas issues in this burner through a number of small holes in a ring, over which the tall glass chimney is placed, and the air rushes up both inside and outside of the circular flame. In order, however, that this burner may give the best attainable result, its several proportions and the supply of the combustible must be as accurately adjusted to each other, as they are in the case of the argand burner of the oil-lamp. If the gas issue from the holes of the burner too impetuously, the brightness of the flame is not so perfect as it should be; and so, again, if the glass chimney be too long, the result is that the flame is smaller and brighter, but that on the whole it gives less light than with the shorter chimney. With an argand burner well-arranged in these several particulars, and fed with five cubic feet of gas per hour, the light equals that of sixteen stearine candles of the size known as six to the pound. But the cost of the five cubic feet of gas is less than a farthing, or very nearly of the same value as the tenth part of a candle, which burns up in an hour. *Gas is therefore sixteen times cheaper than candles where a very strong light is required.* It is also about one-fourth part cheaper than paraffin oil. The chief reason why gas is so much cheaper than most other illuminating agents, is that it is made from coal, which is a natural substance dug out of the ground. The cost of digging the coal, carrying it to the place where the gas has to be made, and manufacturing it at the gas works, is less than the cost of purchasing and preparing an equivalent amount of oil, or stearine.

The chief disadvantage that is connected with the use of coal gas, is that it is usually burnt too far away from the immediate place where the artificial light is required. The gas-burners are almost always placed high up in the centre, or upon the walls, of a room; whilst candles, or a lamp, are placed upon the table where work or some special occupation is being pursued. The obvious result of this is that the gas lights the room rather than the work, and that a great deal of the brilliant illumination is wasted. No one who has become used to the pleasant light of a well-shaded Moderator Lamp for reading and writing at night, can afterwards be satisfied with the distressing and comparatively useless glare of gas flames shining down from some high and inconvenient position in the room. It is quite possible, however, by the exercise of a little thoughtful contrivance, to adapt an argand gas-burner with a reflecting shade, either to a low bracket, or to a movable stand furnished with a flexible tube, so that this disadvantage is entirely obviated. Gas then furnishes the cheapest, most convenient, and most efficient artificial light that can be used.

Where brilliant gas is burned in the interior of a room, it is of considerable importance that additional provision shall be made for ventilation. It must never be overlooked that a single gas-burner, consuming five cubic feet of gas per hour, *spoils as much air for respiratory purposes as fourteen adult women or men.* The unwholesomeness of gas illumination, in insufficiently ventilated rooms, is chiefly due to the fact that, on account of the comparative cheapness of gas, a very much more brilliant light is maintained with it than when oil-lamps or candles are depended upon. A gas flame is hardly more injurious or objectionable than a lamp or candle flame, when the consumption of fuel is the same in both instances. The best authorities, indeed, say that with equal illumination candles produce more impure vapours than gas. The most satisfactory of all methods, for the removal of this objection to the use of bright gas, is the furnishing of each burner with a chimney of its own, in the form of an earthenware or metal pipe, commencing immediately above the flame, and running out in an upward sloping direction, through the wall of the room. A powerful upcast through this pipe is then caused when the gas is alight, and the gas not only carries off its own impure vapours, but also becomes a cause of further purification of the air of the room, by bringing in a powerful stream of fresh air from the outside. The next best expedients are not to use a more brilliant light, when gas is employed, than would be found sufficient with an oil-lamp or candles; to bring the flame down near to the objects that require illumination; and so to adjust a reflecting shade over it as to screen the eye and strengthen the light upon the occupation in hand. This method of procedure has also the further recommendation that it is economical as well as effective. The cheapness of gas is no good reason why it should be wastefully used. The coals from which it is manufactured will be exhausted some day; and will last so much the longer for the many important services they have to render if they be economically, instead of wastefully, consumed.

Some trouble is not unfrequently caused, especially in cold weather, by the gas burning unsteadily and fitfully, and even, now and then, going out. This is almost always due to the condensation of watery vapour within the gas-pipes, in consequence of the employment of the water meter to measure the quantity supplied to the house, and to an improper and unskilful arrangement of the gas-pipes themselves. The pipes should always be laid so as to have a steady and uninterrupted slope up from the meter to the burners. Any vapour that rises from the meter (in which water is employed), and condenses in the pipe under the influence of the cold, then flows down the slope to the lowest part, and can be there allowed to run out of the pipe by turning a tap provided for the purpose. Unfortunately the gas-pipes are generally laid so that there are bends, and up and down waves in them. The water then accumulates in the lowest parts of these bends, and there offers resistance to the free passage of the gas. The gasfitter's clumsy expedient for the removal of this obstacle is to blow through the tube until the water is expelled. The objection to this plan is that it is a temporary relief and not a permanent cure. The water immediately begins to accumulate again, if the same causes remain in operation. The use of the meter which is known as the dry meter, entirely prevents this form of derangement and annoyance.

The explosions which occasionally occur from the accidental escape of gas out of the pipe, are due to the intimate mingling together of gas and air in such proportions that, when flame is applied, the air mingled with the gas can furnish oxygen enough for the instantaneous conversion of the whole into carbonic acid and water. The entire quantity of gas that has escaped, then burns off in a moment, instead of being consumed, in a lengthened and gentle stream, as it draws air gradually to the flame.

Explosions of this character only occur when the gas and air are mingled together in such proportions as enable this instantaneous combination to ensue. The most powerful explosion takes place when eight volumes of air are mixed with one volume of gas. Less violent explosions may occur when the mixture contains as little as from six to eight volumes of air, or as much as from eight to fourteen volumes of air, to one volume of gas; that is, anywhere within those limits. When there are only four volumes of air to one of gas, no explosion can take place; and, with more than fourteen volumes of air to each volume of gas, a flame introduced into the mixture burns with enlarged dimensions and without causing explosion.

The most likely cause to lead to explosions of this character is the tap of the burner having been accidentally and unconsciously turned on without lighting the gas, and having been so left as to go on discharging its stream of unburned gas, until a proportion of something approaching to the one volume of gas to eight volumes of air has been reached. A similar result may also be produced by leaving the tap of the burner turned on, when the gas is turned off at the main; or, in other words, by turning the light out at the main instead of at the burner. Then, when the gas is again turned on at the main, it, of course, issues out in a continuous stream through the unclosed burner. Accidental fractures in the pipe, or in the joinings of the pipe to the tap, may, of course, lead to a similar dangerous admixture of gas and air. A gas-burner discharging five cubic feet of gas per hour into a room containing 1000 cubic feet of air, would turn the whole into a violently explosive mixture in twenty-four hours.

It fortunately happens that coal gas produces a very obvious and disagreeable smell when it is mingled with air in the dangerous proportion of one volume to fourteen. The great rule of conduct in regard to gas, therefore, is never on any account to take a lighted candle into any place where the slightest gas smell is observed; but immediately to open all doors and windows, and then to find out where the escape is occurring. Another precaution, of inconceivable value in regard to gas, is to acquire the habit of always trying whether the tap of the gas-burner has been efficiently turned off before a light is brought near to it after turning the gas on at the main. A very obvious measure of safeguard also is to make it an invariable rule to turn the gas off at the main at night, and to keep it so turned off until gas is again wanted somewhere. There is an additional reason for this practice in the fact that the smaller taps are more easily kept in good order if they be relieved of the pressure from the main at times when the burners belonging to them are not in use.

The principal cause of these explosions with coal gas is the carburetted hydrogen which it contains. Another of the names for carburetted hydrogen is **fire-damp** or **fire-vapour**. It has acquired this designation on account of the dreadful explosions and fires which it sometimes produces in the underground galleries of coal mines, where it is apt to be spontaneously generated by exudation from the coal seams.

Since the combustion of hydro-carbon compounds in flame is, in the main, sustained by the air blast that is furnished, it follows, as a matter of course, that the character of the combustion is liable to be materially modified by altering the supply of air. When some of the air is withheld from the flame of an argand burner, black smoke appears, because some of the carbon then escapes without being consumed. All the air that is available, or nearly so, is under such circumstances required to support the burning of the more readily combustible hydrogen. On the other hand, if more than the usual quantity of air be supplied, the carbon also is consumed before it has had time to furnish its sparkling light by lingering in the red-hot or incandescent condition. This is what is actually accomplished in the arrangement termed the Bunsen burner. A regulated amount of air is first intimately mixed with the gas as it issues from the pipe, and then this mixture of gas and air is burned by the still further addition of air streaming in to the flame in the usual way. The result, however, is that the flame then loses nearly all its illuminating power. The particles of carbon are not made red hot and turned into shining sparks, but are at once changed into carbonic acid gas, without lingering first in the intermediate red-hot state. The Bunsen burner, however, gives more heat than the ordinary gas flame, on account of the increased rapidity with which the carbon is consumed. The non-illuminating flame of the Bunsen gas-burner is therefore used when gas is wanted for heating, instead of illuminating purposes, as in the instance of gas-stoves, and cooking apparatus.

LESSON LVII.

MISTRESSES AND SERVANTS.

In large households the excellent and advantageous principle of division of labour is universally adopted, and the work is economically distributed amongst numerous servants in such a way that different kinds are performed by different individuals.

The servants of primary importance in all households, under this plan of the distribution of labour, are those who are respectively termed cook, housemaid, parlour-maid, and nurse, in consequence of the offices they fill.

The work which falls to the share of each of these classes of servants is pretty well expressed by the names they bear, but the occupation of each servant of necessity varies to some extent in different families, according to the particular circumstances of each. Thus, for instance, the cook invariably takes charge of all that relates to the preparation of food, and of the kitchen and its appliances, but in some families also has to look after the cleaning and arrangement of the hall, and perhaps of one sitting room. The housemaid, where no parlour-maid is kept, attends to all pantry work, waiting at table, and answering the door, as well as looking after the house in general, so far as keeping the rooms, passages, and their contents clean and in order. When there is a parlour-maid in the establishment her share of the service is the parlour and pantry work, and waiting at table, but in addition to this she commonly has the charge of house and table linen, and gives some assistance in needlework.

In large households the parlour-maid is often replaced by a man servant, so far as attendance, waiting, and the charge of the pantry are concerned. In such households two, or even more, housemaids may also be required, of whom one then assumes the superintendence and direction of the rest. In such circumstances the cook, too, commonly has a scullery-maid under her, to take the heavier and rougher part of the kitchen work off her hands, such as all cleaning and the washing up of utensils used in preparing and serving the food.

When many servants are employed in a household, as a matter of course all the varied duties should be performed at the very best—plate, knives, china, and glass, should shine without a speck, and the carpets, curtains, and polished furniture should be without dust or perceptible soil. The same neatness and nicety may be aimed at in small households with only two servants, and with good order and management may be fairly achieved. Indeed where work is not thus thoroughly done, many servants are an evil rather than an advantage, for no single individual in the household is the better for their presence.

When a large family has to be ministered to by only two servants the case is somewhat different. It may then be impossible to have everything kept at the highest point of nicety. Nothing, indeed, more tests the ability and skill of the head of the house than the extent to which this higher standard of completeness is in such cases approached. The best course, in such circumstances, is, for the mistress to aim at the great essentials of cleanliness and order, rather than at extreme finish and nicety everywhere, and to forego some part of her own tastes and liking in these respects, rather than harass herself and her servants by attempting impossible things.

Children are the chief causes of stress of work in households with few servants, but they are none the less the part of the family which has to be most carefully thought of in the matter of attendants. The nurse is the most responsible dependent of the household, because she has the charge of the young children at the tender age when both the health and character are the most largely influenced by judicious or injudicious handling. She needs, therefore, to be worthy of entire trust. No qualification of cleverness in keeping her nursery and the children in good order can possibly make up for the absence of high principle, and a keen sense of her responsibility in those graver matters which touch the health, tempers, and well-being of her charge.

There are certain qualifications, however, which are indispensable for servants of whatever class, over and above those required likewise for the work of the department to which each belongs. Of these general qualifications the foremost in importance are integrity and honesty.

It very rarely happens, at the present day, that servants are guilty of the fault of deliberate theft. But there is a more insidious, and not always recognized, form of dishonesty, unhappily not so rare, which expresses itself in the wasteful use and careless handling of the goods that are supplied by, and that belong to, the head of the household. This fault commonly comes of bad early training, and is generally connected with inconsiderateness on the part of the servant. As nevertheless it is one which is injurious to both herself and her employer, pains and thought should be bestowed to overcome, or at least to lessen it. The best of all influences in this direction is, that the mistress herself set an example of proper thrift and care, taking suitable and well-chosen opportunities to talk kindly with her servants, and to enlarge upon her reasons for doing so. She should point out how right principles and good habits in these particulars are certain at some time or other to benefit them as much as herself, especially if the time ever comes for any one of them to have a house of her own to manage. Few servants who are subjected to a practical education of this kind, will fail to respond to it so far as almost unconsciously to adopt a higher standard of honesty than they may have *recognized* in the beginning.

Candour and truthfulness in words are scarcely less to be desired in servants than honesty in deeds. Here again frankness and the absence of unnecessary reserve on the part of the mistress may help to develop or to strengthen these desirable qualities; they open the only way to a good understanding and to trustful relations between her and her servants; and it is worth while, as a matter of satisfaction and comfort, that these should be established, even if the mutual connection is only to last for a brief period. Without them, the mistress is deprived of her best opportunity of being kind to her servant, and of influencing her for her own advantage. A good mistress desires before all things to show that she feels a real concern for the comfort and interests of her dependents, and is only too glad to avail herself of any reasonable, or seasonable, opportunity to give expression to the feeling. This, however, it is obvious, she can only do when the servant is ready to respond to the desire, and opens her heart to manifestations of kindliness and regard.

The inevitable result of the want of a good understanding of this kind, in which the bond of a common humanity is recognized, must be growing dissatisfaction on both sides, and the exaggeration and perpetuation of shortcomings and failings, instead of their amendment or removal.

After honesty in deeds, such as includes faithfulness in the use of what is entrusted to her, and openness and truthfulness in her bearing towards her employers, order and cleanliness stand next in the list of desirable qualifications in a servant. It is scarcely possible to overrate the discomfort an uncleanly servant can cause in a house. But, in order that cleanliness may be secured, there must be thoroughness in the performance of work. A servant who does not put her heart into what she does, is sure not to perform her task *thoroughly*. When the want of this thoroughness is due to bad early training and to consequent slovenly habits, rather than to perverse determination to neglect what should be done, judicious handling on the part of the mistress may accomplish much in getting rid of the fault. The important point to aim at is patiently but persistently to draw attention to defects, and to give the encouragement of praise whenever improvement appears.

In all work, if any stage be omitted in its proper place, it has to be supplied afterwards when the omission is discovered. But the supply of an omission in that way can only be made at the cost of additional, or in other words of loss of, time. Disorderly servants on this account take longer to do their work than methodical ones, even when they are right-minded enough to do afterwards what they have omitted at the proper time. In addition to which, some dirty or unsightly operation is going on long after it ought to have been completed, a circumstance that often makes a trying demand upon the patience and forbearance of the mistress. For this reason alone, it is well worth the mistress's while to show any good-intentioned servant, even if it have to be done again and again, how to arrange her work in the most methodical and orderly way. As a general rule, however, it will be found that old servants are capable of but little improvement in this respect, while with young ones much may be hoped for.

Good temper is a valuable qualification in servants, which is sure to be highly appreciated by all who come within its pleasant influence. It is a virtue, however, even more imperatively required by the mistress, because with her it means the power to influence and improve the dependents who are under her guidance. To the mistress it is indeed so essential a qualification, that if good temper and patience be not among her natural gifts, she must at least acquire such command of herself as to be able to control irritable and angry impulses, or she will never succeed in ruling her household well. Such control of a naturally quick and impetuous temper will fully compensate for the absence of a gentle disposition, so far as the successful management of servants is concerned; and control is a matter of moral purpose and self-discipline, which all reasonable beings should require of themselves.

Fault-finding is readily borne when the unpleasant business is gone through with gentle words, and with the entire avoidance of hasty and irritating expressions. The mere exhibition of angry impatience and annoyance at some omission or mistake unfortunately arouses a similar state of temper in return. There is, perhaps, no other relation in life in which it is more emphatically true that "the soft word turns away wrath." A mistress should never forget that rebuke of any kind is sure to be disagreeable and keenly felt at the best, and that, therefore, it should be administered in gentle and well-considered words, rather than with angry exaggerations and irritating allusions that increase the smart. For this reason, when a complaint has to be made, or fault to be found, it is always best that the task should be deferred until the first keen feeling of annoyance is past, and until the whole bearing of the case can be referred from impatient impulse to the cooler judgment. The correction of the mistake should also be made as the calm statement of a fact, and not as the urging of a grievance or complaint. It is a most desirable and pleasant thing to have good temper and ready obedience in a servant; but the mistress should bear in mind that the influences which are most sure to call these into play are those moral qualities in herself which are matters of discipline and acquired control; and that these are more reasonably to be expected where the advantages of early education have been great, as with herself, than where they have been small, as is almost certain to have been the case with her servant.

III.—The Economy of Money.

LESSON LVIII.

EXPENDITURE AND ACCOUNTS.

Money has of necessity to be expended for the provision of the necessaries of life; such things as house-shelter, clothes, and food. The indispensable need that there shall be money at command for the acquirement of these is the great stimulus to industry; the great reason why human beings lead active rather than indolent lives. People work to earn money, in order that they may exchange the money they earn for the food that they eat, the clothes that they wear, and the houses that they dwell in.

Money, in itself, is, in consequence, merely the representative of the value which is concerned in the exchange. People work that they may receive food, clothing, and lodging in exchange for their labour. But they take, as the immediate payment for their work, money, which is a token or sign that labour of a certain definite value and amount has been performed; and then they pay the same money in exchange for food, clothing, or shelter of equivalent value. The money is thus the intermediate means, or **medium** as it is called, which enables the transaction to be conveniently accomplished. It is obviously desirable in the highest degree that there should be this accepted medium of exchange. A man works ten hours a day for a week, but during the whole of these six days he wants not one thing in exchange for his labour, but a little of a great many things, and this little, not all in one lump, but day after day. When, at the end of the week, he gets the value of his labour in money, he can so break up and divide the sum total into parts as to be able to pay for all the manifold things that he gets in its stead. In primitive and ruder states of society, the interchange of work for necessities, the thing that has been made for the thing that is desired, is still to a large extent accomplished by direct and immediate exchange. Such exchange is then in that form which is known as **barter.** In more advanced states of civilization, barter is entirely superseded and displaced by operations with money, which are then termed **buying and selling.**

In all civilized lands, money is made of the three metals, gold, silver, and copper, which possess the great recommendation of not being corrodible in the air. If the metal of which pieces of money are made were corrodible in the air, each coin would be continually wasting away and becoming of less value. Another circumstance, which makes the metals, and especially gold and silver, which are distinguished as the precious metals, suitable for conversion into money, is the fact of the largeness of the cost of the material in comparison with its bulk. Gold and silver are so difficult to procure, that small quantities only are added year by year to the amount already in the hands of mankind; the general stock is very large in relation to the additions that are being made to it from time to time. It is this which gives a relatively fixed value to money. If at any time the quantity of the metal of which money is made were very largely increased, money would of necessity be lessened in value in the same proportion. All things are cheap when they are very abundant. Three other circumstances contribute also to mark these three metals as the best materials that can be employed for conversion into money. In the first place, they are of a very enduring nature; they are not easily worn away or destroyed. In the next, they are of very small bulk for the intrinsic value they possess; a given piece of silver will purchase very much more than its own volume, or weight, of most commodities; and a piece of gold of the same size will purchase fifteen times more of anything than the silver. The pieces of gold and of silver can therefore be made of such size as is readily transported from spot to spot. In the third place, these metals are all easily divided into fragments of identically the same weight and dimension, and their division into coins can be so arranged that the silver represents subordinate parts of the gold, and the copper subordinate parts of the silver. As everyone who buys and sells is aware, twenty shillings are of no more value than one sovereign, and twelve pence of no more value than one shilling. Hence, a commodity that is too small to be paid for by a sovereign, can be paid for by shillings or pennies, which practically serve the same purpose as cutting the sovereign into minute pieces.

The sovereign is itself intrinsically of the exact value that it represents, that is to say, it would cost the value which it represents to procure out of the earth as much gold as is contained in the coin. On this account, and because it is one of the rarest and most difficult metals to get, gold is taken for the unit standard of value. A sovereign weighs 123 grains, a number which it is easy to remember, because 1, 2, and 3 are the first numbers in their natural sequence. Four sovereigns weigh 12 grains more than one ounce Troy. The sovereign is, however, not pure gold; there is one part by weight of copper mingled with every eleven parts of gold. This admixture is made because the pure gold is too soft to wear well unless it is hardened. Silver and copper coins, on the other hand, do not contain metal of exactly the same value as that which they represent. They are only artificial tokens contrived to represent fractional values of the golden sovereign. The arrangement is made to prevent these coins from being applied to other purposes. It is clear no one will think of making a silver teapot out of half-crown pieces so long as the same weight of silver can be bought for less than the half-crowns. Coins of silver and copper are always of a higher value when coined than the same metal is before it is turned into money.

The first good rule in the economical employment of money is, **never spend for any purpose more than is necessary.** Everything has its proper value. or market-price, and is, therefore, to be purchased for the money which is at the time the representative of such value. It seems, at the first glance, that it must be a very easy thing to observe this rule. But it is not so in reality, because the value of commodities varies from time to time according to their greater or less abundance; and because very commonly indeed, commodities are not as good as they appear. On this account, there is a very large field for the exercise of caution and judgment in making outlay of money. Observation, forethought, and in addition to these, a considerable amount of training and experience are required to enable anyone to practise a sound economy in making purchases.

Attention has already been incidentally drawn to the danger that lurks in the insidious allurements of bargains. Since everything has its due market-value, as a general rule **bargains are not to be had.** There are some small and not very important exceptions to this statement. But the rule is of such general acceptance that bargains should always be looked upon with suspicion, and be held to be most probably either things which have been furbished up to wear a false face, or that are like sprats thrown out to catch a whale; cheap trifles placed before unwary purchasers to lead them on to some larger and not always desirable expenditure. If the normal and more legitimate purchase of goods requires the exercise of judgment and experience, the purchase of bargains needs a manifold larger expenditure of the same qualities.

Young housekeepers should take every opportunity that falls in their way to improve themselves in the art of making good outlay of money when purchasing the necessaries of life, and to turn to account the lessons of a riper experience than their own. They must acquire as speedily as they can the power of distinguishing good articles from bad, and reality from pretence; and above all things must cultivate an abhorrence of the superficial gloss and display which are intentionally designed to wear the appearance of more solid worth. The great canon in this particular is that empty show must never be preferred to solid value.

Payments of every kind should at all times be made in ready money, so far as this can be done; and it is surprising how far it can be done if the wisdom and advantage of the course are adequately understood, and the mind is made up to bear a little pinch rather than a great waste. Taking credit and running up a bill, is a wasteful operation at all times, as it unavoidably means that the money is, in the end, to purchase less than the proper amount of the commodity for which it is exchanged. But it is a dangerous procedure over and above the waste, because it so commonly leads to the contracting of debt, which is the spending of money before it has been earned. Debt almost always ends in poverty and distress, and very often is in reality little else than dishonesty in a covert form. The first step in debt should be avoided at any cost, and it is manifest that the surest of all ways to shun that first step must be to adopt from the beginning the habit of ready-money payments.

One of the most valuable aids, in the practical training which leads to sound economy in the outlay of money, is the custom of keeping a regular account of expenditure. Everything that is spent should be forthwith entered in a book, with a statement of the article, or purpose, for which the expenditure has been incurred; and then, at regular intervals, such as once a month or so, the several particulars of this daily current account should be sorted out and classified under appropriate heads, as for instance, house-rent, rates and taxes, fuel and lighting, meat, bread, grocery, dairy-produce, clothing, and similar divisions of essential expenditure. Besides these, there should be one final section of the register appropriated to casual and *unessential* outlay. The figures under these several heads should be added together from time to time, and the several results be made the subject of careful study and comparison. The sum totals of the different heads of expenditure for different years should also be examined and weighed. One result of this system of classified accounts is that it promotes the habit of apportioning beforehand the sums that may properly be devoted to each kind of expenditure, and so leads to a judicious and orderly organization of outlay. The practice is one of the most powerful checks upon imprudent and wasteful, not to say unwarrantable, expenditure that can be devised. Few consciences can bear to see shortcomings and mistakes in the matter of spending, registered permanently against them in this formal way, without making strenuous efforts to escape from the reproach.

When no regular account of expenditure is kept, people never know really *how* their money runs away. It is only by means of the quiet and searching after-consideration of such a record that it becomes possible to determine what part of the current expenditure is justifiable and necessary, and what part superfluous and wasteful, and therefore to be in future avoided.

After people have, by labour and industry, provided the immediate necessaries of life for themselves and such members of their family and household as are properly dependent upon them, there generally remains, if their affairs are reasonably prosperous, some superfluous income, more or less, which may be turned to other account, or be disposed of in other ways. If this is expended with the rest, as very often is the case, it is still an interesting and gravely important affair for everyone to know in what manner, and to what purpose, that superfluity has been disposed of.

There are three different ways in which any surplus amount of earnings and income may be spent.

1. It may be bartered away for some purely **useless** object, or purpose. It may be devoted to the procuring of some passing gratification, or enjoyment, that leaves no good result afterwards for the spender or anyone else, in which case the money is simply wasted, instead of being used or turned to account.

2. It may be expended for some hurtful and **mischievous** object. It may be applied to the production of some result which is injurious and bad for the spender, and most probably also for others beside. In that case the money is misused, and turned to bad account. It will be unnecessary to point out that all idle pursuits

and all frivolous and merely sensual pleasures are instances of this mischievous expenditure of money.

3. Or, finally, it may be applied to some **useful** object, or purpose. It may be employed in the production of results that benefit, in some way, either the spender or other people.

Under the arrangements of intelligent and civilized life, there are fortunately innumerable ways open to everyone in which superfluity of money may be usefully expended. But amongst these, two methods stand so prominently forward in dignity and excellence that they should be constantly present to the thoughts of everyone. The first of these is the devoting of money to intellectual pursuits, which strengthen and develop the nobler faculties of the mind, and which foster a high moral purpose in life. No money that is disposed of in this way can possibly be otherwise than well and advantageously expended.

The second of the two most excellent methods of spending superfluous income is the employing it in good and beneficent works for the community at large, or for some particular classes or individuals that are comprised within that community; in the endeavour either to alleviate and remove some portion of the burthen of human suffering and want, or to help on the great cause of human progress and improvement, which finally tends to the same issue.

The division of the classified account-book which is devoted to **casual and unessential outlay** affords to everyone a ready means of determining by retrospection and after-examination the way in which the superfluous earnings and income have been distributed, either as an investment for good, as a payment for mischievous and debasing pleasures, or as a useless, although possibly harmless, expenditure.

LESSON LIX.

EARNING AND SAVING.

The money that is earned by the exercise of labour and industry, is in most instances immediately, or at short intervals, paid to the worker in the form which is termed **wages.** The word **wage** is derived from the French term **gage,** which signifies primarily a pawn or pledge. The wages are in reality the money for which the receiver undertakes that certain work or service shall be performed.

The wages, in such instance, are provided by the person who requires the service, and knows how to turn it to account. They are paid because the persons who render the service must themselves be provided with the necessaries of life—with food, clothing, and shelter—whilst they are performing their work. The money which enables the hirer to make this provision, is primarily derived from the proceeds of some labour that has been previously performed. In other words, it is a part of some superfluity already saved, that has not been spent in an unproductive way, but that has been kept to be turned to account in the productive payment of fresh labour.

The superfluity, which accrues from the product of labour when all cost of the actual necessaries of life, and of some incidental, and perhaps additional, outlay has been met, is that portion of the earnings of labour and industry which is called **savings.** The savings are, in fact, the amount which remains to the good when affairs are so successfully administered that the earnings exceed the outlay. No saving is possible unless this is the case. The person who desires to save must of necessity, in some way, have an income that is larger than his expenditure.

This excess of the income over the expenditure may, it is manifest, be secured in two different ways. It may be brought about either by increasing the income until it is in excess of the expenditure, or by reducing the expenditure below the earnings, whatever they may be. In other words, self-denial, thrift, and simple, inexpensive habits of life, have quite as much to do with saving, as well-directed industry and successful work. There are many instances of persons with large incomes who are the poorest of the poor, because they will spend more than they earn, however ample this may be; and there are no less frequent instances, on the other side, of persons of small income who are in very easy circumstances, because they do manage, notwithstanding the smallness, that the outlay shall be less.

The whole secret of saving, therefore, is in this way resolved into the art of spending less money than is earned, and of keeping the wants that involve outlay within the means.

But when by the exercise of frugality, forethought, and care, the first step towards the establishment of a balance on the right side has been made, it is in every sense well that the second step should follow the first; and this consists in doing all which can be properly done to increase the income.

There is one method by which the income of everyone may assuredly be enlarged. That method is the simple plan of doing the work, whatever it may be that is required, or on hand, in the most thorough and perfect way possible; to leave no stone unturned that can improve the finish and skill with which the appointed task is performed. Since wages are the money-value of work, it is clear that the most direct and least exceptionable mode of increasing the wages must be by rendering **the work more valuable, in consequence of its excellence.** This applies to every calling in life. It is, indeed, a great universal truth which lies at the root of all successful industry and of all prosperous labour.

Taking into consideration, therefore, both ways by which a superfluity of earning over expenditure may be secured, there are four qualities of character and mind that must be looked upon as contributing, before all else, to the desirable result. These are **thrift, sobriety, intelligence,** and **industry.** Without these attributes the chances are very great against success in life. With them few persons, in any kind of calling or pursuit, will fail.

No greater or more lamentable mistake, however, can be made than to conceive that money is the only value that is earned by work. It is not possible to exercise the higher faculties of the mind without realizing by the effort a yet higher kind of gain; without creating another form of saving and superfluity, which, under a proper estimate of results, is of much greater consequence to the individual possessing it than silver or gold. This is the increase of reason, intelligence, high purpose, and moral strength.

Perhaps there is no more important lesson for any young person—of whatever sex, or station in life—to learn at the commencement of a career, than that one which teaches the **sacredness and the intrinsic value of work,** over and above any money-result that it may bring. The wages thus earned are satisfaction and happiness as well as money. Money is but the least part of the gain. A large part of the realized savings are the development of the mental faculties to higher capabilities, and the accumulation of knowledge and experience, which can be quite as usefully employed and be made to do as good service as money. It is a noteworthy truth that people who work honestly and earnestly for work's sake, and look upon money-payment as an incident in the result, receive their due share of both kind of wage; but that people, who work only for payments of silver and gold, are almost sure to miss the higher gain, and to find dissatisfaction and disappointment in the end, however large may be the more material superfluity they can show for their industry.

The first economical duty in life obviously is to provide the necessaries of existence, with some little margin of saving over and beyond. When these have been adequately secured, the right has been fairly earned to give some care to that other kind of saving which is expressed in intellectual and moral gain. The due apportioning of effort to this double aim is a matter that requires judgment and forethought, together with some allowance for the circumstances of each case.

The energy which is devoted to the mere making of money, cannot also be applied, except in a very limited degree, to the development of the mind, and to the strengthening of the character. This is why it so frequently occurs in life that those who have been the most successful in the accumulation of money, are not also the most cultivated and intelligent members of the community. Any extra force that is given to the creation and saving of money, is necessarily withdrawn from pursuits that lead to mental development and power. In all probability, those people find the most satisfaction and happiness in their career, who, when they have reached a moderate competence through industry and care, prefer for the remainder of their days to exchange the rest of their work for intellectual gain rather than money.

At any rate, there is only one thing that can justify excessive accumulation of wealth beyond what is required for necessaries, comforts, and wholesome enjoyments—that is, the wise application and good use of the superfluity. There can be no question as to the fact that large means give large opportunities for doing good. But it will be at once perceived that this doing good implies that the possessor of the means has not neglected the higher faculties of his nature. There will be little inclination for that noble application of wealth, and little knowledge of the way in which such application may be efficiently made, unless a fair share of the attention and time has been directed towards mental and moral culture.

LESSON LX.

INVESTMENT OF SAVINGS.
BANKS, LIFE INSURANCE, AND ANNUITIES.

When people, through the exercise of thrift and industry, have managed to save some little superfluity of money that is not required for current expenditure and present purposes, the consideration arises, what may be best done with the excess. The old plan used to be to tie up the superfluous money in a stocking. At the present day the Dutch farmers in South Africa, who are called *Boers*, and who still lead a rude and primitive life like that of the olden time, not uncommonly put their superfluous gold into their waggon-chest, and carry it about with them wherever they go. Neither of these plans is good, because so long as the money remains in either the stocking or the chest it is of no use to anyone; and it is in the very nature of all the arrangements of civilized society that money should always be turned to some account.

When money that has been saved out of the proceeds of work is taken to pay the wages of workpeople, in order that they may have the necessaries of life whilst they engage in further labour, that saving is applied in a very different way to the tying of it up in a stocking or locking it up in a chest. The money is then at once, and very profitably, used. The hirer of labour, when he makes the advance of money as wages, knows that it will in due time come back, and that it will return to him with increase. He merely lends the superfluity which has fallen into his hands, that it may come back with interest, or increase. In other words, he **invests** the superfluity instead of spending it. This word, which is taken from the Latin **investio**, means to clothe or garnish. Money that is invested, and not merely laid by, is clothed or garnished with increase, instead of being left naked, or of being consumed.

There are various ways in which savings may be invested. With all of them the condition equally applies that the money is employed in the production of an increased return, and that the person to whom the money belongs receives at the least some share of the superfluity created by its use, and which in such instances is called **profit.**

One very convenient method in which savings may at all times be invested, is that they can be put into some **bank.** The bank is a place where superfluous money is taken care of for the persons to whom it belongs. The bank answers first the immediate purpose of making the deposits of savings, which are put into it, safe from carelessness, accidents, and robbery. But, over and above this, when the deposits are made for some stipulated period of time, as, for instance, for an entire year, the banker then uses the money for that time. He either lends it to be turned to account in the payment of wages for productive work, or employs it in some other way, and then divides the profit, or superfluity which is returned from its use, between himself and the person to whom it belongs.

The share, which falls to the owner of the money and which is paid to that owner by the banker, is then called **interest.** Such interest is a part of the superfluity that is made by the productive employment of the money. When people have saved so much that the interest which they thus receive for their savings, is sufficient for their daily wants and current expenditure, they are said to be independent, which means that they are **independent of work,** because they can then, if they please, live without doing any more. The cost of necessaries and comforts for the rest of their lives is then provided beforehand. But people, who live in this way upon their past savings, forego the advantage of the further productive employment of what they have saved. In other words, they then consume the savings of the past, and cease to save any more.

Taken as the expression of a broad general truth, it may be said that the most prosperous communities are those which save the most money. On this account it is to the advantage of the community or state that every-one comprised in it shall work and, to some extent, save. Such a condition of affairs is, indeed, the tendency of all civilization. What is called the **wealth** of any state is, as a matter of fact, the sum total of the savings of its people. This is in some measure expressed by the word itself. The term wealth is derived from the old Anglo-Saxon word **weal,** which meant **well-being,** or a sound condition of things.

It is, hence, a very important matter that banks for the due protection and investment of savings should be within easy reach of everyone. This has been so strongly felt by the Government of Great Britain, that care has been taken to bring a bank for the investment of savings almost to everyone's door. The **Post-Office Savings Bank** takes deposits of money at all receiving houses for letters,—places which are now found pretty well in every village and town,—and undertakes to make payments that may be required out of those deposits, at any office in the kingdom. The depositor has merely to apply for the sum that he requires upon a form provided for the purpose, to state where it is wished that it should be paid, and to produce the book which contains the record of his transactions with the bank.

In the Post-Office Savings Bank the sum of sixpence is added to every complete sovereign that is on deposit for an entire year. This is the interest which is allowed by the bank for the investment, and it amounts to $2\frac{1}{2}$ per cent. per annum upon the sum. The whole of the money which is thus deposited is used by the authorities for some productive purpose, and so much of what is saved out of its use is given to the depositor as the due share of the profit.

No single depositor is allowed to put more than 30*l*. in one year into the bank, or to make any further deposit when the entire sum amounts to 150*l*. The reason for this is that the bank is intended for the benefit only of persons of small means, and to encourage in such the first steps in saving and thrift. When the savings amount to more than 150*l*. they can easily be transferred to banks of another class.

It is scarcely possible to form too high an estimate of the advantage that is offered by this Post-Office Savings Bank. In the first place it is ready to the hand of everyone; and in the next place, it is absolutely safe. The money which is put into it is as secure as if it were put into the Bank of England, which everyone knows is an establishment that is not to break, or to fail in its responsibilities, so long as England itself continues to be. The guarantee for the safe custody of the money and for its return into the hands of the owner when asked for, is no less than that of the Government of the State; that is to say, the entire community, through its ruling authorities, guarantees that all deposits held shall be well taken care of and properly returned. The Government and the State are the security for the safety of the money.

The $2\frac{1}{2}$ per cent. which is allowed for the use of the money placed in this savings bank, is considered, under all the circumstances of the case, to be the proper share that should be paid to the depositor. It is true that a higher rate of interest than this might be made if the money were employed in some other way, instead of being deposited in the bank. But one part of the advantage that results from depositing in this bank, is the absolute safety of the savings so placed. It cannot be too clearly understood that high rates of interest, in a general way, mean risk. The higher the rate of interest that is paid for any investment of money, the greater is the probability that some unlucky day the money itself will be found to have disappeared, having been consumed in some untrustworthy scheme instead of being productively employed so as to yield a return. A comparatively low rate of interest is given for deposits in the Post-Office Savings Bank, because the sums so deposited are absolutely safe, and because it is held above all things important to the persons who take their first lessons in frugality and thrift by making these deposits, that their superfluous earnings shall be secure against all possibilities of loss.

Another of the ways, in which the earliest savings may very wisely be invested, is in making provision against such accidents of life as may put a premature end to all further powers of earning and saving, and against possible infirmity and need in future years. The remark has been well made that the chief difference between the savage and the civilized man is that the savage does not recognize the claims of the future, and does not withstand any impulse towards immediate gratification and enjoyment, whilst the civilized man willingly and gladly encounters present self-denial, and sometimes even pain, to provide for future claims. This is unquestionably true, and furnishes a test which, if it were unconditionally and uncompromisingly applied, would show that there are yet some savages contained in the midst of the most civilized communities.

The effecting of a **life insurance** is a good illustration of the way in which an investment may be made to provide against accident, or to meet future need; and it is an exceedingly interesting illustration, on account of a certain excellent principle which the practice involves. If a woman or man, who is 30 years of age, puts by and keeps in a box 26*s.* every year for 38 years, and then dies at the advanced age of 68, there will, at the time of death, be an accumulated saving of 50*l.* ready for the use of any child or relative, or for any provident purpose that may have been desired. The accumulation of that sum, in such a way, is however manifestly contingent upon the continuance of life for the 38 years. If, however, the sum of 26*s.* be paid to an insurance office every year, instead of being put in a box, the 50*l.* is given at the time of death, even although this take place after only 10, 5, or any yet fewer number of the annual payments of 26*s.* have been made. In this way the child or the relative of a person, who has in reality saved perhaps only 6*l.* 5*s.*, and who then dies prematurely at the early age of 35, gets 50*l.*, just in the same way as if the full number of 38 payments had been completed.

At the first glance it seems somewhat strange that a payment of 50*l.* can be made in return for an investment of savings of but a little more than 6*l.* There is, however, a very plain reason why this can be done. The remaining part of the money is made up by the relatively large number of the people who insure. Each one is charged a higher rate of annual payment than would otherwise be needed for the insurance, in order that the superfluity thence accumulated may be available to make up the deficient deposits of those who have the misfortune to be suddenly and prematurely snatched away from life. The system of life insurance is based upon the benevolent principle that the hale and strong, who live to a mature age, contribute to the provision that is made by the frail and less fortunate. A small extra payment from each is sufficient to secure this provident result, because comparatively many people endure to an advanced period of life, and comparatively few are snatched away prematurely.

The great reason why it is well to insure the life, where there are children or dependents to be provided for, is, that each person may possibly be one of those who, by premature death, is prevented from completing the amount of saving that is proposed. The entire arrangement hangs upon the consideration, that, as each one pays something for the advantage of the affairs of those who die before their time, each one may fairly and honestly receive the benefit for his own affairs in case of premature death.

This opportunity again is brought to everyone's door by the arrangements of the Post Office. In many of the principal offices, insurance may be effected up to the extent of the provision of 100*l.* to be paid at the time of death. Tables are prepared to show how much each insurer is required to deposit according to the age at which the insurance begins. Thus, it will be seen, in these tables, that a woman or a man thirty years old may insure 100*l.* being so paid, by depositing twenty-six pence every month, or 2*l.* 6*s.* 7*d.* every year.

A third notable form, in which some provision for future need may be made out of the savings of the present time, is that which is effected by what is termed purchasing **an annuity**, to begin at a certain age. If a woman, at the age of 30, began to put by 1*l.* 17*s.* 6*d.* a year, at the age of 60 there would be a saving of 56*l.* 5*s.*, irrespective of any increase made meanwhile by the use of the accumulating money. But if, at the age of 30, she began to deposit 1*l.* 17*s.* 6*d.* a year with an insurance office, she may claim, at the age of 60, an annual payment of 10*l.* for the rest of her life, however long that may be, instead of the return of the deposit. A man receives the same advantage on making a yearly payment of 1*l.* 8*s.* 4*d.* for the same 30 years, because he is to a small extent less likely to live long enough to claim the payment. This business also is conducted by the Post Office. A woman or a man may secure an annual payment, commencing at 60 years of age, and not exceeding the amount of 50*l.* a year, on making yearly deposits, according to the scale which is marked in tables that are furnished by the department. The advantage of this form of provision is that at the advanced age a larger yearly payment is secured than the money could otherwise yield.

In these arrangements, again, it is the advantage, it will be observed, of those persons who are learning the first lessons of saving that is provided for. When larger sums require to be dealt with and more ample provisions to be made, there are various insurance and annuity companies ready for the purpose, which impose no limit whatever upon the amounts that are secured either in the form of payments at death, or of annuities on arriving at ripe age.

The official notice of the opportunities which are offered by the Government, in connection with the department of the Post Office, for fostering the habit of saving in the working classes of the community, states for the information of the public, that there is a Post-Office Savings Bank in every town, and in most villages of the kingdom, and that, at the chief of these savings banks, there is also an office for effecting insurances on life, and for the sale of annuities. A list of the places where there are provisions for these purposes, and printed papers giving the most detailed information as to the conditions that have to be observed and the sums that have to be paid, are kept in *all* post-offices. It should be universally known also that any further information desired, over and above that supplied in such papers, is at all times furnished in reply to inquiry addressed, in the form of a letter, to the Secretary of the General Post-Office, at London. The care of the Government to *spread as much information as possible* about these admirable arrangements for the provident investment of small savings, is so great, that such letters of inquiry do not need to be paid, or to bear the usual postage stamp. It is an interesting proof of the extent to which the Post-Office Savings Banks are already used, that they recently contained very nearly 27,000,000*l.* of deposits.

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