MURCHÉ'S SCIENCE READERS

BOOK VI.

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SCIENCE READERS

BY

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REVISED AND ADAPTED FOR USE IN SCHOOLS, WITH A PREFACE BY
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BOOK VI

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PREFACE

Of this series of Science Readers, Books I, II, and III are adapted to Secondary Grades comprising pupils who are in their third and fourth years of school work. Both the reading and the subject matter of Books IV, V, and VI are suitable for Grammar Grades.

At the end of each of the first three volumes will be found a short summary of the lesson. This is a helpful feature. The teacher who reads this carefully, then the reading lesson itself will secure both the needful knowledge and valuable suggestions for a successful method of imparting it.

Books IV, V, and VI have no such summary. None is needed, however, because the lessons themselves are sufficiently full and definite to enable the teacher to find out for herself both the matter and method for the preliminary lessons, whenever such are needed.

All the lessons bearing on Physics should thus be prepared, but many of the others may be successfully used as reading, pure and simple, making them vivid to the children by showing them living illustrations.

Many of the products mentioned in this volume, such as the grains, fruits, nuts, spices, the various stages in the preparation of cotton, linen, woolen, silk goods and leather may be had for the asking from wholesale grocery houses and manufacturing establishments.

When once obtained, they should be properly labeled and made a part of a permanent collection.

The heart of a sheep or beef, "lights," tallow, muscle (meat), bones, may be obtained from a butcher who usually charges nothing, except when bones with meat on them are wanted for each member of an entire class.

L. L. W. WILSON.

Philadelphia Normal School.

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BOOK VI

Lesson I

THE FORCES OF NATURE

THE examinations were over, the class promotions were all made, and the boys (especially those of the upper classes) were looking forward with considerable eagerness to the new year's course, on which they were about to embark. None were more eager and enthusiastic than our young friends the two cousins, whom we have watched with so much pride and pleasure year after year.

"There is just one thing more to do," said Mr. Wilson, "and then we can settle down to work. We must have the desk brought into our new room. Put your shoulder to it, Fred, and push it along. What! can't you move it?" he said again, as he saw Fred exerting all his strength to no purpose. "One or two of you help him. That's right; you can push it along easily now."

Sure enough they did go easily — in fact a little too easily, as boys very frequently do; for Mr. Wilson was just in time to prevent them from running the desk into the glass front of the museum cupboard. This he did by pushing hard at the side of the desk, so as to change the direction in which it was moving, and make it veer off sideways. Then by exerting all his strength, and pushing in the opposite direction to that in which the boys were pushing, he brought the desk to a standstill, and the cupboard was saved. It was all the work of a minute, and the boys scarcely knew what had happened till Mr. Wilson said sternly, "Boys, you should be more careful; I did not wish you to push like that." After they had got to work, however, he thought over the little incident, and determined to make use of it to introduce his first lesson in the new science course.

When the time for the lesson came round, therefore, he began by calling the attention of the class to the moving of the desk, and showed them that in order to move the heavy body at all it was necessary for them to make an effort—to put out their strength. "Whenever we lift a heavy weight, whenever we set a body in motion, whenever we stop a body that is already in motion, we are conscious of exerting some effort. The name which we give to this effort is *force.* We say that force is any cause which tends *to move a body, to change the direction of its movement,* or *to arrest it* when in motion. The particular kind of force which you used just now in moving the desk was your own bodily strength. This we call *muscular force.*

"Fred tried to move the desk alone, but he found his muscular force was not sufficient, and I called upon some of you to help him. Uniting your exertions with his, and pushing in the same direction, you were able to propel the desk along the floor; but as soon as I began to push it at the side there was a change in the direction of its movement, and when I pushed in the opposite direction to you, it had the effect of bringing the desk to a standstill. I was exerting muscular force as well as you: that force, acting on a certain point of the desk, was able to change the course of its movement; when applied at another point it arrested its movement altogether.

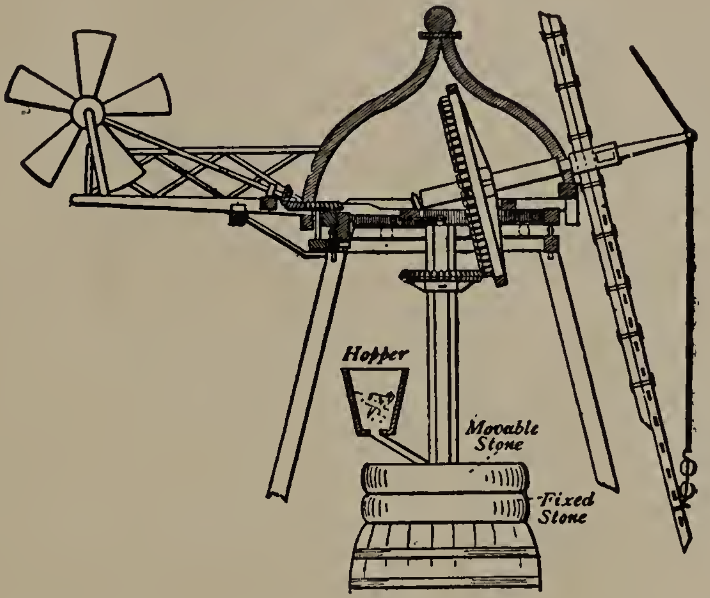
"Man, in his primitive state, learned first to use this muscular force. In fact, the only force he employed was his own muscular force, and that of the animals he subdued. Savage nations of to-day know very little of any other forces beyond this.

"But civilised man gradually learned, and is learning still, that there are many wonderful forces existing around him, and his ingenuity teaches him how to utilise them. His observation soon taught him, for example, that *wind is a force,* and after a time he learned to turn this force to account in various ways. In like manner, things floating down a stream suggested to him *the force of running water,* and this became, through his ingenuity, another powerful working agent.

"In fact, science has taught man gradually to utilise these and other forces, such as *gravity, cohesion, heat, steam, chemical force, magnetism, electricity.* We group these all under the name of natural forces, *i.e.* the forces of nature.

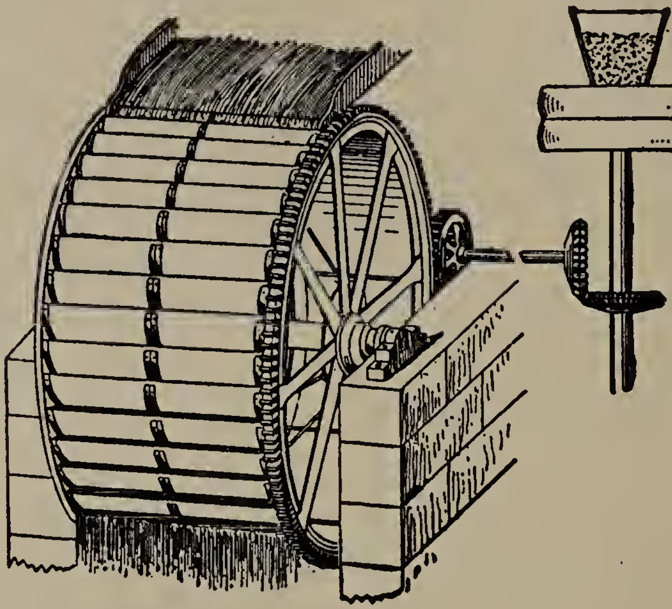
"Let us go back once more to the work of moving the desk. When Fred tried to do it we might have noticed three things: first, he applied force to a particular part of the desk; secondly, he pushed in a certain direction ; and, thirdly, when his own muscular force was insufficient, he increased it by the help of more force, and so did the work. In all our attempts to utilise a force, these same three things must be considered—(1) *its point of application, i.e.* the portion of matter on which it acts; (2) *its direction*; (3) *its intensity* or *magnitude.* In almost every instance a force can only be turned to account after we have altered it in one or other, or all of these particulars, to suit our requirements.

"This will be readily understood by a glance at the construction and working of a wind-mill or a water-mill. The essential part of either mill is the great mill-stone, which has to be set in motion. The force to accomplish this work is, in one case, the wind, in the other the running water. The wind-force acts on the sails, the water-force on the large wheel; and the mill-stone cannot, in either case, move till the force is transmitted to itself.



"But not only must the force be transmitted to the stone, its direction must be changed. The sails of

the one and the wheel of the other revolve vertically, the mill-stone horizontally. The whole contrivance of the mill is to effect these changes in the force, and so render it available for the work of grinding corn.



"We call any contrivance *for transmitting a force* from one point to another, or *for altering the direction of movement, a machine.*"

Lesson II

ELEMENTS AND COMPOUNDS

"This morning we are going to commence a series of simple lessons in chemistry," said Mr. Wilson; and the boys were at once full of curiosity as to what they were to expect next.

"Let us begin with some of the red powder in this bottle. We call it *red oxide of mercury.* I think you know something about it already. I will put a little of it into this test-tube, and heat it over the flame of the Bunsen burner."

"You showed us this experiment once before, sir," said Fred, "and I remember that by heating the solid powder over the flame you can make it give off an entirely different substance—a gas—and that gas is *oxygen.*"

"Quite right, Fred; and oxygen is now passing off from the red powder while I heat it. Our present business, however, is not to collect the gas for further experiment, as we did in our other lesson, but merely to show that it is coming off. How can I do this?"

"If you plunge a red-hot splinter of wood into the mouth of the tube, sir, we shall soon see whether the tube contains oxygen."

"Very well, my lad, you come and do it," said Mr. Wilson. Fred did so, and immediately the red-hot splinter burst into a brilliant glow, thereby proving the presence of oxygen.

"We know, then," continued Mr. Wilson, "that this solid, dry red powder contains the gas—oxygen. But what are these little silvery-white, shining globules all round the sides of the tube? They look like little balls of silver. They are not at all like the red powder we put into the tube. If we continued to heat the powder till we could get no more oxygen from it, and then stood the tube aside for a while to cool, we should be able to scrape off and pour out the shining little balls and leave the vessel empty. Moreover, as we poured out these tiny silvery balls, they would run together and form a little pool of liquid metal—the metal *mercury.* The red powder, therefore, which is a mass of minute solid particles, contains a liquid metal—mercury, and a gas—oxygen. We call it *oxide of mercury.*

"But not only so. It has been found to be impossible, either by still further heating the powder or by any other treatment, to make it yield anything but these two substances—*mercury* and *oxygen.* We say, therefore, that oxide of mercury is a compound substance; it is made up of two other substances—mercury and oxygen. The red powder may be actually made by heating the metal mercury in a closed vessel. The metal, as it is heated, robs the air in contact with it of its oxygen, the two substances unite, and form the entirely new body—oxide of mercury. The process is long and tedious, and takes two or three days to complete. Hence we shall not attempt to do it now. I merely want you to know that it can be done.

"Let us take another experiment. I have here two lumps of chalk. I will place one piece in the middle of the fire, where it is bright and red; and while it is heating we will deal with the other piece on the table.

"I want you to carry your minds back to an experiment I once showed you with some chalk by pouring over it dilute hydrochloric acid. I put the pieces of chalk into a bottle, covered them with water, and added some hydrochloric acid, till little bubbles began to form all round the chalk."

"Oh, I remember, sir," said Will. "You made the chalk give off *carbonic acid gas;* that was what the bubbles were. You collected the gas in a bottle that stood on the table."

"Perfectly true, my lad," said Mr. Wilson; "and I will do the same thing now, in a somewhat different way. As, however, I do not wish to collect the carbonic acid gas this time, but merely to show that it is actually passing off, it will be sufficient to put the chalk into a basin and pour the liquid over it. You can see the bubbles rising up through the liquid. Those bubbles are bubbles of *carbonic acid gas*, and that gas *came from the solid chalk.*

"Your earlier lessons have made you familiar with the fact that this carbonic acid gas is composed of two substances—the solid substance, carbon, and the gas, oxygen. We can make it for ourselves by burning carbon in oxygen. Therefore carbonic acid gas is itself a compound substance.

"Let us next turn our attention to the lump of chalk which I placed in the fire. I will take it out now with the tongs, and stand it on this iron tray.

"As soon as it is cool I will pour some of the dilute hydrochloric acid on it as we did on the other. It does not give off bubbles of gas as the other did, you see. Why not? The heat of the fire has driven off all the carbonic acid it contained, and the substance we have here now is not chalk. It is *lime.* In its present state we call it *quicklime.*

"So then chalk is a compound substance, made of *lime* and *carbonic acid;* and you have already learned that carbonic acid is itself a compound of carbon and oxygen. Chalk, therefore, consists of *lime, carbon,* and *oxygen.*

"Now, instead of dilute acid, I will pour water on this hard, solid quicklime. Watch what happens.

"The water instantly disappears—it seems to be sucked up by the quicklime; tremendous heat is generated; and the solid substance falls away in powder. This powder we call *slaked lime.*

"Let us see what has happened. The solid substance, quicklime, has become united with water. We say that the two have combined to form a new compound substance—*slaked lime.*"

Lesson III

THE BLOOD AND ITS WORK

We have learned, in the course of our lessons, a great many things, in a simple way, about our body, both in regard to its structure and the work it has to do.

We shall now enter into a more detailed investigation of the functions of the principal vital organs.

The body is a sort of living machine. Some part or other of it is always at work, night and day, sleeping and waking; for even when we are asleep the heart and lungs cannot rest—their work must go on, and that work must be guided and controlled by some part of the nervous system.

We know too, from our earlier lessons, that all bodily work is done at the expense of the substance of the body itself. Every act of our daily life, the movement even of a finger, the flashing of a single thought through the brain, or the blinking of an eyelid, destroys some of the substance of the body.

Think of a steam-engine at work. It is the fuel in its furnace and the water in its boiler that enable it to perform its work; but the living machine works at the expense of its own substance. Each little particle of brain, nerve, muscle, or skin, moreover, having once performed a certain work, becomes henceforth worn-out, dead matter. Our body lives by dying—some part of the body is dying every moment. Notwithstanding this constant destruction of the substance of the body, a person in good health varies very little in size and weight for years. The reason for this is that all over the body there is not only constant waste, but constant renewal. Bit by bit, every part of the body—muscle, brain, bone—is not only being destroyed by work done, but, as it is destroyed, it is renewed or built up again in its original form.

This building-up work is done by the blood. If I prick myself in any part of my body, blood will flow. There is blood in all parts of the body, and it is this blood which builds up what has been worn out. It carries all the materials for building the various tissues.

To the muscles it gives certain particular materials for making muscle; to the bones it gives up other materials for making bone; in the brain and nerves it leaves other materials again for making nerve matter, and so on. But it never leaves bone-making materials for building up muscle, brain, or nerve; nor does it take to the ear what is wanted for the eye. It never makes mistakes.

We know that there is blood all over the body. But this blood does not stand in the body, as water stands in some vessel; nor is it still and stagnant. It is a restless stream, incessantly on the move, bringing to every part the materials required for building purposes, and carrying away whatever is no longer wanted there. As long as life lasts this stream of the blood must flow on.

We say that *the blood circulates.* We mean to say by this that it does not merely pass through the body like a stream and disappear, but is carried *round and round, over and over again,* very much in the same way as the hot water circulates through the pipes provided for it in a large building. This thought leads us to the fact that the blood itself circulates through a system of pipes. These pipes commence at the heart, and form a complete circuit through the body and back to the heart again, penetrating into every part except the nails, the hair, and the enamel coating of the teeth. Our hair and nails do not bleed when they are cut.

These pipes have the one common name—*blood-vessels,* although they are not alike, either in structure or the work they have to do.

The heart is the centre of the circulation. Those blood-vessels through which blood flows from the heart to other parts of the body are called *arteries.* Those which bring blood back again to the heart are *veins.*

Both arteries and veins branch out continually into smaller and smaller vessels the farther they get from the heart. Between the smallest branches of the arteries and veins are multitudes of extremely fine tubes, like the most delicate hollow hairs. These are called *capillaries.* The word *capillary,* as you know, comes from a word that means *a hair.*

The constant stream of the blood, then, flows from the heart, along the arteries, into every part of the body. The arteries are continually splitting up into smaller and smaller branching tubes, until at last they become the merest hair-like vessels, the capillaries.

The blood continues to flow through these capillaries, and is collected up, as it flows, by the smallest branches of the veins. The veins gradually unite into larger and larger pipes, as they get nearer the heart, and at last discharge the blood which they carry into the heart itself. From what we have already said about the heart, you will be prepared to learn that it is a hollow vessel. You have all, I suppose, seen a sheep's heart.

It will be sufficient for us now to remember that the heart does the work of a pump. It is constantly at work *pumping blood into the arteries.* From the first dawn of life till death takes us, the heart never rests for a single minute from its pumping.

Lesson IV

PLANTS USEFUL FOR FOOD

Bread Food—The Cereals

In no part of our daily wants do we show our dependence on the vegetable kingdom so much as in our food. All our food is, directly or indirectly, of vegetable origin; for although we eat the flesh of certain animals, the animals themselves derived their support, all through their lives, from plants of one kind or another.

Man, in every part of the globe, makes bread of some kind his staple food; and although the bread is not always made of the same sort of material, it is in every case a vegetable substance.

The cereals, or corn grains, form the bread-making materials for the greater part of civilised mankind. Indeed, they provide the staple food of more than four-fifths of the population of the globe. These grains contain two important food materials—*starch* and *gluten*. One, you already know, is valuable as a fuel-food, the other as a tissue-forming food. The various corn grains owe their relative importance as food-stuffs chiefly to the amount of gluten which they contain.

The gluten of the grain always resides in the outer part, immediately under the skin or husk. This explains why the bran of English wheat, which consists largely of this outer skin, contains more gluten than the finest white flour. Fine white flour is obtained only by sifting the meal through sieves after it is ground. The sifting removes all the particles of bran. Sometimes the meal is used without sifting, just as it leaves the mill, in fact. It is then known as *whole-meal.*

The bran of English wheat contains 16 per cent of gluten; the whole-meal 12 per cent; fine white flour rarely contains 10 per cent. Bread, therefore, made from whole-meal is more nutritious than that made from fine, sifted, white flour.

Reference has been made to the relative value of the corn grains, and it will be well now to compare them one with another. Oatmeal is very rich in gluten; it contains about 16 per cent of this substance—that is, about the same proportion as we find in the bran of English wheat.

Barley and rye contain about the same proportion of gluten as is met with in wheaten flour, but the meal of both is coarser in flavor and color, and the bread made from them, instead of being light and spongy, is heavy and close. Rye forms the chief food of the masses in Russia. In this country it is eaten mixed with other flours.

Rice is remarkable among the corn grains for containing the smallest proportion of gluten. Even in the undressed rice, or *paddy*, such as is eaten by the people of the East, there is not more than 7 or 8 per cent—about half the amount we find in oatmeal; and the grain as we use it contains much less, because, with the removal of the outer skin, much of the gluten is also removed.

Corn contains only about 9 per cent of gluten, but it is richer in fatty or oily matter than any of the other grains. This makes it more easy of digestion, and it is well adapted for fattening animals.

Let us see now how Nature suits her foods to the requirements of the various populations of the world.

Rice forms the food of fully one-third of the entire human race. The majority of these people inhabit the tropical and sub-tropical regions of the world. From the nature of the climate, they are unable to undergo the physical and mental labors which form the everyday life of man in the more temperate climates; hence the bodily wear and tear are less, and the need of nutrition also less. Rice, with its small proportion of gluten, contains sufficient nutriment for such people. The nature of the hot climate, moreover, has a relaxing effect on the system; and rice, containing as it does very little fat, is less relaxing than any other of the corn grains—indeed, it is rather binding than relaxing in its effect. It is therefore just the food suitable for such people and such climates. How remarkable and wonderful then it seems that Nature should supply this special food, so peculiarly adapted to the needs of the people, in those very localities where the other corn grains could not be grown. Notwithstanding all this, Europeans in those countries have frequently been astonished at the enormous quantities of rice which the natives are obliged to devour at a meal, because of the small amount of the necessary gluten which the grain contains.

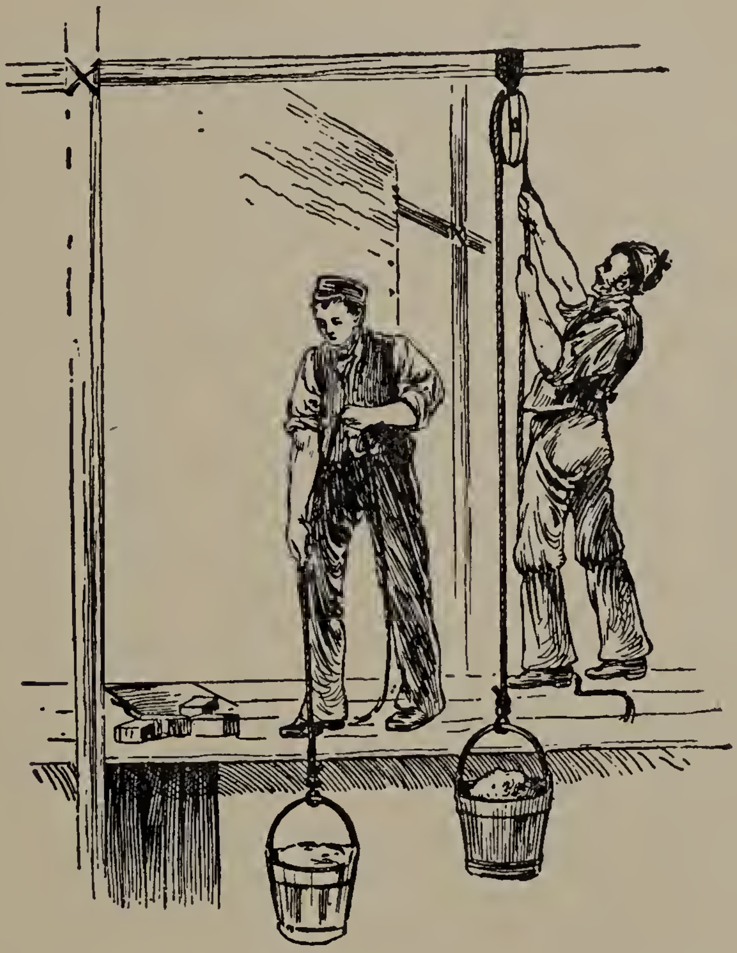
In cold, bracing climates, such as that of Scotland, oatmeal forms the staple article of diet. But this same food would not be found suitable in warmer and more relaxing climates, because oatmeal itself has a decidedly relaxing effect. Here again we see that the special food which Nature provides is a hardy plant, able to withstand the rigor of the climate in which wheat cannot be grown.

Lesson V

MACHINES

"We closed our lesson on the Forces of Nature," said Mr. Wilson, "by glancing at the wind-mill and the water-mill—two contrivances by means of which man is enabled to utilise for his own benefit the natural forces, wind and running water.

"Without attempting to inquire into the precise manner in which these mills accomplish their work, we were content to learn through them a new name

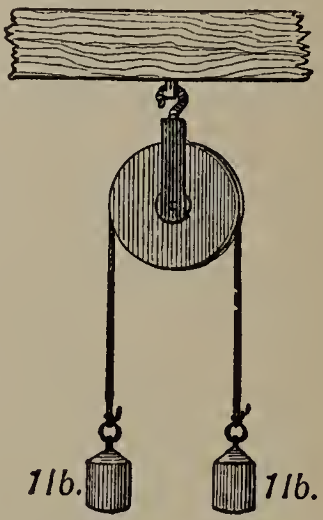


—*machine.* We learned that *any contrivance for transmitting a force from one point to another, or for altering the direction of movement, is a machine.* Let us now take another example.

"A workman wants to raise a basket of bricks or a pail of mortar from the ground to the scaffold at the top of the building where he is working. He does not wish to descend and remount the ladder, so he lowers a rope. One end of this is hooked on to the basket, and he raises the weight by his own muscular force. This force is actually applied at the upper end of the rope, but the rope transmits the force to the basket. Hence the rope *is a machine.* It changes the point of application from the upper end of the rope to the basket at the bottom.

"It is important to remember that the man raises the basket in this way by exerting a direct upward force, greater than the force of gravity caused by its weight, which is tending to pull it downwards.

"We will now proceed with a little experiment. I have here a simple contrivance, consisting of a small wheel with a hollow, grooved circumference, the wheel itself being fixed to a bracket. I will pass this cord round the wheel, and to each end of the cord attach a pound weight. The weights, when left to themselves, balance each other; there is a downward force of one pound on either side of the wheel.



"Now I will hang a small weight (this half-ounce weight will do) on one side. That, and the pound weight together, immediately overcome the weight on the other side; they fall and it rises. We will now return to the workman's scaffold, and imagine such a wheel set up there. Two baskets of bricks, both pulling downwards by the force of gravity, would balance each other; but one brick more in either basket would cause that one to sink and the other to rise.

"Suppose the man were to unhook one of the baskets;

how could he manage to keep the other in its original position?"

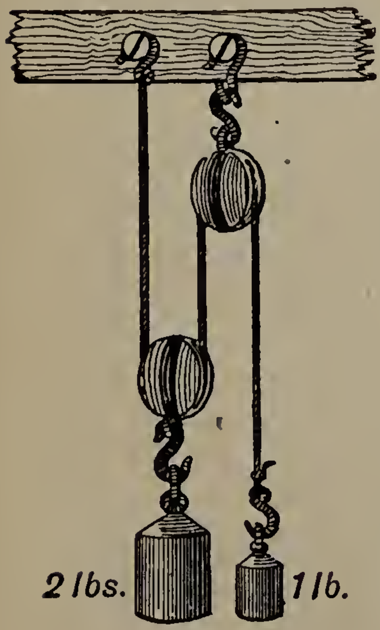
"To do this he would have to pull downwards, just as the basket did, and with the same force, sir," replied Fred.

"Exactly; and if he pulled a little harder, what would happen then?"

"I suppose the basket on the other side would rise, sir."

"Yes, Fred, it would; that is to say, the man by pulling the cord downwards over the wheel, exerts an upward force on the basket at its opposite end, and causes it to rise. In other words, the wheel and the cord constitute *a machine,* for they change the point of application, and they alter the direction of the force.

"Workmen usually employ this means of raising their materials to the scaffold, because it is easier to pull downwards than it is to lift the entire weight upwards.



"It frequently happens, however, that the men have to raise heavy masses of material (such as great sheets of lead, or coils of leaden pipe) which it is impossible for them to lift from the ground with only their own muscular force. We will see how they do it. Let us return to our wheel and cord experiment. I will take one part of the cord, as it hangs over the fixed wheel, pass it round and under a similar loose wheel, and then fasten the end of it to the beam above. Here we have a contrivance consisting of a fixed and a movable wheel, with the same cord passing round both. When I pull at the other extremity of the cord, the second wheel actually moves up as the cord is pulled down.

"Now, we will hook a 2 lbs. weight to the movable wheel, and a 1 lb. weight to the free end of the cord. When left to themselves the two weights balance each other. It would be just the same if we used 4 lbs. and 2 lbs., 100 lbs. and 50 lbs. They would balance, and the slightest additional weight hung on the end of the cord would cause the movable wheel with its heavier load to rise.

"This is the kind of contrivance used for raising heavy weights. With such a contrivance fixed to the scaffold, men are enabled, by pulling downwards at the end of a cord, to raise a heavy mass of material, which they could not possibly lift without help. Such a contrivance is *a machine*. The men apply the force at one end of the rope; it is transmitted to the other. The force is applied downwards; the heavy mass is raised upwards. The small force exerted by the men is increased in magnitude or intensity, so that it is enabled to raise a much heavier weight than it could without such a machine.

"We employ a vast number of machines to do an almost endless variety of work. Some of them are very complicated. But however complicated they may appear to be, they are all found on examination to be made up of a few simple contrivances, which have been invented for the purpose of altering force in one or more of the ways we have mentioned."

Lesson VI

NATURE OF AN ELEMENT

"The other day I tried to make clear to you the meaning of the term *compound*," said Mr. Wilson, "and we must go back this morning to the experiments I showed you then. In our first experiment we made one compound body—red oxide of mercury—resolve itself into two distinct substances—the liquid metal, mercury, and a gas, oxygen.

"No one has ever been able, by any treatment, to split up either of these substances into simpler kinds of matter. It is impossible to get anything from oxygen but oxygen, and it is equally impossible to get anything from mercury but mercury. Hence we say that oxygen and mercury are *elements.*

"In our second experiment we separated chalk into two distinct substances—lime and carbonic acid gas. The solid lime can be further split up into oxygen and a metal called calcium. This calcium, which is a metal somewhat resembling sodium, cannot, by any kind of treatment, be made to yield anything but calcium. Hence we say that calcium is an element, and lime is an oxide of calcium.

"The other constituent of the chalk—carbonic acid gas—is, as we already know, a compound in itself. It is composed of the solid substance, carbon, and the element, oxygen. Carbon is a simple body, and will yield nothing but carbon. It cannot be split up or separated into anything else. Thus we know that carbon is an element.

"If you will now carry your mind back to some of our former lessons, I think you will be able to remember a very simple-looking substance, and, moreover, one of the commonest substances in nature, which is a compound, formed of two distinct bodies."

"I suppose you mean water, sir," said Fred; "for I remember that water is formed of the two gases, hydrogen and oxygen. Hydrogen is an inflammable gas, and when it burns in oxygen or in the air, the product of the burning is water. Water, therefore, must be a compound body, made of the two substances, hydrogen and oxygen."

"Yes, Fred, you are quite right; and water was the very body I had in my thoughts. Now, as regards one of its constituents—oxygen—we already know that it is an element. Hydrogen, likewise, is a body in its simplest form. Nothing can, by any means, be got from hydrogen but hydrogen; and we therefore place it among the elements.

"The chemist has been able, by experimenting on various substances—solid, liquid, and gaseous—which exist in, on, and around the earth, to find about sixty-four distinct elements or simple bodies. That is to say, the earth and all it contains are built up of these sixty-four elements.

"Some of these elements, such as oxygen, hydrogen, nitrogen, and chlorine, are gases; mercury is a liquid, but most of them are solids.

"Among the solid elements, iron, silver, gold, copper, tin, lead, zinc are metals; carbon, sulphur, and phosphorus are known as non-metals. In all there are forty-nine metallic elements, and fifteen non-metallic elements.

"These sixty-four elements combine to form compounds much in the same way as the twenty-six letters of our alphabet combine to form words. Nearly every word we use is a compound of two or more letters; and the letters make totally different words according to the manner in which they are combined. Just in a similar way the chemical elements may be called the alphabet of chemistry; and they form various compounds as they vary in their mode of combining.

"Thus, we might say that the red oxide of mercury is like a word of two letters—mercury and oxygen. Water, a compound of hydrogen and oxygen, and carbonic acid gas, a compound of carbon and oxygen, are two similar words. Chalk would then represent a word of three letters—calcium, carbon, and oxygen; and slaked lime—calcium, hydrogen, and oxygen—would be another similar word of three letters.

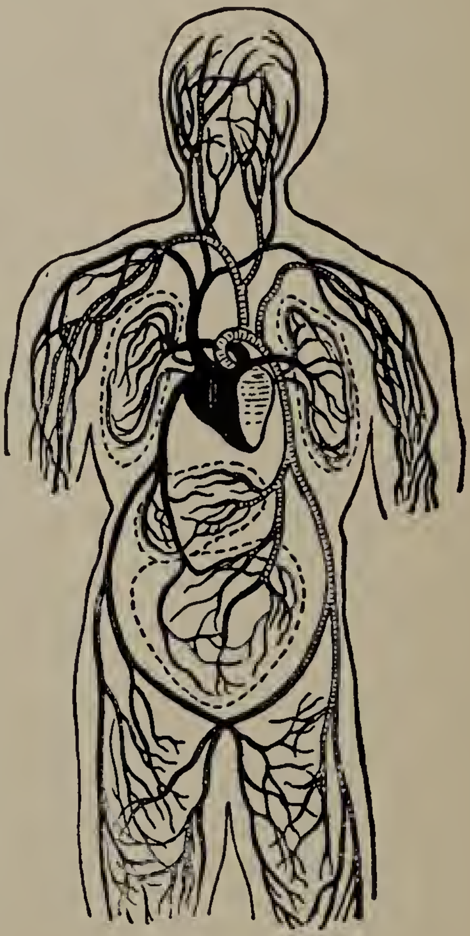
"As we learn to read and understand these words better, we shall find that some of them are very long, and, like the hard words in our books and newspapers, contain a great many letters."

Lesson VII

The Blood-Vessels of the Body

Our lesson on the blood showed us that fluid coursing through the body in tubes or pipes, which are called *blood-vessels.* We shall now proceed to examine these vessels, beginning with the *veins,* because we know something of them already. They are the vessels which can be seen as dark purplish cords just beneath the skin; they convey the blood back to the heart. We may easily trace them upwards from the hand, as they unite into larger and larger trunks. We might compare them to the numerous tributaries of a great river, all bringing their contributions to swell the main stream.

In all these vessels the blood is perpetually flowing one way—from the smaller into the larger trunks, and so on to the heart. We cannot see the blood flow along our veins, but a microscope shows it very clearly in the thin transparent web between the toes of a frog.



The veins, as seen just beneath the skin, are of a dark purple color. The blood in them is not bright red blood, such as we usually see, but purple — almost black. It is, in fact, loaded with impurities—the waste, worn-out, dead particles of muscle, nerve, brain, and bone, which the blood in its course has caught up, and is carrying away to the heart. These waste matters could not be allowed to remain in the body. They would be as injurious there as a heap of rotting, putrefying refuse matter would be in and about our homes. Their very presence in the blood has changed its character and appearance; it was bright red blood once, now it is dark purple and impure. It is the duty of the veins to collect all this impure blood, and pass it along through larger and larger trunks, and finally discharge it into the heart.

Let us turn next to the *arteries*—the vessels which carry blood away from the heart. Their great main trunk, which springs directly from that organ, is a pipe rather larger than one's thumb. This sends off branch after branch, each branch dividing again and again into smaller and still smaller ones, until they are at last as fine as the finest veins.

But the blood which passes from the heart along these channels is good blood, free from impurities, and loaded with materials for renewing those parts of the body which have been worn out. Its color, too, is changed to a bright red.

You would form a very good notion of these arteries if you could picture to yourselves the water-supply system of some large town. Trace, in your mind, the course of the water from the central pumping station, first along the great main, then into the pipes leading from it under the roadways, then again into smaller and smaller branching pipes leading to the streets and lanes, and finally into the delivery pipes in connection with the individual houses.

The veins and their work might be as clearly illustrated by comparing them to the drainage system of the same town. The water company's pipes bring pure, fresh, wholesome water to the houses; but this same water, after performing its office, finds its way, polluted with filth and all sorts of impurities, to the drain. The drains from the various houses run into larger pipes, and these into still larger ones, until the great main sewers are reached, and these carry the filthy stream away from the town, where it can do no harm. The arteries are usually embedded deep in the flesh, and cannot be seen. This is a most providential arrangement, because if an artery be cut or wounded, it is a very difficult matter to close up the wound and stop the bleeding. The person is in extreme danger of bleeding to death. Packed away deep in the flesh as these vessels are, they are comparatively safe from injury.

If an artery were removed from the body of any animal and examined, it would be found to be a plain, simple pipe, through which water might be poured from either end. If a vein were removed, and treated similarly, we should find an important difference in this respect. It would be easy enough to pour water through from one end, but if we tried to do so from the opposite end, the pipe would become closed or stopped up. The reason for the stoppage would soon become apparent if we slit the pipe open. The walls of the veins are provided with little bags here and there, which stretch across the tube with their mouths opening all in one direction — towards the heart. These little bags or pouches form *valves.* They allow the blood to flow readily past them on its way to the heart, but should it, from any cause, attempt to flow backwards, it would fill up the little pockets, and swell them out till they blocked the way altogether. There are no valves in the arteries.


A VEIN SLIT OPEN.

We now clearly understand that in every part of the body there must be two sets of vessels—arteries to bring pure fresh blood, veins to carry it back to the heart contaminated with impurities. Every artery ends and every vein begins in a network of still smaller hair-like tubes—the *capillaries.* So close are these tiny vessels placed that it is impossible to prick the skin anywhere without piercing the walls of some of them, and causing the blood to flow.

The walls of the arteries are stout and muscular; those of the veins are thinner and somewhat flabby, but the capillaries have the thinnest of thin walls.

It can only intensify your feelings of wonder and surprise when you learn that, in the horse the complete round of the circulation from the heart, along the arteries, through the capillaries, and back by the veins to the heart again, *is accomplished in about half a minute.*

Lesson VIII

PLANTS USEFUL FOR FOOD

Other Breadstuffs

The bean, pea, lentil, lupin, and vetch are included under the common name of pulse. They form a most useful class of breadstuffs, and enter largely into the food of both man and animals. The usefulness of pulse is due to the large amount of glutinous or tissue-forming matter which they contain; 100 lbs. weight of pulse averages about 24 lbs. of gluten.

The gluten of pulse is known as legumin. It resembles the gluten of oats rather than that of wheat. Pulse meal, although it is highly nutritious, will not make light, spongy bread; and in the countries where it is most eaten it is prepared in the form of cakes. The Scotch people, you remember, make their oatmeal into cakes; this, however, is not because they prefer close, heavy cakes to ordinary bread, but because the oatmeal will not make up into light, spongy loaves. Pulse meal alone would not make a good food, as it contains a very small percentage of fat. This perhaps will show you that it is no mere whim or accident that leads people to prepare a dish of bacon and beans. The fat of the bacon gives the very thing that is wanting in the beans, and the two together make an excellent food. On the same principle a mixture of beans and oats is found to make the best food for horses which are engaged in laborious work. The oats contain a large proportion of tissue-forming matter (about 16 per cent), but they contain in addition an abundance of fat, which makes up for the deficiency of that material in the beans. On the other hand, the proportion of tissue-forming matter is much larger in the beans than in the oats. Thus a mixture of the foods gives more strength and endurance than either could give separately.

The common French or kidney bean is mostly eaten in the green state in this country. These beans are natives of India, but they are now grown in most temperate climates. The useful haricot-bean is simply the ripe seed of the French bean.

The broad or great bean is not only grown largely for use as a green vegetable, but it is also often used, in the ripe state, for feeding horses. In this state the beans are commonly known as horse-beans. Lentils make excellent soups; and they also yield a highly nutritious meal, from which is prepared a food for infants and invalids.

There is a small kind of pulse grown in the

East, and known as *chickpea* or *gram*. Travellers about to cross the deserts carry with them a supply of these peas, roasted ready for use. Heavy, bulky food would be an encumbrance; these peas are light and take up little room, while they are said to be more life-sustaining in their properties than any other food.

In Lombardy immense quantities of lupins are grown, and the meal which their seeds yield forms the staple food of the common people. The pea-nut or ground-nut belongs to the pulse family; and in the tropical regions where it is grown it forms a staple food for both man and animals. These nuts contain 50 per cent of oil. The English import ground-nuts into their country for the sake of the oil, which is worth from twenty to thirty shillings a ton, and is employed in soap-making. The residue left after expressing the oil forms a valuable oil-cake, worth from £8 to £10 a ton.


THE SAGO-PALM.

Sago, as you know, is obtained from the pith of the sago-palm. The tree, when mature, is cut down, and the pith, after being extracted, is washed in water on a sieve. The meal, which is mostly starch, settles at the bottom of the water, and is collected by draining off the water and drying in the sun.

The tree is cultivated widely throughout the tropics, but its natural home is New Guinea and certain parts of the coast of Africa. Here it forms the staple food of the natives, who bake the meal into a kind of bread or hard cake. Its importance to them as their chief breadstuff is seen from the fact that a fully-grown tree yields about 700 lbs. of sago-meal, while it is said that a healthy man can live on a diet of 2½ lbs. of the meal daily.

THE BREADFRUIT TREE.

The natives of the Pacific and Indian Archipelagoes depend almost entirely upon the breadfruit tree for their food supply. It yields a fruit which is to them what our wheaten loaf is to us. It is their bread.

This is a most wonderful tree, and affords a splendid illustration of Nature's lavish bounty in these regions. The fruit grows in such abundance that each tree bears and ripens crop after crop in succession during the year. Three trees are said to be sufficient to support a full-grown man for eight months out of the twelve. The fruit contains a porous and mealy pith, enclosed in a tough outer rind. It is usually plucked before it is quite ripe, and baked on hot stones. It tastes, when cooked, very much like wheaten bread.

LEAVES AND FRUIT OF THE BREADFRUIT TREE.

THE BANANA TREE.

To the natives of Central America, the West Indies, and other tropical parts, the banana or plantain is an equally important tree; it supplies their staple food. The fruit which it yields contains within its outer rind a mealy substance, which, when dried in the oven, resembles bread both in taste and composition. It is the bread of the people there.

In composition it is less nutritious than some of the other breadstuffs already named, as it contains only about 2 per cent of gluten mixed with about 20 per cent of starchy matter. The average daily allowance of food for a laborer in those regions is about 2 lbs. of the dry banana meal, with the addition of a quarter of a pound of fish or meat. This is said to afford ample sustenance. A single tree bears from 40 to 70, and sometimes 80 lbs. weight of fruit. Indeed no plant in the world is more prolific in its products than this tree. It has been calculated that 1000 square feet of land will produce,

LEAF AND FRUIT OF THE BANANA.

on the average, 462 lbs. of potatoes or 38 lbs. of wheat; but that same space will yield as much as 4000 lbs. of bananas, and in a shorter time.

The date is justly called the "bread of the desert."

DATE-PALMS.

Its home is the northern part of Africa. Wherever a spring of water exists in those burning sandy deserts, the date-palm is sure to be found. Where every other crop fails, this tree will flourish in spite of the drought.

The people of the oases dry and pound the fruit into a kind of cake, and it becomes the bread of nineteen-twentieths of the population for the greater part of the year.

LEAF OF THE DATE-PALM.

FRUIT OF THE DATE-PALM.

Lesson IX

THE LEVER

"Our lesson on the Forces of Nature showed us one important difference between civilised man and the untaught savage," said Mr. Wilson. "Both are surrounded by these wonderful forces. One makes a rough-and-ready use of some of the simplest of them; the other, by his ingenuity, has been able to subdue them all to his own will,—change them, adapt them, and even magnify their intensity to an almost unlimited extent, so as to compel them to minister to his wants in thousands of ways. The contrivances which he has invented to assist him in this subjugation of the natural forces are known as the mechanical powers. They form the basis of every machine in use in the civilised world.

"Our business this morning will be to consider the first and simplest of these mechanical powers. You shall come to the front and help us, Fred, by trying to raise this heavy cupboard off the floor."

Fred tried, but found it impossible to move the cupboard. Its weight offered too great a resistance to all the muscular force he was able to exert.

"Now I will show you," continued Mr. Wilson, "how to raise the cupboard with the greatest ease, by calling in the help of this iron crow-bar. I will push one end of the bar under the cupboard, place this small block of wood a little distance off, and press the other end down. The cupboard moves easily. Try it for yourself, Fred. You now see that this simple bar of iron enables you, with the expenditure of a comparatively small muscular force, to raise that heavy body, which you were unable to move before by exerting all your strength.

"The force which you applied at one end of the bar downwards was transmitted to the other end, and acted in an upward direction on the cupboard. Moreover, the small force which you applied was converted, by this bar, into a force sufficient to lift the heavy weight.

"This altering of the force is just what all mechanical contrivances are meant to do; and hence the iron bar is a machine. It is the simplest of all machines. We call it a *lever*.

"All that is necessary is that it must be perfectly rigid. A cane, or a bar of any yielding material, could never serve the purpose of a lever, because the force applied at one end, instead of being transmitted to the other, would be used up in bending the cane itself.

"The lever, from its simplicity, was, in all probability, the first of man's inventions in the mechanical powers. We must now learn the principles on which it works.

"The first essential is, that *the bar shall be perfectly rigid.*

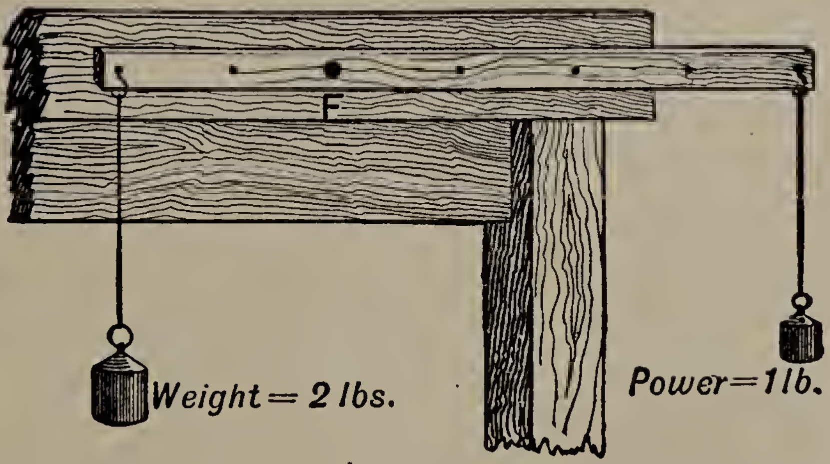
"Here is a stout, flat lath, which will satisfy all the conditions in this respect. I have bored a number of holes in the lath, at exact distances apart, and I am going to fix it up to the edge of the table, by means of a large round nail through one of these holes. It is quite immaterial where we place the nail, as the bar is free to move in every position. This is the other essential in a lever. Besides being a rigid bar, it must be capable of moving about a fixed point. *This fixed point about which the lever moves is called the fulcrum.* Our lath then in its present position is a lever, and the nail which holds it to the edge of the table is its fulcrum. It is usual to call the parts of the bar on either side of the fulcrum *the arms* of the lever.

"We will commence operations by placing the nail through the middle hole of the lever, so that the arms are of equal length. If now we hang a 2 lbs. weight at the end of each arm, they will balance.

"Now Fred shall remove the weight from one end, and still keep the bar balanced by holding it in his hand. How do you manage to keep it balanced, Fred?"

"I am pressing down on the end of the bar, sir."

"Can you tell me with what force you must be pressing?"



"With the force of the weight I removed, sir, I suppose," replied Fred.

"Exactly. The two weights at first balanced, because they were both pulling downwards with equal force at the two ends of the bar; and you must now exert an equal amount of muscular force downwards, at the one end, to balance the weight hanging at the other. If you use the smallest amount of additional force now, you will raise the weight at the other end.

"We usually call the force which you have been exerting *the power;* and the heavy body whatever it may be at the other end is called *the weight* or *the resistance.* In like manner the two arms of the lever are known as the *power-arm* and the *weight-arm.*

"Let us now alter the position of the lever, so as to make the power-arm twice the length of the weight-arm. If, with the lever so arranged, we hang a 2 lbs. weight at the end of the short arm, we shall easily find by experiment that a weight of 1 lb. at the end of the long arm is sufficient to balance it. The slightest extra pressure of the hand on the power-arm would then raise the 2 lbs. weight at the other end.

"By making fresh rearrangements of our lever, we may have the power-arm three, four, or six times as long as the weight-arm; and at every change our 1 lb. weight at the end of the long arm will balance a still heavier weight on the other. With the power-arm six times as long as the weight-arm, the 1 lb. weight would exactly balance 6 lbs. If we tried to balance the lever by holding the end of the power-arm, we should feel that very little muscular exertion would be necessary. We should press it down with only a force of 1 lb. to balance the 6 lbs. at the end of the weight-arm.

"Here we have a machine which gives a distinct advantage. When we used the lever with equal arms, the only advantage gained was a change in the direction of the force. To raise the weight, the power pressed downwards instead of upwards. With the power-arm longer than the weight-arm, a small force will raise a heavy weight; and the longer the power-arm is, as compared with the weight-arm, the greater will be the weight which that small force can raise. This explains the ease with which you raised the heavy cupboard. The power-arm of your lever was very long compared with the weight-arm."

Lesson X

Chemical Combination

"We have already had occasion to mention certain metallic elements," began Mr. Wilson. "I have one in this bottle, of a very different nature from the metals we are accustomed to meet with every day. We call it potassium. It can exist in its pure state only while it is bottled up like this in paraffin-oil.

"You have seen before now another element—phosphorus—which, in like manner, must be bottled up in water. But water is not able to keep this element—potassium—out of mischief; we have to put it in paraffin-oil."

Mr. Wilson then proceeded to take the potassium out of the bottle, and cut off a small pellet about the size of a pea. This he threw into a large basin of water standing on the table.

The metal was so light that it floated on the surface, but the most wonderful thing of all was that the moment it touched the water it seemed to burst into flame. The boys saw the beautiful purple flame playing all round it, as it floated about on the surface of the water.

The piece of metal gradually became smaller and smaller, and at last disappeared altogether.

"Now let us find out," said Mr. Wilson, "what all this means. You saw that we had to keep the potassium in paraffin. The fact is, this metal has such a great liking for oxygen that if it were left exposed to the air, it would go on abstracting oxygen from it. The two elements could not keep apart; they would rush together to form a new compound substance. It is for this very reason that we cannot keep it in water even, for it would rob the water of its oxygen for the same purpose. Hence we bottle it up in paraffin.

"Now watch, while I cut another small pellet. Notice the bright, bluish, metallic lustre of the newly-cut edge. But even as you look at it, you can see the bright lustre gradually disappear. The fact is, the metal, as soon as it was exposed to the air, began to rob the air of its oxygen, and to combine with that oxygen, to form a new substance all over its surface. It is this new substance which dulls the lustre of the newly-cut surface. Let us try now and learn the meaning of that flame on the water. The moment the potassium touches the water, it begins to rob it of some of its oxygen. Now, as water is composed of only the two gases, oxygen and hydrogen, what must happen when the metal takes away some of the oxygen? A certain amount of hydrogen must be set free.

"The potassium and oxygen and some of this hydrogen combine, and form a new compound substance—caustic potash—which dissolves in the water. In other words, the oxygen, set free from the water, burns up or oxidises the potassium, the result of the oxidation being the new substance—caustic potash.

"We have already learned that whenever chemical combination takes place heat is given out. Now then let us see. Hydrogen, a very inflammable gas, is set free all round the floating piece of metal. The metal combining with oxygen gives off great heat, and the burning flame is really the hydrogen, set free from the water, and blazing round the pellet of potassium. All this takes place because of the great attraction that potassium and oxygen have for each other. We call this attraction *chemical affinity*, or *chemical attraction*. It is another of the great *forces* in nature.

"It was this chemical attraction, or chemical affinity, that enabled us to obtain carbonic acid gas from chalk by means of hydrochloric acid. The calcium of the chalk has a stronger affinity for the chlorine of the hydrochloric acid than for the carbonic acid. It consequently breaks its connection with the carbonic acid, and enters into new relations with the chlorine, forming a new substance, chloride of calcium, and setting free the carbonic acid gas.

"In the same way, it is the strong affinity of phosphorus, sulphur, carbon, and hydrogen for oxygen, that causes them to burn so fiercely in that gas.

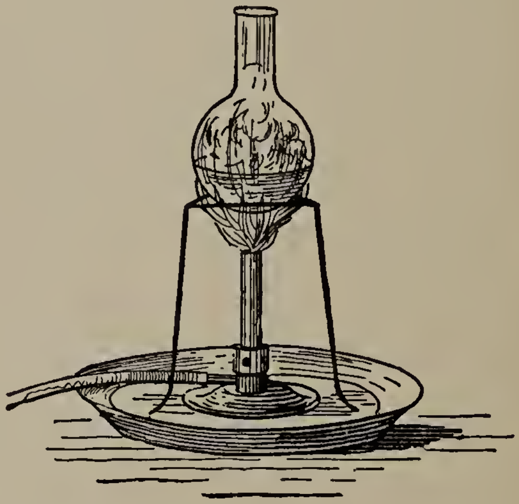
"We may sum up the results of our investigations as follows:—

"1. Certain elements have an attraction or affinity for others.

"2. This attraction does not exist between all bodies, and it differs in degree. It is stronger between some than it is between other bodies.

"3. It is so strong in some that they at once unite if they are brought into contact.

"4. In others heat must be applied to start the chemical action. The water poured on the quicklime gives a good illustration of the powerful affinity existing between these two substances. They instantly enter into combination, the lime drinking in the water with greedy avidity not only without the application of heat, but itself actually evolving intense heat during the combination.



"Now let us have another experiment. I will put some flowers of sulphur in the bottom of this glass flask, and on the sulphur a small coil of fine copper wire. Watch what takes place when I heat the flask over the Bunsen burner.

"First the yellow powder melts and becomes liquid sulphur; then it begins to change color, till at last it is quite black. By this time the liquid begins to boil, and the copper also becoming heated, begins to glow with an intensely bright light and great heat, and eventually melts and seems to disappear.

"If the flask is now set aside to cool, and afterwards broken open, it will be seen to contain neither sulphur nor copper, but a black solid substance quite unlike either.

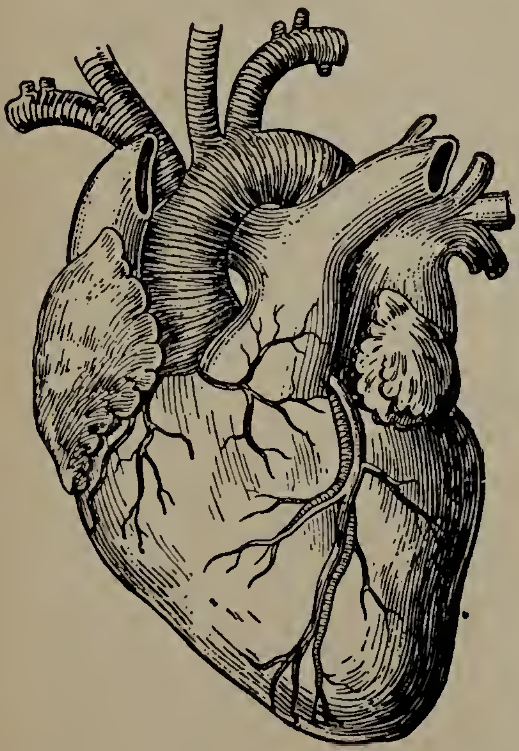
"The copper and the sulphur have combined to form this new substance, which contains in itself every particle of the two original elements. While they were combining in this way they gave out intense heat; it was this heat that melted and burned the metallic copper.

"The great thing to remember in this chemical combination of two or more elements is that, although each element is present in the compound, and can be recovered from it, it loses entirely its distinctive properties while it is in combination."

Lesson XI

The Heart

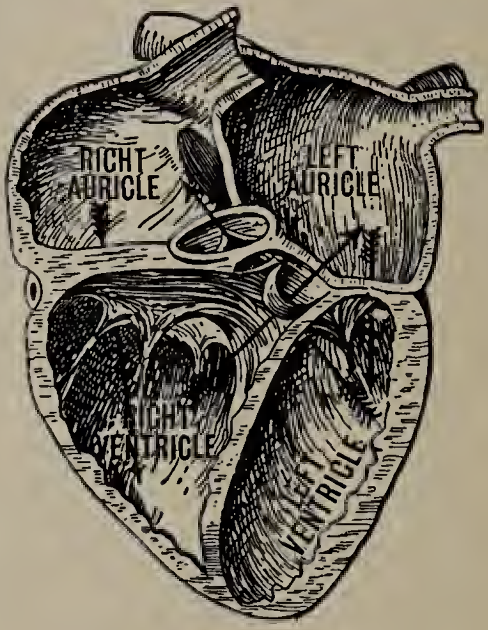
Now that we know something of the blood-vessels, which carry the blood, we naturally turn to the central pump which forces it along.



The heart is situated in the middle of the thorax or chest, between the two lungs. It is a pear-shaped organ, and has its broad end or base turned upward and backward towards the spine, and its pointed end or apex downward, forward, and to the left.

It is a hollow organ, about the size of one's closed fist, and is made entirely of muscle. It contains two great chambers, completely separated from each other by an immovable wall of muscle, which reaches from the base to the apex. Each of these great chambers is further subdivided by another partition, stretching cross-wise. Thus, the heart really contains four chambers of the same size —two upper and two lower.

The upper chambers are called the *right* and *left auricles;* the lower, the *right* and *left ventricles.* There is a passage between the upper and lower chamber on each side, so that whatever is in the auricle can pass through into the ventricle below; but there is no direct communication between the right and left sides. The heart is a muscular organ, and its pumping work is accomplished by the contraction of its muscles. These muscles, under the direct guidance and control of certain nerves, always work in one particular way. The auricles and ventricles are never at work together.



Both auricles begin to contract at the same moment, but this is only the signal for the ventricles to cease working; and when the ventricles in their turn begin to contract, the auricles cease work. In this way, at the very moment when the two ventricles are contracted to their smallest size, the two auricles are expanded or stretched out to their fullest extent. When the auricles take their turn to work or contract, the ventricles in like manner expand to their utmost.

It is by this alternate contraction of auricles and ventricles that the heart does its pumping. Every time the auricles contract they force the blood that is in them through the passage in their floor into the ventricles below; and every time the ventricles contract, the blood is driven out from them in like manner. We want to see what becomes of it. Let us begin with the blood in the auricles, for we have not yet learned how it gets there.

The veins from all parts of the body collect up the impure, purple blood, and unite again and again into larger trunks on their way to the heart. They finally pour their contents into the expanded right auricle of the heart by two great vessels—one draining, so to speak, the upper part of the body, the other, the lower. These two great veins are called respectively the *superior* and the *inferior vena-cava.*

Once in the right auricle, the blood is forced by the next contraction into the right ventricle; but the ventricle is no sooner filled than it begins in turn to contract, and this must force the blood somewhere. It cannot flow back into the auricle, because the passage between the two chambers is guarded by a valve which blocks the way. There is an easy passage, however, by which the blood can leave the ventricle, and that is the entrance to a great vessel, called the *pulmonary artery.* When the contraction of the ventricle comes, therefore, the blood takes the only course open and rushes into this great artery. It is called the pulmonary artery because it leads to the lungs. Remember that the blood which it carries away from the right ventricle of the heart to the lungs is the same impure, purple blood which the great veins poured into the auricle. Both chambers on the right side of the heart contain this dark purple blood.

The blood once in the great artery must not be suffered to return; it must go forward. This is provided for by a pouch-like valve, known as the *semi-lunar valve,* which guards the entrance. It consists of three little pouches with their mouths all opening towards the artery, and away from the heart. They allow an easy passage onward, but the least attempt of the blood to flow back would fill those little bags and so block the way.

It is curious to note that the muscular walls of this right ventricle are thicker and stronger than those of the auricle above it. The auricle has merely to squeeze the blood into the ventricle; the ventricle has to pump it out of the heart altogether into the lungs.

If we next turn our attention to the left side of the heart, commencing with the auricle on that side, we shall find four large vessels opening into it. These are the *pulmonary veins,* so called because they come from the lungs—two from each lung. They bring back to the heart the blood which was sent to the lungs; but it comes back no longer impure and purple, but pure and bright scarlet in color.

The expanding auricle receives it from these vessels, and as soon as it is full begins to contract, the contraction forcing it through into the ventricle below. The passage between the two chambers is guarded, like that on the right side, by a valve. Hence when the ventricles contract the blood cannot return.

Leading from this left ventricle is a great artery—

the main artery for supplying blood to the body. It is called the *aorta*, and its entrance is guarded, like that of the pulmonary artery on the other side, with a valve to prevent any return, but to allow an easy passage onward. The contraction of the ventricle forces the blood along this channel, and the work of the heart is complete.

Semi-lunar valves, like those at the entrance of the pulmonary artery, guard the gateway into the aorta; and the enormously increased labor of pumping the blood into every corner of the body is also provided for. The walls of the left ventricle are much *thicker and stronger* than those of any other part of the organ.

Lesson XII

PLANTS USEFUL FOR FOOD

Useful Vegetables

In addition to the plants which furnish man in all parts of the world with some form of bread material, there are others of a different character on which he depends to a large extent for his daily food supply. He uses the root of one, the stem of another, the leaves of another. In some cases it is the underground tuber which yields the food supply.

Among the useful roots are the carrot, turnip, and parsnip—the fleshy taproots of the respective plants. The mangold-wurzel—one of the turnip family—is a valuable root used by the farmer for feeding cattle.

The potato, although obtained from that portion of the plant which is in the ground, is not a root, but a swollen part of the underground stem. We call it a *tuber.*

It does not require very much explanation to show that these underground parts of the plant (roots and tubers) must of necessity contain a large amount of water, for they are always absorbing water from the soil. Every 100 lbs. weight of turnips contains 92 lbs. of water and only 8 lbs. of dry solid matter. The same weight of carrots contains 88 lbs. of water and 12 lbs. of solid matter; while potatoes yield 75 lbs. of water and 25 lbs. of solid constituents.

If these roots and tubers be dried until all the water is driven out of them, the dry solid matter will be found to consist mainly of the same substances, *gluten* and *starch,* with which we have become familiar in the breadstuffs. It is because they contain these substances that they are valuable as nutritious foods. The dried solid substance of the parsnip, for instance, yields a meal, which consists of gluten in addition to starch and sugar combined. The turnip is said to be quite equal in its composition to the meal of the Indian corn, except that it is deficient in fatty matter. Therefore to make turnips really nutritious, they should be eaten with some fatty or oily food. The farmer makes turnips combined with oil-cake common food of his cattle during the winter months, when they are for the most part housed, and unable to seek their own food in the meadows.

Next to the cereals, the potato is the most valuable of all vegetable foods. It feeds domestic animals as well as man, and is more extensively and universally grown than any other cultivated plant. It is very largely cultivated in mild climates, and to some extent in warm, and even in cold regions.

The 25 per cent of dry solid matter which it contains consists largely of starch, with less gluten than is found in rice, banana, or breadfruit; yet in conjunction with other food it forms a valuable article of diet. To the Irish peasant it is as much the staple food as rice is to the Hindoo and the Chinaman, or the banana to the negro.

The sweet potato of our country, and the yam of the East and West Indies and the South Sea Islands, are varieties of the potato which form important articles of food in the regions where they are grown.

The onion is a most valuable and nutritious article of food; its solid substance when dried is found to contain from 25 to 30 per cent of tissue-forming gluten. In its sustaining power it is said to equal the *gram* of the Eastern desert-lands. It is largely cultivated in this country, and is also imported from Spain and Portugal to the extent of many hundred tons yearly.

The Spanish peasant works contentedly from day to day on a diet of bread and onions—the onions contributing very largely to the amount of nourishment provided by his simple meal. The onion is the lower part of the stem of the plant swollen out to form a *bulb*.

The leaves of plants provide a by no means inconsiderable proportion of our daily food, both directly and indirectly. Our sheep and oxen and other animals, whose flesh supplies us with food, live for the most part on grass.

The cabbage family of plants, including the cauliflower, broccoli, etc., are extensively grown in all European countries. They contain a large proportion of water—as much as 90 per cent; but their dry solid matter is rich in tissue-forming gluten, and this makes them a highly nutritious article of diet.

A common dish in Ireland and in the South of France is made of potatoes and cabbage beaten up together. The potato supplies abundance of starch, but little gluten; the cabbage is rich in gluten; the two combined approach the composition of wheaten bread. Add to the mixture a little fat pork, and the whole gives as nearly as possible the composition of Scotch oatmeal.

One important constituent of every variety of vegetable food we have hitherto ignored. If we burned any one of the food substances we have examined, we should leave a residue—*the mineral ash.* This ash represents the earthy or mineral matters absorbed from the soil by the plant during its life. These mineral matters are of the highest importance to the growth and well-being of the body—particularly in the work of bone-making. At the same time, most of them are valuable as storehouses of potash, a mineral matter of great importance to our health and well-being from its anti-scorbutic properties—that is, as a preventive of scurvy and other eruptions of the skin. People who from any cause are deprived of these fresh vegetables are sure to suffer from such diseases sooner or later.

Lesson XIII

ANIMALS USEFUL FOR FOOD

In dealing with the vegetable food-stuffs we took bread in some form to be man's staple food. We commenced our investigation of these vegetable foods by examining the composition of wheaten bread, and we found that every kind of bread must contain similar materials, and possess similar nutritive properties.

We shall now follow the same plan in dealing with flesh foods, taking a piece of lean beef for our first investigation. If we get a piece of newly-cut lean beef, fresh from the butcher, we find that it is moist. This is due to the water which the flesh contains. We must get rid of this water before we can learn anything about the composition of the beef. The best plan is to let it dry slowly on a tin plate in the hot sun. The water will evaporate gradually, leaving the meat dry.

As the drying goes on the beef shrinks considerably in size. In fact, if the original piece weighed a pound, we should have, after the drying, less than a quarter of a pound of perfectly dry flesh. That is to say, three-quarters of its weight is water.

We can find out by experiment what are the constituents of the dry flesh. A piece of fresh beef has a red appearance, owing to the blood which it contains. We can easily get rid of the blood by repeatedly washing the flesh in fresh water, and it will then be seen to consist of a mass of whitish fibres or threads, with little particles of fat interspersed among the fibres.

If this be put into spirits of wine, the fat will all dissolve out of it, and nothing will remain but the fibrous tissue, which is the principal solid constituent of the muscles, or lean flesh, of animals. It is known in the scientific world as *myosin.*

When we eat meat it is this part of it—*myosin*—that becomes tissue-forming food. It is the nutritive part of flesh food, as gluten is of vegetable food. In fact, myosin of flesh and gluten of the vegetable may be considered as identical in this respect.

Lean meat, however, contains nearly three times as much flesh-forming material as bread. It contains no starch, while bread has half its entire weight of this material.

Civilised man in all parts of the world has always reared and kept certain animals for food. To distinguish these from the wild animals of the chase, we speak of them as *domesticated animals.* The chief of them are the ox, the sheep, and the pig. The cow not only provides us with flesh food when dead, but also while living gives milk. Milk is in itself a valuable food; we use it in its simple form, and we convert it into butter and cheese.

The flesh of the sheep is eaten only as fresh mutton; the pig's flesh is not only eaten fresh, but it is salted, smoked, and cured into bacon and hams.

Poultry, eggs, and game form important items in our animal food. In addition to our home-supply we import eggs from other countries. In the twelve months ending June 1896, we imported 947,138 dozen, of the value of $88,682.

Fish of various kinds must be reckoned among the important articles of our food-supply; and the fisheries of our waters are a source of great wealth to the country. The cod, herring, mackerel, salmon, haddock, and pilchard are among the most valuable catches; and oyster cultivation is prosecuted on various parts of the coast.

The herring fishery is carried on chiefly round the north coasts; the salmon fishery is confined to other quarters.

In 1887 it was estimated that 125,000 men and 32,000 boats were actively engaged in the British fisheries. The most valuable of the British fishing-grounds is the Dogger Bank, between England and Holland.

Among the most important and productive fisheries of the world are those of Newfoundland, Nova Scotia, and New Brunswick. Cod is the chief fish caught, but the deep and shallow waters absolutely teem with fish of almost every variety.

In the year ending June 1896 our fish imports were valued at $6,323,299, our exports at $5,226,247.

Lesson XIV

FIRST ORDER OF LEVERS

Our investigations into the nature and use of the lever led us to discover how it is that this simple machine is able to give such immense mechanical advantage. We know that we have only to make the power-arm very long as compared with the weight-arm, in order to overcome great resistance with the expenditure of a very small amount of force.

But we can go further than this. We can easily calculate the exact weight which any force is capable of raising by means of a lever, if we know also the respective lengths of the two arms of the lever. The power multiplied by the length of the power-arm is always the same as the weight mutiplied by the length of the weight-arm. If you go back to our trial experiments with the lever, you will find this absolutely true in every case; *the shorter the weight-arm, the greater the weight;* and *the longer the power-arm,* the *smaller the power.*

It is important to remember that in every rearrangement we made with the lever the other day, we were careful to place the fulcrum each time between the power and the weight. Whenever levers are used in this way, they form a class by themselves, and are known as levers of the first order.

We will now enumerate a few practical examples of the use of this first order of levers, which you often meet with in everyday life.

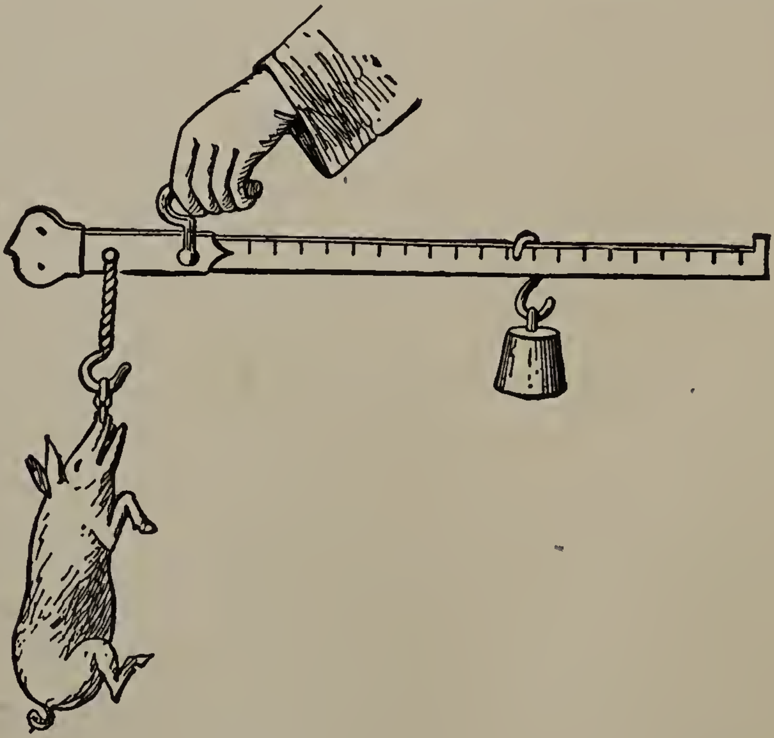
To you the most familiar example of all will be the see-saw. The moment I mention the word you picture it in your mind's eye, and are mentally pointing out to yourselves its fulcrum, and the two arms, one on each side of it. You know that, when the two boys are about the same size you make the two arms equal by placing the fulcrum in the centre of the plank. But how do you act when one boy is smaller than another? You give him the longer end of the plank—the long arm of the lever. You do this simply because you have seen other boys do it; now you know the reason for doing it.

It will be instructive to notice also how each boy on the see-saw in turn becomes first the weight and then the power. When either end of the plank is down, the boy at that end is the weight, and the one at the other end becomes the power which is to raise him, and so it goes on.

Among the other familiar illustrations of the use of this first order of levers are: (1) the poker in the act of stirring a fire; (2) a crowbar in the act of raising a paving stone; (3) the claw-hammer in drawing a nail; (4) the common pump-handle; (5) an ordinary pair of scales for weighing goods; (6) a spade in the act of digging. Take each of these familiar examples one by one, and point out its fulcrum, power, and resistance, and you will see that it acts just as our model did.

In addition to the above we have the steelyard, a very useful instrument for weighing purposes. If we compare the steelyard with a pair of scales, we shall easily understand the principle on which it acts.

In the scales the two arms are equal, and we use a great number of weights. In the steelyard the arms are unequal, the object to be weighed is hung from the short arm, and only one weight is used on the long arm. A little thought now will quickly tell you the reason for this.



A pair of scissors, pincers, and nippers are examples of double levers of the first order. Think for a moment, and try to explain why we bring hard, stiff material as close as possible to the rivet of the scissors when we wish to cut it.

Let us now go back to our see-saw. We will imagine two boys, a big one and a little one, riding on it. The little boy, as you know, sits on the long arm, the big boy on the short arm; and each, in turn, becomes the power and the weight.

When the big boy on the short arm is down, he is the weight, and the little boy on the long arm becomes the power to raise him. The little boy represents a very small power; but when that power acts at the end of the long arm, it increases, and he is able to raise the bigger boy.

When it becomes the turn of the big boy to act as power, that power is considerably greater than the weight to be raised, but it is acting at the end of the short arm of the lever. Now, consider for a moment. Which boy has the best ride? The little boy, of course, has the best ride. His end of the see-saw rises higher, and moves more quickly than the other end.

Now I think you will be able to understand what I am going to say next. When the power acts at the end of the long arm it increases in magnitude; but the weight which it acts upon moves slowly, and through a short distance. When the power acts at the end of the short arm, the weight moves through a greater space and at a greater speed, but there is loss of power. It takes, that is to say, a great power to raise a little weight. This is a universal law as regards levers. *Gain in power* must mean *loss in speed;* and *gain in speed* must mean *loss in power.*

Lesson XV

COMBUSTION

Mr. Wilson commenced the next lesson by repeating some of the old experiments with oxygen. He had several jars of the gas prepared beforehand, and he plunged into them, one by one, in succession, the burning splinter of wood and the pieces of carbon, sulphur, and phosphorus, just as he had done in the earlier lessons. In each case, too, he allowed the substance to burn first in the air of the room, to show the striking difference in effect when he plunged them into the pure oxygen.

"Now why do these things burn at all in the air?" he asked.

"Because the air contains oxygen," said several boys at once.

"Think over our last lesson on chemical combination, and tell me what the burning means in each case."

"It means, sir," replied Fred, "that each of these substances has an affinity or attraction for oxygen; and, because of that affinity, abstracts oxygen from the air, and enters into chemical combination with it to form a new compound substance."

"Excellent, my lad," said Mr. Wilson. "Now, of course you noticed, too, that the wood and the carbon did not burn as briskly as the sulphur, nor the sulphur as briskly as the phosphorus. The reason is that the chemical attraction of all these substances for oxygen is not equally strong. In phosphorus, as we have seen, it is so strong that, unless the element is kept in water, it takes fire and burns away. You must remember that the burning which took place in the air and in the pure oxygen is precisely the same in kind; it differs only in degree. In either case it was entirely due to the presence of oxygen. Each of these substances combined with oxygen to form a new compound, and while combining gave off more or less heat and light. This is just what we mean by combustion.

"Suppose we have another experiment now; I am going to show you some iron in the very act of combining with oxygen to form a new compound."

Mr. Wilson then took a piece of very thin iron wire, and, after coiling it round a ruler to make it into a sort of spiral, he fixed one end of it into a cork, and dipped the other end, red-hot, into some sulphur. He then showed the boys a large, bottomless, glass bell-jar which was standing on an iron tray on the table. "This jar," said he, "is filled with oxygen. I shall remove the stopper presently, and fix in its place this cork, which holds our coil of wire. The cork fits the neck of the jar exactly. Watch what happens." When all was ready, he first held the sulphur-tipped end of the wire in the flame for a moment, and then, while the sulphur was blazing, he rapidly took out the stopper and put the cork in its place as he had said. The instant the iron wire was plunged

into the oxygen in this way, it burst into a most dazzlingly brilliant flame; intense heat was given out, and white-hot, fused drops of some newly-formed substance were seen to fall continually as the burning proceeded.

"Now," said Mr. Wilson, "we see the same thing taking place with this metal—iron—as we have seen with other substances. Chemical action is going on fiercely in the oxygen. The iron and the oxygen are entering into chemical combination, and those fused drops are the new compound which is being formed. In other words, combustion is going on between the iron and the oxygen.

"As this kind of chemical action cannot take place without the presence of oxygen, we always speak of this gas as *the great agent of combustion.*

"I think we now clearly understand that, whenever combustion is going on, a new compound is being formed, as the product of that combustion.

"Take, for example, the piece of carbon, which burns, as you know, either in the air or in pure oxygen. Why does the carbon burn? Carbon, when once it is heated, has a strong affinity for oxygen. It combines with oxygen to form a new substance, *carbonic acid gas;* and while the combination is going forward, heat and light are produced.

"We have already learned that coal, wood, coke, peat—everything we use as fuel—as well as the coal-gas, paraffin and other oil, and candles, which we use for lighting purposes, consist largely of the element carbon. None of them would burn in an atmosphere deprived of its oxygen.

"The burning of any one of these illustrates clearly what is meant by the term combustion. It is simply the chemical combination of the substance which is being burned with the oxygen in the air around it. It is important to keep clearly in mind the fact that the carbon so burned is not destroyed. It is merely changed into a new form in combination with oxygen as carbonic acid gas.

"We utilise for our own purpose the heat and light given out by these substances during combustion ; while the poisonous product, carbonic acid, is made to disperse as rapidly as possible.

"Whenever combustion takes place, and the substance unites chemically with oxygen, we use one word to describe the new compound that is formed. We call it an *oxide.* For example, the piece of sulphur burned with a pale blue flame, and gave off the well-known powerful smell with which we are familiar when we strike a lucifer match. This smell came from the newly-formed compound of the sulphur and oxygen, which we may call an *oxide of sulphur.*

"So with the burning phosphorus and the iron wire. In one case the product of the combustion was an *oxide of phosphorus ;* in the other an *oxide of iron.* In like manner we may have oxides of lead, zinc, copper, tin, mercury, calcium, etc.

"You have seen the *red oxide of mercury,* and you know, too, that quicklime is the *oxide of calcium.* This rusty piece of iron is covered with the oxide of that metal, for the rust is the *oxide of iron.* If I scrape off some of this reddish-brown powder from the surface, I know that I have a compound formed of iron and oxygen. It was formed as other oxides are formed ; the only difference is that the combustion was so slow, owing to the small quantity of oxygen in the air, that the usual heat and light were not evolved during the process."

Lesson XVI

OXIDATION OF THE WASTE TISSUES

Our lessons thus far have shown us two kinds of blood coursing through the body; and we have learned to associate the impure, purple blood with the waste, poisonous matter from the worn-out tissues which that blood is carrying away. But how does it carry these impurities away? This is what we have to learn next. Think of the dark purple blood as it is being collected by the veins. It was, just before, flowing through the arteries, as bright red, arterial blood. The blood carried by the veins up to the heart, and thence to the lungs, is the same dark purple fluid. It returns to the heart by the pulmonary veins pure, bright-red blood. It has been cleansed from its impurities while passing through the lungs. But it has not only given up its poisonous impurities, it has taken in something in the lungs which is very necessary to our existence.

You know that one-fifth of the bulk of all the air around us consists of oxygen, and that the chief property of this gas is its power of burning or oxidising other substances. Suppose I placed a piece of burning candle in a jar of oxygen, what would happen? It would burn rapidly, with a very brilliant glow; and it would continue to burn till all the oxygen was consumed. In the meantime the substance of the candle would disappear. But how does it disappear? The oxygen, you know, burns the carbon and hydrogen of which the candle is composed, and changes these into the form of gases—carbonic acid and water-vapor. Think of the coal burning in the fire-grate. The smoke which rises up the chimney is very different in appearance, and yet it contains all the substance of the coal itself, converted into another form by the oxygen of the air; for burning is merely a change; nothing is lost; there is no destruction.

Now let us see what all this has to do with getting rid of waste matters from the body. The solid particles of brain, muscle, and other tissues, although they have by their work become worn-out and waste matter, cannot be carried away out of the body in that state. They must undergo a complete change into new and totally different substances. This change is brought about by the gas, oxygen. Throughout life the work of breathing never ceases, and the work is twofold. We *exhale*, or send out; and we *inhale*, or breathe in. That which we inhale is pure air, one-fifth of it being the gas, oxygen. The oxygen, thus taken in as we breathe, is absorbed into the blood in the lungs, and carried into all parts of the body.

Wherever the oxygen meets with tissues which have been used up, or worn out by their work, it seizes upon them, and a slow burning or combustion at once commences. The harder we work the faster our tissues are destroyed, and the quicker must we breathe, in order to take in sufficient oxygen to carry on the burning. It is this constant burning up of the waste matters by oxygen in all parts of the body that keeps us warm.

When we are in bad health, and the blood does not circulate freely, we are always cold. There is not enough oxygen sent through the body at such times to do the necessary work of burning or oxidising the waste matters.

What happens when we have been undergoing some unusual exercise? We breathe more rapidly; the heart beats at a quicker rate; and we feel the blood coursing through the body.

Why is this? More of the tissues than usual have been used up and become waste matter, and more oxygen must be taken in and carried to them by the blood to burn them up. The increased burning makes us feel warmer. If you notice the surface of the skin at such a time, you will find it covered with drops of moisture. This moisture oozes out from the skin—*we sweat* or *perspire.* If I breathe, moreover, on a slate or some polished surface, I find that my breath contains moisture too.

Now our lessons in chemistry have shown us that water is one of the products of burning. It is always produced when hydrogen burns. Hence we learn that hydrogen is one of the materials of which our bodies are made.

You remember, of course, our now familiar experiment of breathing into lime-water, and what it teaches us. Carbonic acid is another of the products of the burning, for it is given off with our breath.

These two substances, *water and carbonic acid, are being constantly formed* by the oxidation of the hydrogen and carbon, which enter largely into the constituent materials of the body. There are other products of the burning—one in particular, ammonia; but carbonic acid and water are the chief.

The blood, as it courses through the body, absorbs these products of oxidation, and they change its character from a life-giving to a poisonous stream. It becomes dark purple in color, and is carried in this state by the veins back to the heart, and so on to the lungs. There it gives up carbonic acid and water, and takes in oxygen in exchange. It is this exchange which reconverts the venous into arterial blood once more.

Lesson XVII

PLANTS USEFUL FOR FOOD

Fruits and Nuts

Our recent investigations have led us to assign to certain fruits their proper and distinctive title as actual breadstuffs. The populations in many parts of the world depend to a very large extent upon the fruits natural to the soil for their daily food. Thus the Arab of North Africa and Arabia lives almost entirely on the date; the Negro of the tropics on the banana; the South Sea Islander on the breadfruit.

We, in temperate climates, regard fruit rather as a luxury than a necessary of life. Our commonest native fruits are the apple, pear, plum, cherry, apricot, peach, strawberry, raspberry, gooseberry, and currant, etc., most of which are cultivated in all parts of the country; but in addition to this, our home-grown supply, we every year import immense quantities of fruit. Steam navigation has had the effect of bringing distant lands into such close touch with our own, that we are able to enjoy, all the year round, at moderate cost, the fruits of foreign countries, in addition to those of our own land. Most of our foreign fruit supply comes from Italy, Asia Minor, and other countries bordering on the Mediterranean. Bananas reach us from Central America and the West Indies, from Cuba and South America also, and the Hawaiian Islands. In the year ending June 1896 our imported fruit was valued at the great sum of $16,958,608.

This shows the high place which fruit takes as an article of food. In the same year our exports of fruit amounted to no less than $5,679,066. There were 359,436 barrels of apples, 26,692,529 lbs. of dried apples, and much canned fruit.

Our annual imports of oranges and lemons amount to more than $2,560,000. The greater part of these come from Italy. Our own orange groves are now so finely developing, however, that we are more and more depending upon our own supplies in Florida and California. The development of refrigerating cars, and the ready passage of fruit-trains over the long distances of our country, help to distribution of our fruit.

The Seville orange (from the south of Spain) is distinguished by its slightly bitter taste, and is used in the manufacture of marmalade. The Malta orange is a seedless variety, with a crimson pulp ; they are commonly called blood oranges. The European fruit are distinguished as a rule by their smooth, thin skins ; they come to us rolled up separately in thin white paper. The West Indian variety are coarser and rougher-skinned fruit. They are not packed in separate papers.

The lemon, sweet lime, shaddock, and citron are sent from Madeira; and large quantities of pine-apples are exported from the Azores and Bahamas. The banana of Central America and the West Indies, and the pomegranate of Southern Asia are both to be seen in our fruiterers' shops; and we also import hundreds of tons of grape-fruit from southern latitudes.

In addition to the fruits we have already mentioned, and which are known as raw or green fruits, we see, in the grocer's shops, others, such as raisins, currants, and figs, which have been dried in the sun. Our annual imports of these dried fruits amount to many thousands of tons. Raisins come from Valencia and Malaga in Spain; sultanas (a seedless variety) from Smyrna; currants from Smyrna and the Ionian Islands; and figs chiefly from Smyrna.

It should be carefully borne in mind that the name *currant* has nothing to do with our common red, white, and black currants. Raisins and currants are both dried grapes. The currant takes its name from Corinth; it is *the Corinth grape.*

Nuts, like fruit, form an important article of commerce. The most wonderful nut in the world is the cocoa-nut; and it is the fruit of, perhaps, the most wonderful tree in the world—the cocoa-nut palm.

This tree, we already know, has nothing whatever to do with the cocoa-tree, which supplies the material for the well-known beverage. It is very widely distributed throughout the tropics; and is to be met with in the East and West Indies, in Central America, in India and Ceylon, and in all the islands of the Pacific and Indian Archipelagoes. In Ceylon there are extensive plantations of these palms, said to contain no fewer than twenty millions of trees.

The trees are usually found fringing the low shores. They are stately trees, rising often to the height of 100 feet; the summit is crowned with feathery leaves from 12 to 15 feet in length. They bear immense bunches of flowers, and when these die off, they give place to the fruit—the cocoa-nut of commerce. The tree usually bears about sixty nuts each year.

The nuts, as we see them in the shops, have been stripped of their outer covering, which is a thick, fibrous case, or husk. This supplies the material for cocoa-nut matting, brushes, etc.

To the natives of the lands where it grows this tree is invaluable; its uses are said to equal in number the days of the year. They build their houses, and make every utensil and household article they require from the wood of the trunk. They thatch their houses with the leaves, and the fibrous husk of the nut supplies them with material for matting. The nut itself forms an important part of their food; the milk supplies them with drink; and they make *palm wine* and *arrack,* a spirituous liquor, from the fermented juice or sap of the flowers. From the kernel of the nut cocoa-nut oil is obtained. The timber of the trunk is also a valuable article of commerce, known as porcupine wood.

England imports annually about £300,000 worth of cocoa-nut oil from India and Ceylon. Most of it is used in the manufacture of *marine soap*—a soap that will form a lather with sea-water.

Among the other common nuts are the filbert, walnut, almond, chestnut, and Brazil nut. Hazel-nuts and filberts are natives of our own country; but we import large quantities from Spain, under the name of Barcelona nuts.

The walnut is also grown in this country; but we import many thousand bushels every year from Germany and the South of France. The almond belongs to the countries bordering on the Mediterranean. There are several varieties—the sweet, the bitter, the Valencia, and the Jordan almond. The last has nothing to do with the river Jordan. The name is a corruption of *jardin*, the French word for *garden*. The chestnut is extensively grown in Spain and Italy. The people of Lombardy mix chestnuts with their lupin meal to make their bread. We import chestnuts largely from Holland and Belgium. The Brazil nut is the fruit of a large tree which grows mostly in the region near the Orinoco. The fruit is a smooth, round case, half as big as a man's head, and in it the three-sided nuts are packed closely together, as many as twenty or thirty in one case. It is extremely dangerous to pass under the trees when the fruit is growing ripe; for the nut cases, owing to their great weight, frequently fall as they ripen.

Lesson XVIII

Second Order of Levers

"We are going to talk about levers again this morning," said Mr. Wilson, "but we shall have to deal with levers of a different kind from those with which I have already made you familiar. Perhaps, however, it would be better if I said that we are going to learn to use the lever in another way, rather than call it a different kind of lever; for every lever, of whatever kind, is simply a rigid bar, and the difference lies only in the manner in which we employ it.

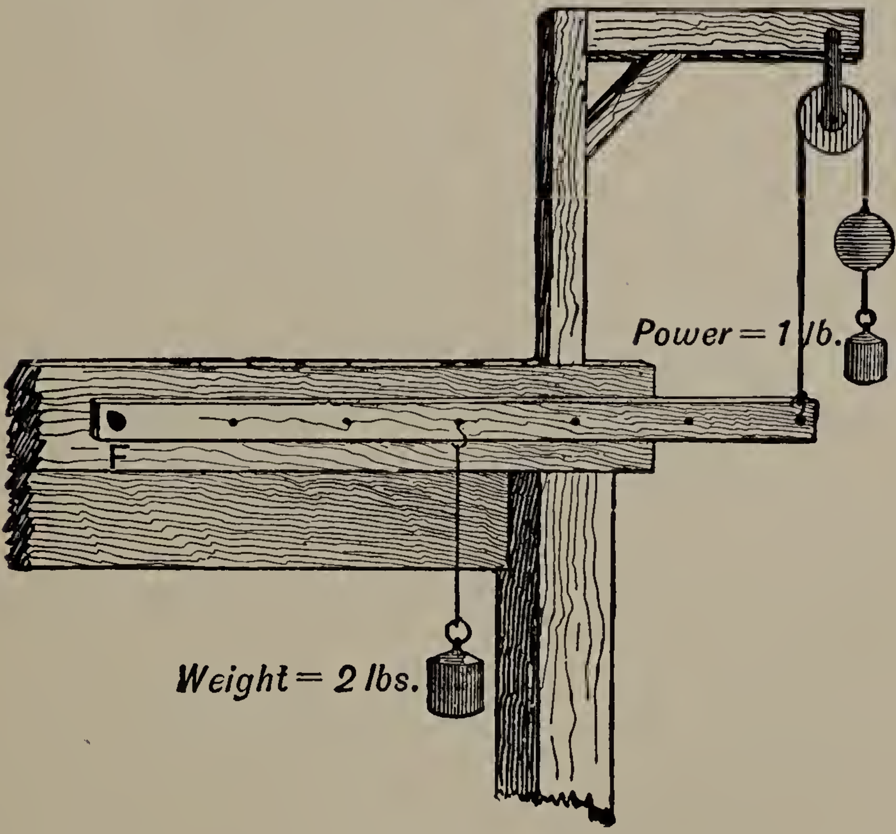
"As a proof of this, we shall use our lath, as before, for a model lever; but this time I shall put the fulcrum nail, not through the middle, but through a hole at one end. The levers we are now about to consider always have the fulcrum at one end. We call them the second order of levers, to distinguish them from those of the first order, in which the fulcrum lies somewhere between the two ends.

"Now that we have our lever-bar fixed at its fulcrum, you shall come and hold it horizontal, Fred. You at once find that it requires considerable exertion, for you are supporting the lever itself, which would otherwise fall by reason of its own weight. We must get rid of this difficulty before we can set the lever to work.

"To do this I must call in the help of the little suspended wheel, with a grooved circumference, which we used in our first lesson on machines. We will fasten one end of a fine cord to the last hole (No. 6) in the bar, and pass the other end of it over the wheel. It will be easy now to attach to the free end of the cord something just heavy enough to keep the bar horizontal, and after that we may disregard its weight entirely. It is now merely a lever free to work on a fulcrum, placed at one extremity.

"We will commence operations by hanging a 1 lb. weight to the hole in the bar (No. 6) from which the cord passes over the wheel. This weight would cause the bar to fall, but I can at once bring it to rest in the horizontal position by attaching a similar 1 lb. weight to the cord itself. That is to say, a weight of 1 lb. at the end of the lever is supported by a power of 1 lb. acting also at the end of the lever.

"This is just as we might have expected it to be, from what we already know. The weight-arm and the power-arm are the same length; hence the weight and power must be equal.



"Now, without interfering at all with the cord, or the weight attached to it, Fred shall remove the 1 lb. weight suspended from the end of the bar, and place it midway between the end and the fulcrum.

"Does the lever assume the horizontal position now? No; the two forces do not balance. It requires a 2 lbs. weight at the middle of the lever to bring it to rest again in the horizontal position. In other words, the cord, with its power of 1 lb. acting at the end of the lever, can support a weight of 2 lbs. suspended from the middle. The power-arm is twice as long as the weight-arm. If we continue our experiments, we shall find that the same power of 1 lb. at the end of the lever will support a weight of 3 lbs. suspended at one-third of that distance from the fulcrum, or a weight of 4 lbs. at one-fourth of that distance.

"This, of course, is only repeating what we said about the other class of levers, except that with these we always have the fulcrum at one end, and, consequently, *the power-arm and the weight-arm are both on the same side of it.*

"The distinctive point about these levers of the second order is that the power always acts at one end, the fulcrum being at the other, and the weight somewhere between the two. The longer the power-arm is, as compared with the weight-arm, the greater will be the weight which a given power can raise; because *the power multiplied by the length of the power-arm is always the same as the weight multiplied by the length of the weight-arm.*

"In this second order of levers the weight is always nearer the fulcrum than the power can be, for the power always acts at the opposite extremity of the bar. Hence the mechanical advantage gained by such a machine is *an increase of power.*

"Our two boys on the see-saw illustrated a universal law in the science of levers—namely, that *a gain in power* must be accompanied by *a loss in speed.* Let us apply this to our lever of the second order to find how far it is true.

"We have seen that we do actually get an increase of power with these levers. Now think of the power acting at the end of the long arm, and the weight somewhere between it and the fulcrum. It is clear that the weight does not move so far or so quickly as the power.

"The mechanical advantage therefore of levers of the second order is *gain in power;* and this means *loss of speed.* Let us now glance at a few practical examples of the use of this second order of levers.

"A crow-bar in the act of raising a block of stone becomes a lever of the second order. In this case the ground is the fulcrum, the weight of the stone rests on the bar between it and the power, which acts by forcing the lever upwards.

"When the same crow-bar was used to raise the paving stone, the end of the lever was forced under it, the fulcrum was formed by the neighboring stone, which lay between the power and the weight, and the man overcame the resistance by pressing down on the power arm. We had then a lever of the first order. A wheel-barrow is a very familiar example of a lever

of the second order. The fulcrum is placed at the axle of the wheel, the power is applied at the handles, and the weight lies between the two.

"A boatman's oar is another good example of the same order. Here the water is the fulcrum, the boat itself the weight, and the man applies the power at the handle of the oar.

"A chopping-knife by its very action explains itself. You can have no difficulty in pointing out fulcrum and power. The work of the machine is to overcome the resistance offered by the substance to be chopped, which of course is placed between the fulcrum and the power.

"A pair of nut-crackers afford an illustration of a double lever of the second order, in which the fulcrum, power, and resistance are very apparent."

Lesson XIX

Water, a Compound of Oxygen and Hydrogen

"Our lesson on combustion led us to form a clear conception of the whole process of burning," said Mr. Wilson. "We know that in the burning nothing is lost, nothing is destroyed; the substance, whatever it is, enters into chemical combination with oxygen to form a new compound body. That is all.

"I intend to devote our lesson this morning to the consideration of one element, and the results of its combustion, or chemical union with oxygen.

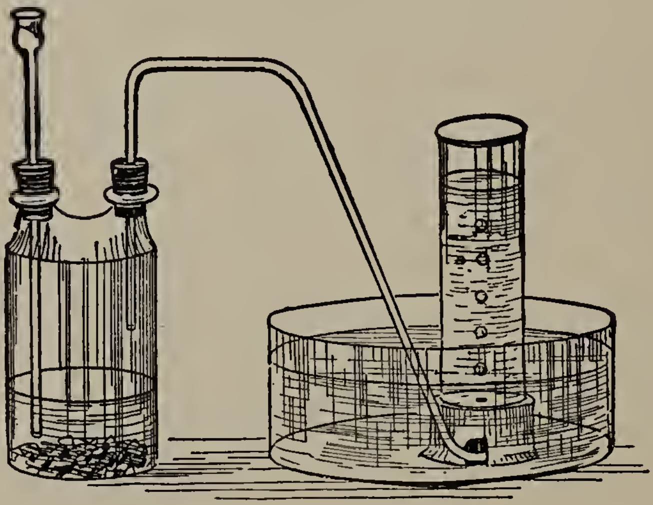
"What is the name of that very inflammable gas which takes fire immediately a flame is brought near it?"

"Hydrogen."

"Right. This gas, then, and its action in combining with oxygen, shall form the subject of our lesson.

"We shall want some hydrogen for our experiments; and as you have seen me prepare the gas before, perhaps you will be able to tell me how to proceed to make some now."

"You must put some zinc clippings into a flask, sir, with just enough water to cover them," said Fred, "and then carefully pour in, through the funnel, some sulphuric acid, till the liquid mixture begins to bubble all round the zinc. Those bubbles will be bubbles of hydrogen; the zinc separates the hydrogen from the dilute sulphuric acid."



"Perfectly correct, my lad. Now do you remember that, when I last prepared this gas for you, I was very careful to wait for some few minutes before I attempted to collect it for actual use?"

"Yes, sir. You waited till you were quite sure there was nothing coming from the flask but pure hydrogen. The flask was at first filled with air, and, if any of that air were allowed to mingle with the hydrogen, there would be an explosion as soon as a light was brought near it."

"You are right again, Fred; but why should there be an explosion? Let us try and find out. I will follow your instructions carefully and prepare some hydrogen now. But while we are waiting for the hydrogen, I will also prepare some oxygen, as I have the apparatus all ready."

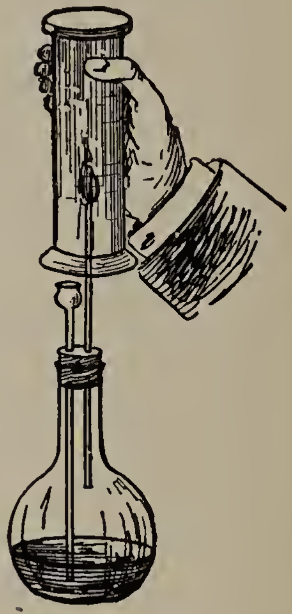
Mr. Wilson waited till both gases were coming off pretty freely. He then filled an ordinary soda-water bottle at the pneumatic trough, and inverted it in the water in the usual way. When all was ready he held the delivery tube from the hydrogen flask under the mouth of the bottle till about two-thirds of the water it contained had been displaced! He then rapidly removed this tube, and replaced it with the one from the oxygen flask, so that the oxygen rose and filled the remainder of the bottle.

"Now," said he, "we have in the bottle a mixture of the two gases, hydrogen and oxygen; and there is twice as much hydrogen as oxygen. Watch what takes place next."

He bound a thick towel well round the bottle, and holding it firmly in one hand, lifted it out of the water, while with the other hand he brought a long lighted taper near the mouth. In an instant there was a sudden, violent explosion.

"This," Mr. Wilson explained, as soon as the class had got over the shock, "is due to the *strong affinity* which hydrogen has for oxygen. While the two were merely mixed together in the bottle, no explosion took place, although the only thing wanted was a flame. But what has become of the two gases now? The next experiment will tell us."

He proceeded to fit a small glass jet-tube to the cork in the hydrogen flask, in place of the long delivery-tube, and when that was done he poured a few more drops of sulphuric acid down the funnel-tube. The bubbling immediately began afresh, and hydrogen was again given off as before.



"This time," he said, "we will light the gas as it comes off at the jet."

He did so, and it burned there with a dull flame. While it was burning he held a large test-tube over the flame, and in a short time *it became covered on the inside with a dew-like deposit.* These, he explained, were drops of water; the hydrogen had burned, and formed water.

"Here we have," he said in conclusion, "another instance of combustion. Hydrogen and oxygen have united chemically to form a new compound substance—*water;* and while uniting have evolved light and heat.

"The combustion goes on quietly here, because only a very small quantity of hydrogen can escape from the jet at one time. When the gases were mixed in larger quantities in the soda-water bottle, the combustion was very sudden and very violent, and we had a loud explosion.

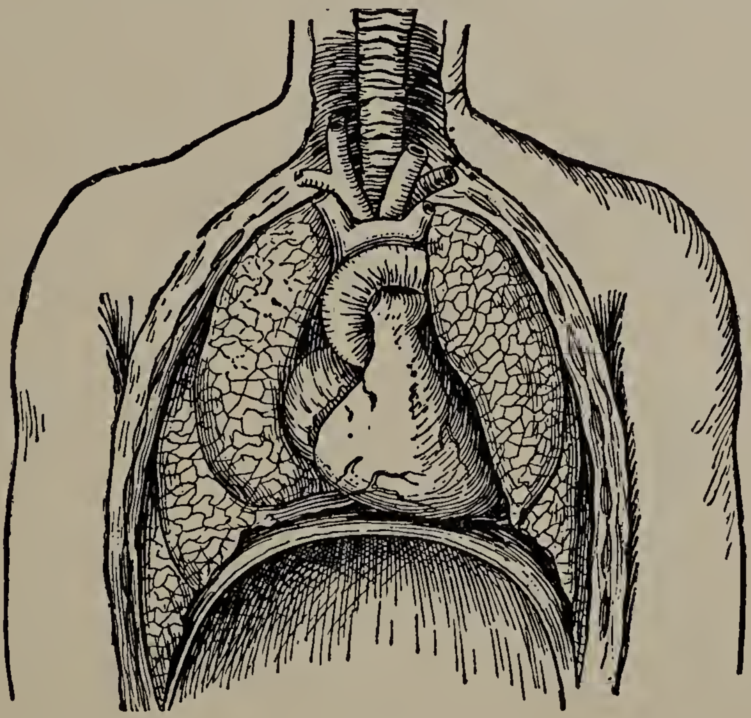
"Then, as now, however, the two gases combined to form water. Water always consists of these two gases, hydrogen and oxygen, chemically united in the proportion of two to one.

"Remember that all wood, coal, oil, candles, gas—whatever we burn for fuel or lighting purposes—contains hydrogen as well as carbon; and, therefore, whenever these things burn *water-vapor must be formed,* and poured out into the air."

Lesson XX

The Lungs

We have followed the course of the blood as it is sent out from the heart by the great main artery—the aorta; we have seen it as it flows through the capillaries become polluted with carbonic acid, water, and other products of the oxidation; we have traced this polluted stream back to the heart, and then on to the lungs; and we know that it returns from the lungs cleansed and purified, and re-invigorated with oxygen. Our next business is to find out how this change takes place in the lungs. We must of course begin by examining the lungs themselves.



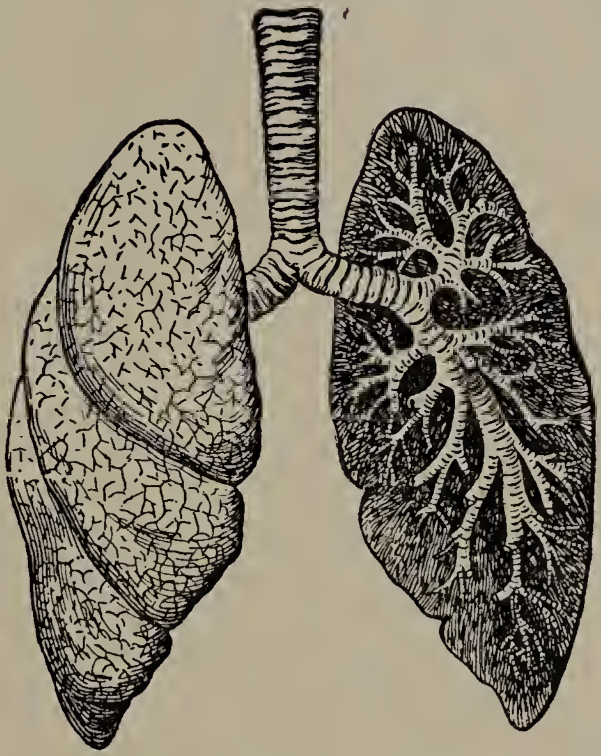
The lungs are the two large organs which, together with the heart, fill the entire cavity of the thorax or chest. This cavity is a sort of conical or beehive-shaped box, having the spinal column, the ribs, and the breast-bone for its side walls, and a stout, strong, flat muscle—the diaphragm—for its floor. It is a perfectly air-tight chamber, and both its floor and its walls are movable.

The ribs are attached to the vertebral column by joints, which allow them a limited up-and-down movement, and instead of passing horizontally round the body, they all slant downwards from their junction with the column behind. It is easy to see that with such an arrangement the up movement of the ribs must have the effect of enlarging the chamber, while their downward movement must have the opposite effect.

The lungs themselves are soft, spongy, elastic, and of a pinkish-gray color. They are securely attached both to the diaphragm (the floor) and to the sides of the thorax; so that there is absolutely no space between them and the walls of the chamber in which they work.

The consequence is that when the walls and floor of the thorax move, and so enlarge or diminish the size of the chamber, the lungs must expand or contract with them in order to accommodate themselves to the space provided.

The back of the mouth and the nasal passages open into a large cavity, *the pharynx,* and from the lower part of this a long, stout tube, *the windpipe,* extends downwards into the chest. This pipe, which is formed of stout rings of gristle, can be felt. The rings make it hard and resisting to the touch, and prevent it from collapsing with pressure. After entering the chest the windpipe branches into two—the *bronchi;* one bronchus going to the right, the other to the left lung.



In the lungs these bronchi divide and subdivide again and again, forming *bronchial tubes,* and end at last in extremely fine branches which spread themselves all through the substance of the organ. In fact they actually form the substance of the lung itself, for each bronchial tube ends in a bunch of little, hollow, elastic bladders, called *air-cells,* and it is the mass of these air-

AIR-CELLS OF THE LUNG.

cells which make up the entire lung. It is because each little air-cell itself is very elastic, that the whole lung has the power of expanding and contracting.

The lungs expand to take in more air; they contract to drive the air out. The air, inhaled at the mouth and nostrils, passes along the windpipe, bronchi, and bronchial tubes till it reaches the air-cells of the lungs. Let us now leave the air-passages and air-cells, and turn our attention to the great artery which brings the blood to the lungs to be cleansed.

This, *the pulmonary artery,* after leaving the right ventricle of the heart, divides into two branches —one for each lung. In the lung each branch divides again and again, until at last it forms the most delicate *capillaries.* These capillaries spread themselves through every nook and corner of the substance of the lung.

But, as we have seen, the substance of the lung is really the thin, delicate, bladder-like walls of the air-cells, and it is round these little air-cells that the finest branches of the pulmonary capillaries spread themselves. These little vessels, like all other capillaries, eventually re-unite into tiny *veinlets,* and they in their turn continue to do the same, until at length they form four main pipes, *the pulmonary veins* (two from each lung) which proceed to the left auricle of the heart.

It is important to remember that the pulmonary arteries are the only arteries in the body which carry venous blood, and that it is this dark purple blood which flows through the capillaries of the lungs. In those delicate vessels it is separated from the air in the air-cells by the finest possible membrane, and here the exchange takes place. Oxygen from the air in the air-cells passes into the blood, and carbonic acid and water from the blood finds its way into the air-cells in place of it.

The double exchange takes place through the actual membrane by *osmosis*. We have already explained and illustrated this passage of fluids through a membrane in one of our earlier lessons.

It is in this way that the blood is purified, and re-invigorated with oxygen; and when at length it is collected up by the pulmonary veins to be carried by them back to the heart, it is *pure, bright, arterial blood.* These are the only veins in the body that carry arterial blood.

Lesson XXI

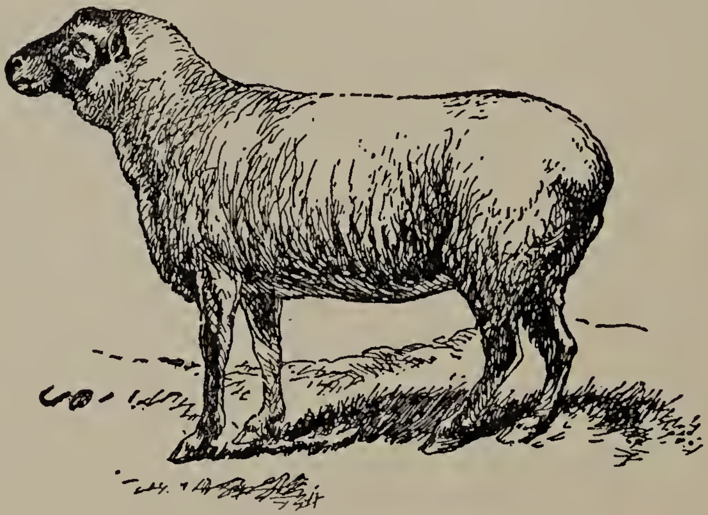
WOOL

Nature provides each of her creatures with exactly the kind of covering suited to the climate and the conditions under which it lives. In the extreme frozen north all animals are clothed with a thick, warm, fur coat; in the temperate regions the fur gives place to wool; and in tropical climates the animals are, for the most part, provided with a covering of thin, scanty hair.

Of all these animal coverings wool is by far the most useful to man. It is the peculiar, wavy, scaly characteristic of wool that renders it valuable for the manufacture of textile fabrics; and it is this same peculiarity which distinguishes wool from hair. Wool is usually classed according to the length of its fibre.

The *short-fibre* or *short-staple* wool is very wavy, and contains a large number of scales; the *long-fibre* or *long-staple* wool is less curly, and has fewer scales, and at the same time it is coarser in texture.

In England sheep are reared with a view rather to their flesh than their wool, and, as a rule, English wool is inferior in quality to most of the foreign varieties. Their manufacturers have to depend largely on imported material, most of which is supplied by their own colonies, especially Australia, New Zealand, South Africa, and India.



SOUTH DOWN SHEEP.

The English sheep include, among the short-woolled varieties, the Dorsets and the South Downs. The latter are a small breed, noted for the fineness of their wool, as well as for the quality of their flesh; they are the most highly prized of the pure English breeds. Among the long-woolled kinds, the Cotswold and Leicestershire breeds are considered the best. In addition to these pure breeds there are several well-known cross-breeds.

The average weight of the fleece of an English sheep is from 5 to 7 lbs.; but the quantity as well as the quality of the wool depends entirely on the breed, the climate, and the soil, and, therefore, the sort of food available.

COTSWOLD SHEEP.

Among the other breeds the merino sheep stands first for the excellence of its wool, alike as regards the fineness of its texture, its waviness, and the number of scales on its surface.

MERINO SHEEP.

The true merino sheep is a handsome animal, the female as well as the male being horned. It was originally a native of Spain, but has been introduced into nearly every sheep-rearing country in the world. Wherever these sheep are bred they are highly cultivated, the principal object being wool. The merino sheep of Saxony and Hungary are especially famous for both the quality and the quantity of their wool. The fleece of the Saxon merino ram is never less than 7½ lbs. in weight, and it frequently reaches as much as 15 lbs.

These sheep have been introduced elsewhere, and have greatly improved the other breeds. They have also been extensively introduced into Australia, New Zealand, and South Africa.

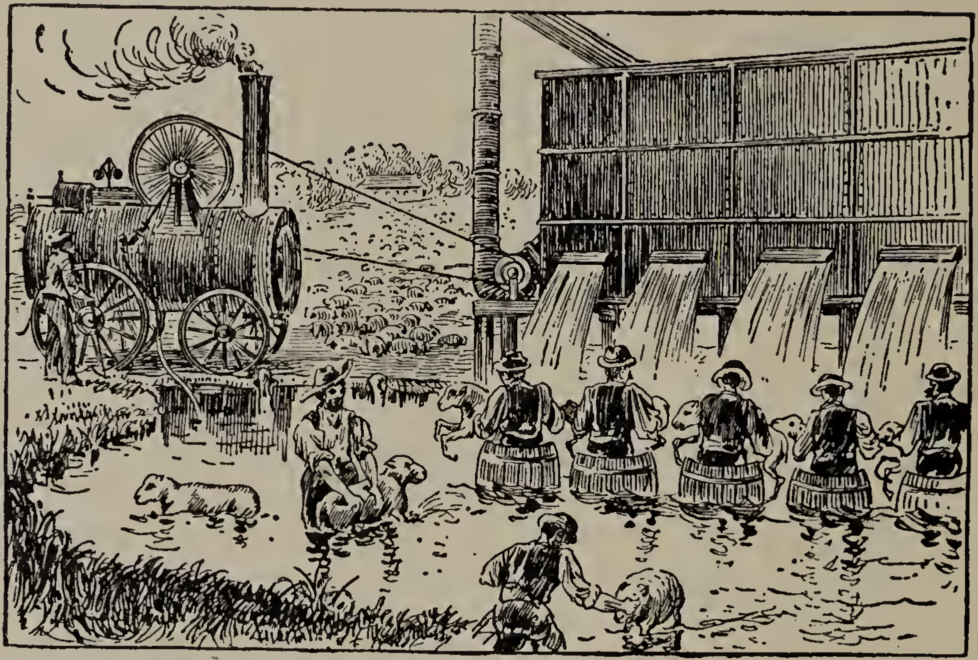
The Continental varieties are tended with great care, housed in stables during the night, and protected at all times from the inclemency of the weather. The sheep are frequently washed, not only in cold water, but also with hot water and soap. The wool is very highly prized, and the sheep, instead of being killed off for mutton, are allowed to live for ten or twelve years for the sake of their annual fleece. As a matter of fact, in many of the foreign countries where sheep are bred, the flesh is not considered fit for food. In Spain none but the poorest would think of eating mutton. Among the other varieties of sheep are the broad-tailed sheep of Asia Minor, Tartary, and Northern Africa. The heavy tail of this sheep is a mass of fat, often weighing as much as 20 or 30 lbs. This tail is considered a great delicacy for the table, and so much trouble is taken to preserve it from injury, that a small carriage is harnessed to the animal for the purpose of supporting it. This sheep is invaluable to the people of those regions. Its milk and its flesh supply them with food, and its wool, although very coarse, provides material for clothing.

Wool is, next to cotton, by far the most important material employed in the manufacture of textile fabrics. The woollen manufacture in Great Britain alone is estimated to give direct employment to more than a quarter of a million operatives ; while the number of persons directly and indirectly engaged, in and for all the branches of the trade, from the time the wool leaves the farmer to the production of the manufactured article, is fully a million.

Our annual home-supply of wool is not sufficient for the wants of our population. In addition to what we have, we import, every year, enormous quantities. In the twelve months ending June 1896 we imported in hair of camel, goat, alpaca, and other animals, 230,811,473 lbs., valued at $32,451,246. Australian wool is improving in quality and quantity. It is estimated that the sheep-runs of New South Wales alone feed upwards of 30 million sheep.

It will readily be seen that the shearing of such immense numbers of sheep could never be accomplished by the ordinary means adopted by our home farmers in their comparatively small farms. The washing, which usually precedes the cutting of the wool, is done with the aid of machinery, and so expeditiously that three sheep can be well washed in two minutes.

A large wooden tank about 3 feet deep is sunk in the ground. This is partly filled with warm water, and the temperature is kept up by a steam pipe from an engine close by. This is known as the soaking tank, and the sheep are placed in it and rubbed over, the warm water loosening the dirt in the wool. On the edge of the soaking tank stands an iron tank raised about 8 feet from the ground. This is kept filled with cold water by means of a pump worked by the engine; and in the side of the tank, near the bottom,



are several horizontal slits, which can be opened and closed at will. When they are opened the water pours from them in several torrents.

After the sheep have been soaked and rubbed sufficiently, they are held under these rushing streams of cold water from the upper tank, and this effectually washes away all the dirt from the wool.

Machinery is also used for removing in a marvellously rapid way the wool from the pelts in the tanyards; but the shearing of the live animals of course has to be done by hand.

Lesson XXII

Third Order of Levers

" You see, boys, I have fitted up our model lever again for a lesson," began Mr. Wilson. " There is still another kind of lever calling for our attention; and it differs in its arrangements from both the orders which we have already studied. We shall speak of it as a lever of the third order.

" If you examine the model, you will see that it is arranged, so far as its fulcrum is concerned, in exactly the same way as we arranged it for the lever of the second order; that is to say, the fulcrum is placed at one end.

" Can you tell me the relative positions of the power and the weight in levers of the second order ? "

" Yes, sir," replied Will; " the power is always at the end of the lever, opposite the fulcrum, and the weight or resistance somewhere between the two."

" Quite right, my lad; and in the third order the difference is that these relative positions of the power and weight are changed. In the third order of levers *the weight is always at the end opposite the fulcrum*, and the power acts between them. Turning now to our model, we will first get rid of the difficulty arising from the weight of the bar itself. If we support it, as we did before, over the grooved wheel with a cord and a sufficiently heavy weight, we shall have our lever ready for work.

"Let us begin, as before, by hanging our 1 lb. weight at the end of the lever. This time, however, we will attach the cord to the middle hole in the bar, and pass it over the grooved wheel above. This cord shall represent, as it did in the other case, the power; but it is acting now just half-way between the fulcrum and the weight.

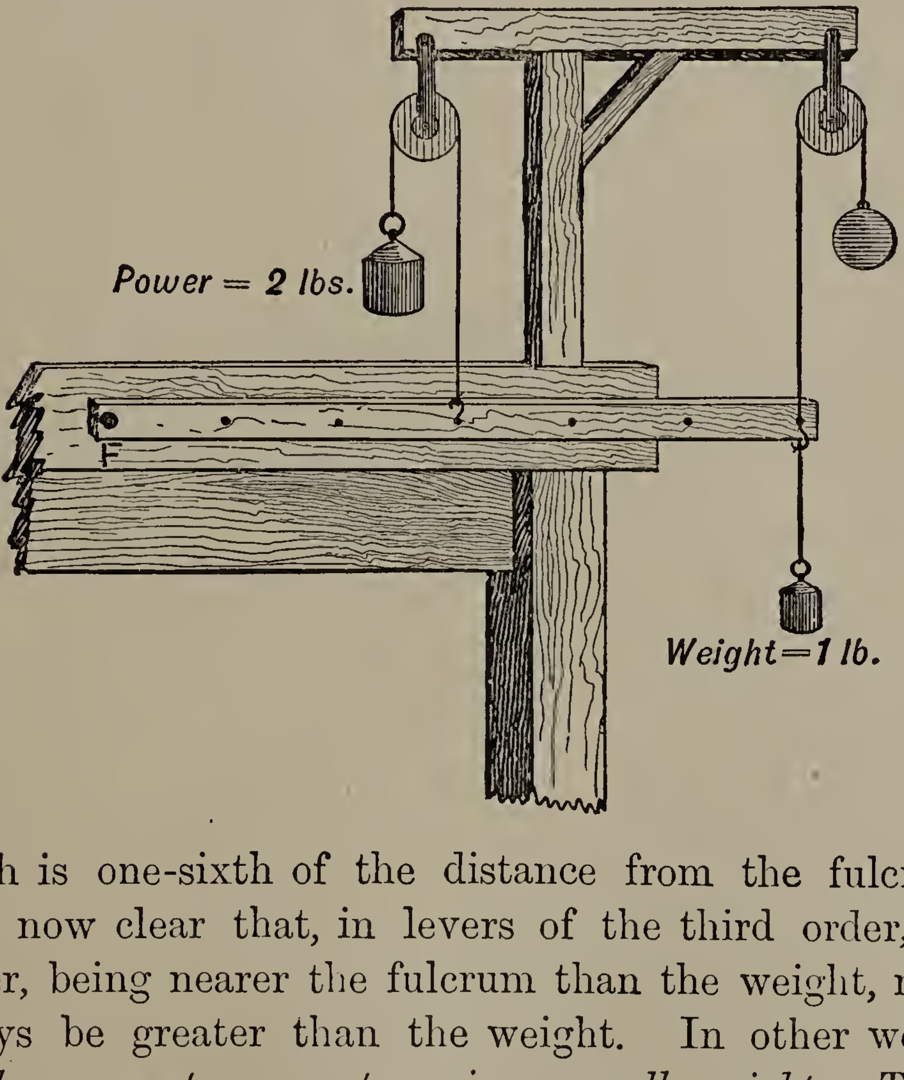
"Take the end of the cord in your hand, Fred, and support the lever, so as to keep it balanced in a horizontal position. What is the weight you are holding up?"

"The 1 lb. weight hanging at the end of the bar, sir," replied Fred.

"Just so, my lad. Now let us see what force you are exerting on the cord to support this 1 lb. at the end of the lever. I will attach another 1 lb. weight to the cord; but now if you let go, the lever no longer rests horizontally—the two do not balance. We shall require 2 lbs. hanging from the cord to balance the 1 lb. at the end of the lever. That is to say, you had to exert just now a downward force of 2 lbs. to keep the bar horizontal.

"You ought to be able, from what we have already done, to tell me the reason for this. The weight-arm is twice as long as the power-arm; therefore *the power must be twice as great as the weight.*

"If we remove the cord for further experiments, we shall find that when we attach it to the second hole, *i.e.* at one-third the distance from the fulcrum, we shall require 3 lbs. at the end of it to balance the 1 lb.; and 6 lbs. weight will be necessary to preserve the balance, with the cord attached to the first hole, which is one-sixth of the distance from the fulcrum. It is now clear that, in levers of the third order, the power, being nearer the fulcrum than the weight, must always be greater than the weight. In other words, *it takes a great power to raise a small weight* There is a loss of power. But the law of levers says that loss of power means gain in speed. Let us see whether this is true of the third order of levers as well as the others.



"Indeed, you shall see for yourselves. I will attach a very small additional weight to the cord, and leave the model to take its own course. The balance is at once upset; the weight at the end of the lever is carried rapidly upwards; and it moves through a much greater space than the weights at the end of the cord.

"Hence we see that in levers of the third order there is no gain, but an actual loss of power; *the mechanical advantage is a gain of speed.*

"A shovel in the hands of a man, shovelling up coals, sand, or corn, will give a good illustration of the use of this kind of lever. The handle held in one hand becomes the fulcrum; the coal, sand, or corn to be lifted is the weight; and the power is applied by the other hand to some point in the shaft, between the weight and the fulcrum.

"The man gains nothing in power—he actually loses power, for the force he expends is greater than the weight he lifts. When the weight is greater than usual, he shifts his power-hand down—nearer the weight. Why?

"What he loses in power, however, he gains in speed; and the heap of coals is rapidly moved.

"A man with a pitchfork and a load of manure, hay, or straw is, of course, a similar illustration.

"A simple illustration of this kind of lever is also afforded by the treadle of a sewing-machine, a harmonium, a grindstone, or a lathe. The hinge of the treadle of course forms the fulcrum; the weight to be moved is attached to the opposite end; and the power is applied by the foot on the treadle itself.

"There is no gain of power. The person using the machine expends greater force than is represented by the weight lifted. But speed is the thing desired here, not increase of power. Think of the sewing-machine.

The movement of the foot on the treadle is slight as compared with the greater and more extended movement of the crank at the back of it, and of the wheels which it causes to fly round. *There is a gain of speed.*

"One other familiar illustration of these levers is presented when a man raises a long ladder with the lower end pressed close up to the wall. That lower end is, of course, the fulcrum. Think of the ladder as it lies on the ground. The man takes the opposite end in his hand and raises it, moving downwards from one round of the ladder to another. For a long time the weight is between him and the fulcrum, and the ladder is *a lever of the second order.* After a time, however, as he still moves on, he gets between the weight and the fulcrum, and the rest of the raising movement shows the work of *a lever of the third order.*"

Lesson XXIII

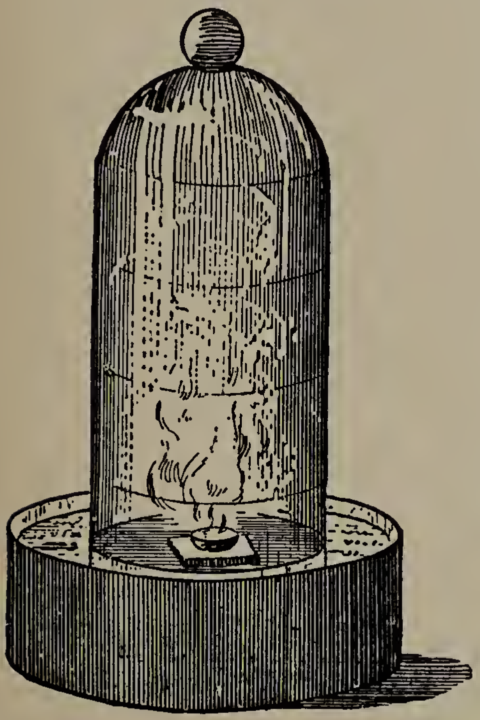
AIR, A MIXTURE OF GASES

"I want you to think for a few minutes about our experiment with the soda-water bottle, and what it taught us," said Mr. Wilson. "You remember, of course, that I filled the bottle with a mixture of the two gases, oxygen and hydrogen. I might have corked up the bottle and left it for any length of time, and in the end it would have contained, not water, but merely a mixture of the two gases, each one possessing its individual and distinctive properties. The flame, however, changed them entirely. With the explosion there was a chemical union of the two gases into a totally new compound—*water*—possessing the characteristics of neither.

"After this little recapitulation, we may now turn to the subject of to-day's lesson—*the air.*

"You remember, I daresay, the experiment which helped us to find out the composition of air. I have everything ready to repeat the experiment now. You shall tell me, as before, how I am to proceed."

"You have only to float the saucer in the water, sir," said Will, "with the little piece of lighted phosphorus on it, and then cover it with the bell-jar."



Mr. Wilson followed the directions, with the usual results. The water rose in the jar to take the place of the oxygen, which the phosphorus had removed by its combustion. That which was left above the water, in the upper part of the jar, was the gas—nitrogen. The jar originally contained four times as much nitrogen as oxygen. The oxygen was now all gone, and four-fifths of the jar was filled with nitrogen.

Mr. Wilson proved it to be nitrogen by plunging a lighted taper into it. The taper was immediately extinguished. Nitrogen is characterised by its negative properties. *It does not support combustion, and is itself uninflammable.*

"But," said he, "we actually saw the phosphorus burning in the jar of air. Why did it burn?"

"Because," replied Fred, "although four-fifths of the air in the jar consisted of nitrogen, a non-supporter of combustion, the remaining one-fifth was oxygen, and it was the oxygen that supported the burning."

"But," said Mr. Wilson again, "water contains more oxygen in proportion than air, for one-third of its bulk is oxygen; and yet we know that the oxygen in the water cannot support combustion. Water at once extinguishes all fire. Why should the oxygen in the air be able to do what the oxygen in the water cannot do?

"Let me make this clear to you. In the first place, although water contains a large amount of oxygen, that oxygen is in chemical union with the other element, hydrogen. It is not free; it forms, for the time, an inseparable constituent of the new substance—water; it has lost all its own distinctive properties. *The properties of water are totally different from those of either of its constituent gases.*

"On the other hand, the oxygen and nitrogen, as constituents of the air, have entered into no chemical union. *Each is free; each retains its own individual properties.* The oxygen of the air is still the active agent and promoter of burning or combustion, although, by being diluted with four times its bulk of nitrogen, it has lost much of its power.

"I am now going to prepare some oxygen in the usual way, and, as the gas comes off, I will let it pass, by means of the delivery-tube, into the bowl of water in which our jar of nitrogen stands. You will see it rise in bubbles, and gradually displace the water in the jar."

When all the water had left the jar Mr. Wilson called attention to the fact that there was now a mixture of nitrogen and oxygen in it, the quantity of nitrogen being four times that of the oxygen. He reminded the class that there was no flash, no heat, no explosion, when these gases mingled. They were not chemically united—they were *merely mixed,* as we might mix salt or sugar with sand; water with wine or vinegar.

"Now," said he, "we will plunge the lighted taper into the mouth of the jar." He did so; but the flame itself did not cause any explosion. The taper burned as quietly inside as it did outside the jar, but no brighter.

"Remember," he added in conclusion, "the taper went out immediately we plunged it into the pure nitrogen just now. But here we have a mixture of nitrogen and oxygen. It is the diluted oxygen which maintains the flame of the taper. We have actually made a jar of ordinary atmospheric air."

Lesson XXIV

VARIETIES OF WOOL

In our former investigations into the general properties of wool, and the leading facts connected with the woollen trade and manufacture, we dealt only with the wool of the sheep; and, generally speaking, whenever we think of wool, it is the sheep's wool that we mean.

Other animals, however, besides the sheep yield valuable wool; we shall now proceed to examine them and their products, one by one.

They are all *ruminants;* and among them the most closely allied to the sheep is the goat. The common goat has a more or less coarse covering of long hair; but some of the goat family are clothed in wool of excellent quality.

The most important of the wool-bearing goats is the *Asiatic,* or, more properly speaking, the *Angora goat.* It has a long, white, silky fleece, which is clipped annually, and averages from 2 to 3 lbs. in weight.

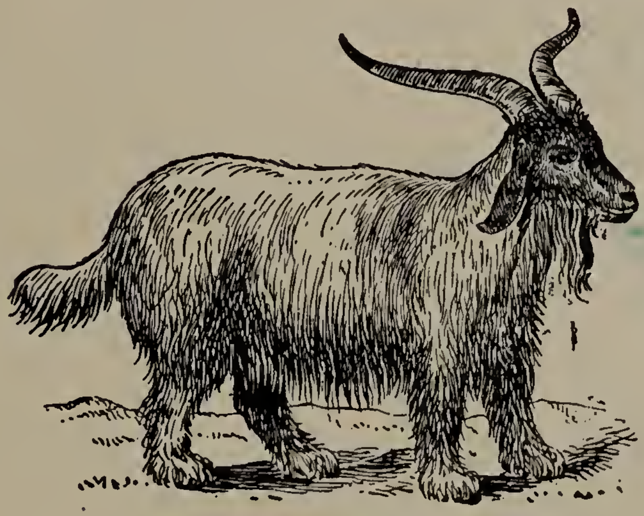
Angora wool is in great demand. The imports at centres of manufacture reach many millions of pounds annually. It is known best as "mohair," and it varies in quality according to the length and fineness of its staple and the softness and silkiness of its appearance. It often rivals silk in lustre.

ANGORA GOAT.

The Angora goat has been transported from its original home into many parts of the world, and is now successfully reared in South Africa, in several of the Australian colonies, and in the United States, especially on the western or Pacific slopes. In all these places the stock is increasing rapidly, as the animals are exceedingly prolific.

In very close relationship to the Angora goat are the *Thibet, Persian,* and *Circassian goats.* Indeed, all four are one and the same animal, differing only according to the varying conditions under which they live.

The *Thibet,* more generally known as the *Cashmere goat,* has long been famous for the soft, downy silkiness of its wool. The best of it is known as *pashum,* or *shawl wool,* and is manufactured locally into costly shawls. Much tedious care and labour are bestowed on the production of these shawls, each part of the process being allotted to separate individuals. Indeed, it is said that the manufacture of one pair of shawls has been known to occupy every member of a workshop for a year and a half. As a consequence of this extreme care on the part of the manufacturer, these Cashmere shawls are very expensive and greatly prized. The production of a single shawl often represents as much as $3500; and Eastern potentates always bestow these costly shawls upon



CASHMERE GOAT.

their most distinguished visitors, as a special mark of their favor.

The *llama* is another important wool-bearing animal. It is a native of South America, where it is used as a beast of burden. Even the cottagers of Peru have their little flocks of these animals, perhaps a dozen or more, to carry their goods to market. The more important traders usually drive them, with their burdens, in flocks varying from 500 to 1000.

THE LLAMA.

The llama wool is not exported from Peru, as it is much in demand locally for the manufacture of carpets, sacking, and ropes. The llama family include, in addition to the llama itself, the *alpaca,* the *vicuna,* and the *guanaco.*

Of these the most important by far, as regards the wool, is the *alpaca.* The fleece, which is shorn annually, averages from 7 to 12 lbs. in weight, and is superior to the wool of the sheep for the length and softness of its fibre.

The Peruvians set such high value on this animal that they long guarded it with jealous care. The consequence was that the value and beauty of alpaca wool were unknown to Europeans till quite recent years.

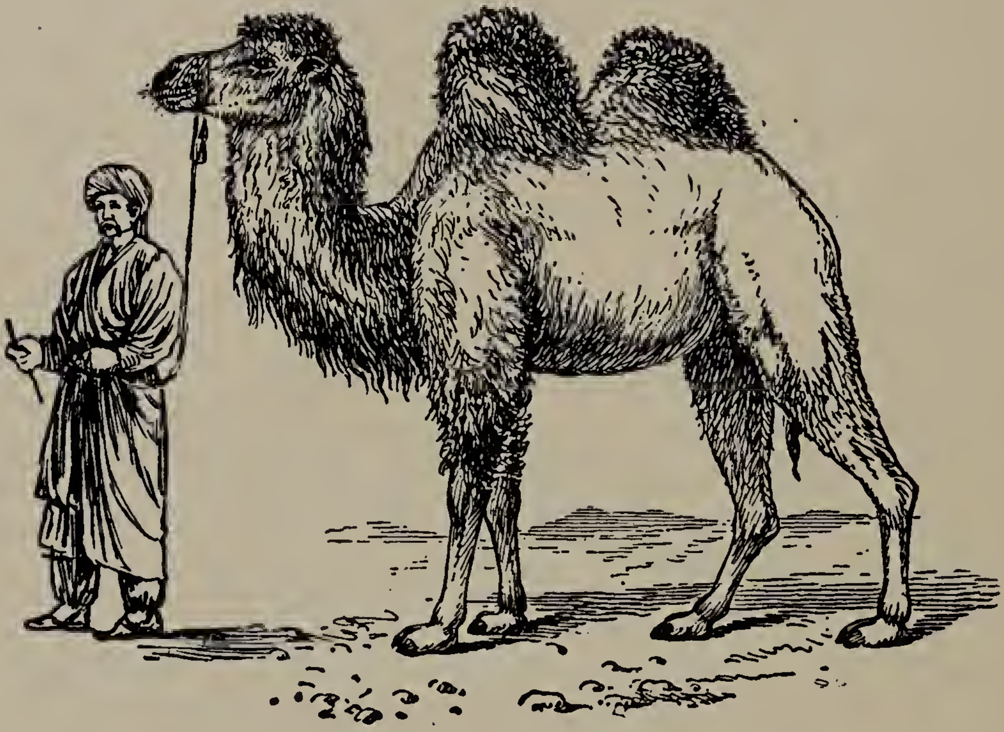
THE ALPACA.

Sir Titus Salt introduced it into Europe, and set up the manufacture of alpaca goods in the village which has since been called Saltaire from his name, and is to-day a flourishing town.

Annual exports of alpaca wool now average from 4 million to 7 million lbs. weight, and the alpaca manufacture ranks as one of the staple industries of the world.

The manufacture of vicuna wool is still in its infancy, although this wool is said to be superior, in many respects, to alpaca wool. The wool of the guanaco is not yet imported to any large extent into this country.

The *camel*, both as a beast of burden and also as a wool-bearing animal, is to the East what the llama is to the people of South America.



THE BACTRIAN OR TWO-HUMPED CAMEL.

The wool of the camel is shorn every spring. That of the two-humped camel is highly valued for the soft silkiness of its staple, and is made into costly articles of clothing. A shawl made of camel's wool often fetches as much as $900.

Camel's hair is imported into this country mostly for the manufacture of delicate brushes or pencils for painting. The camel is a marvellous example of Nature's beneficence in fitting each animal for the special conditions under which it has to live. No other animal would be so suited to those regions, either in its wild state or as a domesticated beast of burden.

In those dreary wastes of sand food and drink are to be obtained only at long intervals apart. Nature provides the camel with what would seem at first sight an ugly, awkward encumbrance, in the shape of an enormous hump on its back. That hump, however, is nothing but a huge mass of nutriment, from which the creature can draw during the time of scarcity of proper food. In this animal, moreover, the honeycomb bag, which is common to all ruminants, becomes a receptacle for storing a large supply of water, so that a severe drought is of very little moment. It has

THE DROMEDARY OR ONE-HUMPED CAMEL.

cutting teeth in both jaws, and powerful grinders for masticating the rough, prickly vegetation, which is the only sustenance it can find on those sandy wastes. Its eyes, ears, and even its nostrils are specially protected against the clouds of loose, shifting sand which often fill the air. Its foot consists of two toes, and has wide-spreading cushions, which prevent the animal from sinking into the loose sand at every step, and even its knees are provided with thick, hard skin, or callosities, to enable it to kneel on the burning sand without injury. It always kneels to rest, and while it is being loaded.

Lesson XXV

THE WORK OF BREATHING

We have now a clear notion of the kind of work that goes on in the lungs—that incessant exchange, by osmosis, through the delicate walls of the air-cells, and the capillaries which surround them, enabling the blood to give up its impurities, and at the same time to take in fresh supplies of oxygen. Think for a moment of those air-cells. The air which they contain is being perpetually deprived of its oxygen, and loaded with carbonic acid and water-vapor in place of it. In a very short time that air, if it were not constantly renewed, would lose the whole of its oxygen, and become completely saturated with carbonic acid. This is why the work of breathing never stops, sleeping or waking. The impure, vitiated air must be driven out, and pure air taken into the lungs to supply its place.

A healthy man, resting calmly in a sitting position, breathes from thirteen to fifteen times every minute, but as soon as he begins to exert himself with exercise of any kind, the breathing becomes more rapid, and continues to increase in rapidity in proportion to the exertion he makes.

Each breathing consists of three distinct acts, following each other in regular order. First, a quantity of air is drawn in. This is called an *inspiration*—that is, a breathing in. As soon as the inspiration is over the second act commences, and the air is driven out, or expelled, from the mouth and nostrils. This is called an *expiration*, or a breathing out. Following the expiration comes a pause; after which the same process is perpetually repeated, and always in the same order—*inspiration, expiration, pause*—like some beautiful piece of machinery.

The mechanical work of breathing is due to three causes—the pressure of the atmosphere, the elastic nature of the lungs themselves, and the character of the air-tight box which contains them.

The thorax is absolutely air-tight; no air can get in between the lungs and the outer walls of this chamber. The lungs themselves, however, are full of air, which is brought to them by the windpipe and other air-passages, and presses with a force of nearly 15 lbs. on every square inch. This enormous pressure from within the lungs forces them outwards against the sides and floor of the chamber. The chest itself is protected by a hard, resisting, bony cage, and not by soft, flabby walls, so that, although the outer air is pressing with the same force, it cannot squeeze that chamber, nor affect the lungs inside. The lungs, therefore, are pressed outwards against the walls of the chest by the air within them, but they feel no pressure from without.

The ribs, which form the walls of the thorax, are jointed to their vertebræ by joints which allow them a limited up-and-down movement. The spaces between the ribs are occupied by stout, strong muscles, whose sole duty it is to move the ribs. One set of these muscles raises them, the other set depresses them; and we have already seen that these respective movements enlarge and diminish in turn the capacity of the chest.

Now let us turn to the diaphragm, which forms the floor of the chamber. It is attached to the ribs all round, and the central part of it rises in the form of a hollow dome or arch. It is clear that, if such a floor could be forced down in any way, it would considerably enlarge the chamber above.

You already know that this diaphragm is a stout, strong, muscular partition. Like all other muscles, it has the power of contracting, and when it contracts its muscular fibres are shortened, so that the dome or arch is pulled down and flattened. This contraction, and consequent pulling down of the diaphragm, always takes place at the very moment when the ribs are being raised; and hence the chest is enlarged on all sides at once.

While this is going on the elasticity of the lungs enables them to stretch out, to fill the larger space, and the air rushes in down the windpipe to fill all the little distended air-cells, or there would be a vacuum. This is the whole mechanism of an inspiration.

Immediately after the inspiration the diaphragm ceases to contract, and springs back by its own elasticity, while the ribs too are being depressed, so that the chest is diminished in size from both causes at the same time. Meanwhile the lungs themselves assert their power by contracting, so that each little air-cell is squeezed into smaller space. In this way some of the air is driven out from the lungs, and we have an expiration.

Lesson XXVI

The Pulley

"If you please, sir," began Fred one morning, "I have been thinking a good deal lately, first about the levers, and then about that grooved wheel, which the workman uses to raise his materials from the ground to the scaffold where he is working. I pictured to myself a large block of stone lying on the ground ready for the workman to use, if he could only manage to raise it. I purposely forgot all about the wheel, and began to wonder whether he could raise the stone with no other help than the lever."

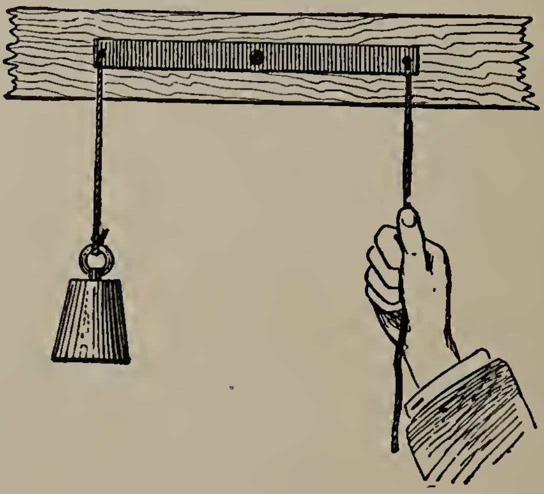
"Well, my lad," replied Mr. Wilson, "and what conclusion did you arrive at?"

"I think he could do it, sir, but it would be done with tremendous expenditure of force and time. The lever would only succeed in raising the stone a little way; then he would have to prop it up in that position, take another fulcrum, and raise it a little higher; and all this would have to be repeated again and again many, many times before he could raise the stone where he wanted it."

"Yes, Fred, you are right," said Mr. Wilson, "or he might fix his lever and its fulcrum on the scaffold itself, and connect one end of it, by means of a rope or a chain, with the block of stone below. The rope or the chain, as we have already seen, would transmit to one end any force which is applied to it at the other. The man, by applying force to the lever at the top, would thus be enabled to raise the block a short distance, as your man did with the lever on the ground. Then it would have to be propped up and lifted, as before, little by little.

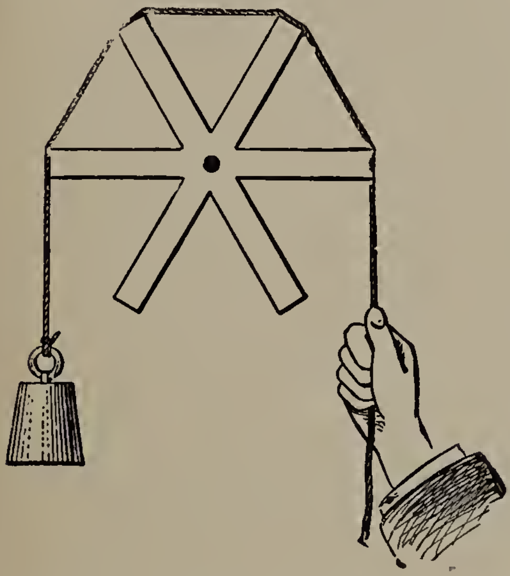
"But your plan as well as mine, Fred, would be exceedingly tedious, and wasteful as regards the expenditure of force.

"Now let us see how this use of the lever first suggested the idea of another machine—*the pulley.* I have here a short wooden bar or lath, similar to the one we used for our model lever, except that it is only about a foot in length. I have drilled a hole through its centre and we will fix it to the edge of the table as before, leaving it free to move on a nail. The nail thus becomes the fulcrum, and *the bar is a lever of the first order, with equal arms.* We will next attach a cord to the end of each arm, and you, Fred, shall hold one of the cords in your hand, while I hang a weight to the extremity of the other.



"Pull your cord down now, Fred, and you will find that, as the arm of the lever on that side is lowered, the other rises on the fulcrum, and with it the cord and the weight attached to it. Continue the pulling and let us see how far you can raise it. You see at once that you can bring the lever into a vertical position, and so raise the weight a short distance; but beyond that it will not move.

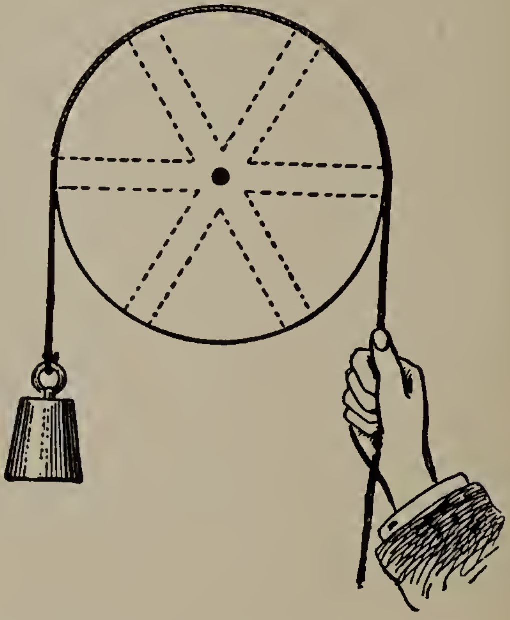
"Now, instead of a single lever, I am going to show you a little contrivance, which consists really of *several levers, all of the same length,* and so arranged as to cross each other at the same point—the centre of each. Through this centre I have drilled a hole as before. Our contrivance looks very much like the spokes of a wheel. Let us now fix our wheel up to the table edge by means of a nail through its centre. The nail thus becomes the fulcrum of each of these separate levers. They are all free to move on this point.



"Before we proceed further, I want you to notice that I have cut a groove in the extremities of each lever. This groove shall receive the cord which is going to help us to do our work.

"Hold one end of the cord in your hand, Fred, as before, while I hang a weight to the other end. Now pull your end of the cord down, and you will easily raise the weight at the opposite extremity. Each spoke of the wheel in turn takes its share of the work, and acts as a separate lever.

"We are now in a position to pass to another little contrivance. Here is a circular wooden disc, with a groove cut round the circumference, and a hole drilled through its centre. On the face of the disc I have marked plainly in chalk a number of diameters, to represent as many levers all crossing at the centre. If we fix the disc to the edge of the table in the usual way, and pass a cord with its weight round the grooved circumference, the principle of action will be at once made quite clear. This revolving wheel is nothing but *a succession of levers of the first order.*



"Your mind goes back, of course, to the grooved wheel which the workman used on the scaffold; and you are quite right, although we are now going to give it a better name. The weight at one end of the cord is raised by the person pulling at the other end. Hence we call this grooved wheel *a pulley.* We also call it a fixed pulley, because it is fixed, and works on some kind of pivot at its centre.

"Suppose we next think for a moment, not of the wheel itself, but of some one of its imaginary levers. These are all of the same length; they are diameters of the same circle. Each one has two equal arms.

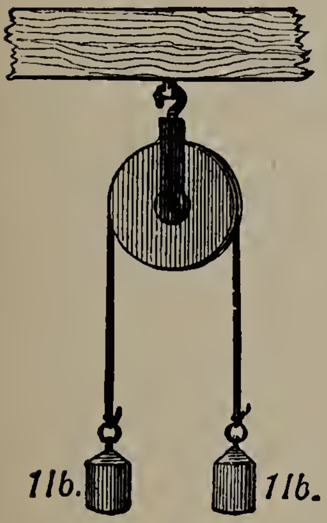
"Now, if I wish to raise a stone weighing 50 lbs. with a lever of the first order, having equal arms, what force must I use?"

"The force or power must be equal to the weight, sir," replied Fred, "because the arms of the lever are equal."

"Then are we to understand that such a lever gives no mechanical advantage?"

"It does give an advantage, sir, although not in the amount of force required, but in the direction in which the force is applied. We raise the weight by applying the power downwards, not by lifting it."

"Quite right, Fred; and what is true of a single lever ought to be true of a number, and hence also of the pulley.



"We have seen that it is true of the pulley as regards direction. Let us next see whether it is also true with respect to the amount of force required.

"If I hang a cord over the pulley, with equal weights at its extremities, they will balance, and the smallest addition to either will cause the other to rise. Hence we see that the forces on either side of such a pulley must be equal if they are to balance. There is no mechanical advantage so far as the amount of force is concerned."

Lesson XXVII

CHLORINE

"In the course of our lessons I have made you acquainted with a great many gases," began Mr. Wilson. "We have had them before us in bottles and other glass vessels; we have experimented with them; and yet we have never seen them. You have been obliged, in each case, to trust to my statement at first that the gas was there at all, although we have always proved its presence afterwards by its action. This morning I am going actually to show you a gas. I will put equal quantities of common salt and black oxide of manganese into this mortar, and you shall crush and mix the two well together for me, Fred, while I get everything else ready."

He first diluted a little sulphuric acid with an equal quantity of water, and stood the mixture aside for a time to cool, and then arranged a flask, the Bunsen burner, and a number of perfectly dry gas-jars on the table ready to hand. As soon as the dilute acid was cool enough, he put into the flask the powdered mixture which Fred had prepared, and poured the dilute acid on it, till it began to look like a thin paste at the bottom. He then passed the flame to and fro under the flask, so as to apply the heat gradually and gently. In a very short time a dense yellowish-green gas was seen to rise rapidly, and pass along the delivery-tube into the dry bottles, one after the other.

"This gas is the element *chlorine*," said Mr. Wilson. "It is a heavy gas—$2\frac{1}{2}$ times as heavy as air. Hence, as it collects at the bottom of the bottle, it forces the air out at the top. We are collecting the gas by displacement, just as we collect carbonic acid gas."

As soon as all the gas jars were filled, Mr. Wilson had them covered, and the whole of the apparatus removed from the room. He explained to the boys that this gas is a violent irritant, and would set them coughing if they breathed it.

"Now," said he, when everything was ready again, "we have plenty of chlorine; let us see what we can learn about it."

He began by taking one of the jars and lowering into it the deflagrating spoon with a piece of phosphorus in it about the size of a pea. The phosphorus immediately took fire, and burned in the chlorine with a pale green flame, till it was all consumed. This bottle, closed as it was, he then set aside. He next showed the class a leaf of Dutch metal, and told them that it was really copper-leaf. This he lowered into the second jar of chlorine, and it was no sooner placed in the gas than it ignited and burned with a smoky flame.

"Now, boys," said he, "before we go any further let us think over what has taken place. In each case we have seen a spontaneous chemical action going on. Both the phosphorus and the Dutch metal ignited of their own accord in the jars of chlorine gas.

"In the first bottle the phosphorus united with the chlorine gas to form a new compound, giving off light and heat during the combination. In the second bottle the copper also united with chlorine to form a new compound, and in this case too heat and light were evolved during the process.

"Now we have already given a name to this kind of chemical action. We call it combustion. But we have hitherto always associated oxygen with the act of combustion. Here, however, we find a new gas—chlorine—as a supporter of combustion, and we see that the usual heat and light are evolved during the chemical combination. When chlorine combines with another element the new compound formed is called a chloride. Thus the compound formed by the combustion of phosphorus in chlorine is a new substance—*chloride of phosphorus;* the compound formed, in like manner, by the combustion of the copper is a substance known as *chloride of copper.*

"Similarly, chlorine forms compounds or chlorides with nearly all the elements.

"I have a most important chloride to show you now. You remember, of course, the metal potassium. Here is another metal very similar to it, and like it, this one must be kept bottled up in naphtha or paraffin. We call it *sodium.*"

He took a piece out of the bottle, and cut off a small pellet from it, calling attention, as he did so, to the bright silvery lustre of the newly-cut edge. He placed the pellet of sodium in the deflagrating spoon, and held it in the flame of the Bunsen burner till the metal was in a molten state. In this condition he lowered it into the other jar of chlorine, and in an instant the liquid metal took fire, and burned with intense heat and a very bright glowing light. As the light died away the jar was seen to be filled with dense white fumes.

"Now it is clear from what we have already seen," began Mr. Wilson again, "that as the sodium has been burned in chlorine, there must be a new compound formed, and that compound must be *chloride of sodium.*"

He pointed out the deposit on the bottom of the jar, left there by the condensation of the white fumes.

"This substance then," said he, "must be the chloride of sodium. Let us see what it is like."

He poured a little water into the jar, and after washing it round, asked the boys to dip their fingers into it and taste it.

"Why, it tastes just like salt," said Fred.

"Yes, my lad, it does," said Mr. Wilson, "for it is really salt. The chemical name for the common salt which we use every day is *chloride of sodium.*

"It is important to remember that neither the gas, chlorine, nor the metal, sodium, is ever found in the pure or free state in nature. The waters of the ocean and the vast beds of rock-salt in the crust of the earth contain abundant supplies of them in this compound form—chloride of sodium."

Chlorine is also interesting to us as forming a chief element by which linen and other cloth is bleached. One of the peculiar properties of this gas is to destroy vegetable colors. Combined with lime into chloride of lime it is used to a vast extent.

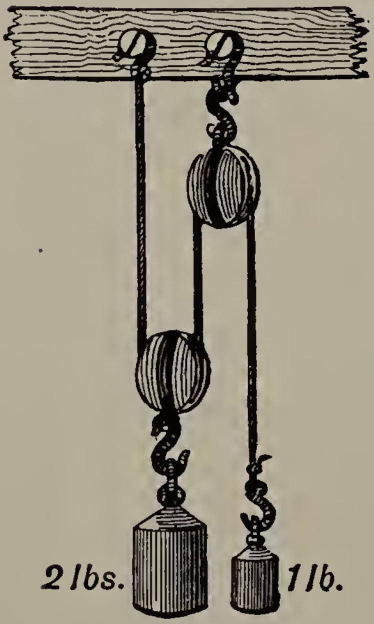
Before the discovery about one hundred years ago of its use in this way, cloth was bleached mainly by exposure to open air and sunshine. Now by a most intricate but speedy process the original browns and yellows of the flax are turned into a lustrous white. Chloride is also used in bleaching paper-making material, and in whitening and cleaning prints, maps, books, and other articles.

Lesson XXVIII

The Movable Pulley

"I saw some men yesterday, sir, raising chests of tea to a loft in a warehouse by means of the pulley," said Fred. "But I have been very much puzzled ever since about that pulley; it was not fixed to a beam, as ours was the other day, but moved up and down the rope. There was a hook fixed to the pulley itself, and this held the chests which had to be raised."

"Ah, Fred," said Mr. Wilson, "your puzzle is nothing more than a block-pulley. Here is one; see, it answers in every way to your description, and it has a hook at one end of it. Let me explain how it is used.



"I will pass this cord round it, and fasten one end of the cord to the cross-beam of our stand. Now we will hook a 2 lbs. weight to the pulley, and you shall mount on the table, and support it by holding the other end of the cord. Try and keep the two parts of the cord parallel, while we examine the working.

"Pull the cord upwards, and watch what happens. As you pull, the block rises and carries with it the weight which is attached to it.

"This pulley, you see, instead of being a fixture like the one in our former lesson, moves upwards when force is applied to the cord. We call it a movable pulley.

"Now the entire weight supported by the block is 2 lbs. The block, that is to say, is being pulled downwards with a force of 2 lbs., the force of gravity due to the weight of the body itself; and this weight of 2 lbs. is supported by two cords.

"Now I want you to notice that there is a strain or tightness about the two cords. We call this strain the *tension of the cord.* In the present case, as the 2 lbs. weight is supported by two cords, each one (or rather each part of the cord) ought to bear half the strain or tension. That is to say, you ought to be supporting the 2 lbs. weight with the expenditure of a force of 1 lb. at your end of the cord.

"If this be true, the movable pulley gives a distinct mechanical advantage, as far as power and weight are concerned. Any given power will raise a weight of twice its value.

"But what have you to say about direction? Is there any advantage in the direction in which the power is applied?"

"I don't think there is, sir," replied Fred, "and I ought to know, for I have been supporting the weight all this time by pulling the cord upwards."

"You are quite right, Fred; *the single movable pulley gives no advantage in direction.* At the same time it gives us no means of testing the truth of our statement with respect to the tension in the cord. But we will test it, for all that.

"You shall pass the free end of the cord over the fixed pulley, suspended from the beam, and after taking care to see that the two parts of the cord are parallel, we will then hang a 1 lb. weight at that end, and leave the machine to take care of itself. The result is proof at once. The 1 lb. force at the end of the cord balances the 2 lbs. weight hanging from the block.

"We have already learned that the fixed pulley, from its very nature, gives no advantage in power—a certain weight on one side requires an equal weight on the other to balance it. In other words, the tension of the cord on both sides is the same. But our pulley tells us that the tension of the cord on one side is 1 lb. Therefore the tension of that on the other side is 1 lb. also.

The movable pulley gives a mechanical advantage in power. It divides the weight equally between the two parts of the cord. Hence, by using a fixed pulley with a movable pulley *we get a double advantage.* The movable pulley divides the weight between the two cords, so that only half the force is necessary; and the fixed pulley effects a change in direction downwards.

"Just one thought more. We will first lower the 2 lbs. weight, and then you shall raise it by pulling the opposite end of the cord down over the fixed pulley. Notice that the distance through which the power end of the cord moves is twice that through which the weight moves. In other words, the weight moves at only half the speed and through half the distance travelled by the power. We see once more that *gain in power* means *loss in speed.*"

Lesson XXIX

PLANTS USEFUL FOR FOOD

SPICES

We have now to deal with another very useful class of vegetable products, distinguished by their powerful aromatic odor and pungent flavor, and known by the common name of spices. It is to these special properties that they owe their importance. They are valuable as flavorers. Chief among them are the clove, nutmeg, mace, cinnamon, ginger, pepper, and allspice.

The clove is the dried flower-bud of a kind of myrtle-tree. The tree itself is a very beautiful evergreen, which grows four or five times as high as a man.

When the flower-buds first appear they are of a pale yellow color, but they gradually pass to green, and finally to a bright red. As soon as they begin to turn red, and before they open into actual flower, they are plucked and dried in the sun. When dried, they assume the dark brown color with which we are familiar. The little round knob or ball at the end of the clove is the actual corolla of the flower folded up. The name *clove* is given from the Latin *clavus, a nail,* because the clove is said to resemble a little nail.

Cloves are used by the cook and confectioner for flavoring purposes. When pressed they yield a useful volatile oil, known as *oil of cloves,* which is largely employed in perfumery and medicine.

The clove is a native of the Moluccas or Spice

Islands, but it is now grown in Sumatra, Mauritius, Zanzibar, Brazil, and the West Indies.

The nutmeg, another valuable spice, is the seed of an evergreen tree, which is a native of the Moluccas, and is now grown in most of the East India Islands, in the West Indies, and in South America.

The fruit when ripe is a rich golden yellow, and something like a peach. Indeed, it is a kind of stone-fruit. The outer fleshy part encloses the stone, the hard brown shell of which contains a round nut or kernel—the actual nutmeg. As the fruit ripens the outer fleshy covering splits, and then may be seen the dark brown, almost black shell of the kernel, enclosed within a leafy-looking network of a brilliant red color.

This is the time for gathering. The fleshy outside part is not unlike candied fruit, and is preserved and eaten as a sweetmeat. The bright red network-covering is stripped from the shell and dried. As it dries it assumes a yellow color; it is the mace of commerce, in itself a distinctive and very useful spice.

The nuts, with the mace removed, are carefully dried in the sun, until the kernels begin to shrink, and can be heard to rattle in the shell. The shells are then broken with wooden mallets, and the kernels—the actual nutmegs—sorted for use.

The smallest of the nutmegs are not sent into the market. They are pressed, and made to yield a valuable volatile oil, known in commerce both as *oil of mace* and *oil of nutmeg.*

Cinnamon, which we have next to consider, is neither the flower-bud nor the fruit. It is the inner bark of another tropical evergreen. The best cinnamon is grown in Ceylon, but it is now to some extent cultivated in China and South America.

The tree is usually grown from seed, and the branches are cut when they are from two to three years old. They are then about the size of an ordinary cane. The bark is peeled off with a knife, and laid in the sun to dry. As it dries it turns brown, and curls up into little rolls as we usually see it. Cinnamon is a very valuable spice, and is largely used in cookery, confectionery, and perfumery.

Ginger is the underground stem of a plant, something like a common reed, which is cultivated in most tropical countries. It was originally a native of Southern Asia and the adjoining islands, but is now largely grown also in the West Indies. The ginger of Jamaica fetches the best market prices. A delicious sweetmeat is made by preserving the young shoots in sugar-syrup. It is known as candied or preserved ginger.

Although pepper may be regarded rather as a condiment than a spice, it is usually classed among the spices.

Pepper is the berry of a climbing shrub, which, although a native of the East Indies, is now cultivated in most tropical countries.

We use the berries whole as well as ground. Black pepper and white pepper come from the same berry. If the dried berry is ground as it is, we get black pepper; white pepper is obtained by soaking the berries in water, and rubbing off the black outer covering.

Allspice is the berry of an evergreen shrub—the pimento; it is sometimes called Jamaica pepper. It is grown in that island and the other West India Islands, and in South America. The name *allspice* is given to the berry because it is said to have the flavor of cloves, nutmeg, and cinnamon combined.

Lesson XXX

Carbon

"You all know this light, brittle, porous, black substance," began Mr. Wilson. "It is charcoal, or, to use the language of the chemist, carbon. Carbon, then, is to be the subject of our lesson this morning.

"Carbon is the main basis of all vegetable matter. If a plant be carefully dried, so as to drive off all the water it contains, more than half of what remains will be this substance, carbon."

Mr. Wilson then proceeded to show the class some carbon, which he had prepared in readiness for the lesson.

"Look at this piece of iron gas-pipe," he said; "it is full of carbon. This morning I filled it with chips of wood, closed up both ends with clay, bored a few holes in the clay stopping, and then put the pipe into the hottest and brightest part of the fire. After a time I removed it from the fire, and left it to cool.

"Let us now break away the clay, and see what we have inside. The wood has been changed in the pipe into charcoal or carbon, exactly like the piece I showed you just now.

"You must clearly understand that the wood has not been burned. If we put some similar chips on the fire, and let them burn in contact with the oxygen of the air, we shall notice that the whole of the substance will disappear, leaving nothing but a little white ash. By placing the wood in the closed pipe, within the fire, we caused the wood to decompose or separate into its constituents. Some of these constituents passed off, in the form of gases, through the holes in the clay; but the carbon itself, being closed in, was not allowed to come into contact with the oxygen of the air, and was therefore not consumed.

"We have already said that carbon is the chief constituent of all plants. We obtained it from the wood chips, and we could obtain it from any vegetable matter.

"Now, think for a moment of coal, which, you know, is formed from the buried remains of the forests of far-distant ages. The vegetation of those times, like the vegetation we meet with now, had carbon as its chief constituent; and hence the coal which we burn to-day consists very largely of carbon. If we heat coal in a closed vessel, as we did the chips of wood, we shall find this constituent, carbon, left behind in the form of coke, while all the other constituents pass off as gases."

Mr. Wilson next crushed a few pieces of lump-sugar in a mortar, put the powder into a saucer, made a syrup by pouring hot water on it, and then added a few drops of sulphuric acid. The syrup instantly turned color, and swelled up into a black mass, resembling a piece of coke.

"Sugar, you know," said he, when the class had got over their surprise, "is a vegetable substance; it is prepared from the sweet juice of the sugar-cane, beetroot, maple, and other plants. It is clear that the juice contains carbon, for the black mass you now see is simply carbon which has been set free by the sulphuric acid.

"Turning next to the animal world, we know that man and all animals feed directly or indirectly on plants. Hence the carbon of the plant is used to build up the tissues of the animal. There is carbon in all the tissues of the body; a special kind of charcoal, known as ivory black, is prepared from bones.

"Fat consists very largely of carbon, and the presence of carbon can soon be detected in the charring of the joint of meat before the fire, if the cook forgets to turn it.

"Among mineral substances carbon forms an important constituent in limestone and other rocks, and in plumbago, graphite, or black-lead, as it is sometimes called. The beautiful diamond—the most precious and brilliant of all gems—is simply a special form of carbon.

"Let us now have an old experiment, performed in a somewhat different way. I have here a jar of oxygen which I prepared in readiness for our lesson. I will place this piece of carbon in the deflagrating spoon, heat it to redness in the flame of the Bunsen burner, and then plunge it into the oxygen.

"The combustion goes on with greatly increased brilliancy, showing the powerful affinity that exists between carbon and oxygen. This is why, in preparing the carbon for the lesson, I put the chips of wood into the closed pipe. If they had been in contact with the oxygen of the air, the whole of the substance of the wood would have been consumed. You have already become familiar with the product formed by this combustion of carbon in oxygen. You call it carbonic acid gas. The chemist usually calls it *carbon di-oxide.* You are aware that all substances which combine in this way with oxygen form oxides. This is called *di-oxide* because it contains two parts of oxygen to one of carbon. *Di* means *two.* Our jar, then, is now filled with *carbon di-oxide.* You know many of the properties of this gas already. Let us learn a little more about it by means of an experiment. I have here a solution of blue litmus, which is a vegetable coloring matter. We will pour some of the solution into the jar of carbon di-oxide, and note what takes place. The blue color instantly changes to a bright wine-red when I shake the jar.

"Just one more experiment before we close the lesson. I will close the mouth of the jar with my hand, and place it, mouth downwards, in this bowl of water. As soon as I take my hand away, some of the water rushes up into the jar.

"Carbon di-oxide is very soluble in water. Water will dissolve its own bulk of this gas. This is why the water rushed up into the bottle."

Lesson XXXI

LEATHER—HIDES

The skins of many animals provide the material for making leather. Before we can properly understand what leather is, and how it is made, we must know something of the structure of the skin itself. We have already learned that the skin of all mammals consists essentially of two layers, one above the other. The outer layer is called the *scarf-skin, epidermis,* or *cuticle;* the under layer is the *cutis, dermis,* or *true skin.*

The cutis or true skin is composed of a mass of fibres, crossing and recrossing each other in all directions, the spaces between the fibres being filled up with gelatine, nerves, and blood-vessels. We usually speak of it as *fibrous tissue.* It is this fibrous tissue of the true skin which provides the material for leather.

If a skin be taken from an animal and thrown aside in a damp place, it will soon begin to smell badly and decay, for the gelatine in it has a strong tendency to putrefy when wet. But if the skin be at once hung up in a dry place, it shrinks and becomes horny and stiff, as the gelatine in it dries and hardens. The dried skin, however, would not only become soft again if it were soaked with water, but would soon begin to putrefy and rot away. A piece of leather, made from the same skin, loses this tendency to putrefy, increases in thickness, and, at the same time, becomes waterproof. It will be our business now to learn how the manufacturer is able to effect these changes in the skin.

The skins of animals used for leather are known as hides or pelts. It must be carefully borne in mind that only the fibrous matter of the true skin is of use to the manufacturer. The hair, the whole of the epidermic layer, and all particles of fat and flesh, must be removed. The hides are first soaked for about a fortnight in water; after which they are taken out and thrown into tanks of lime-water, where they are

allowed to remain for about ten days. The lime has the effect of loosening the hair and the epidermis on one side, and the particles of fat and flesh on the other. When they have soaked sufficiently they are taken out and scraped with knives on both sides to remove all these useless parts.

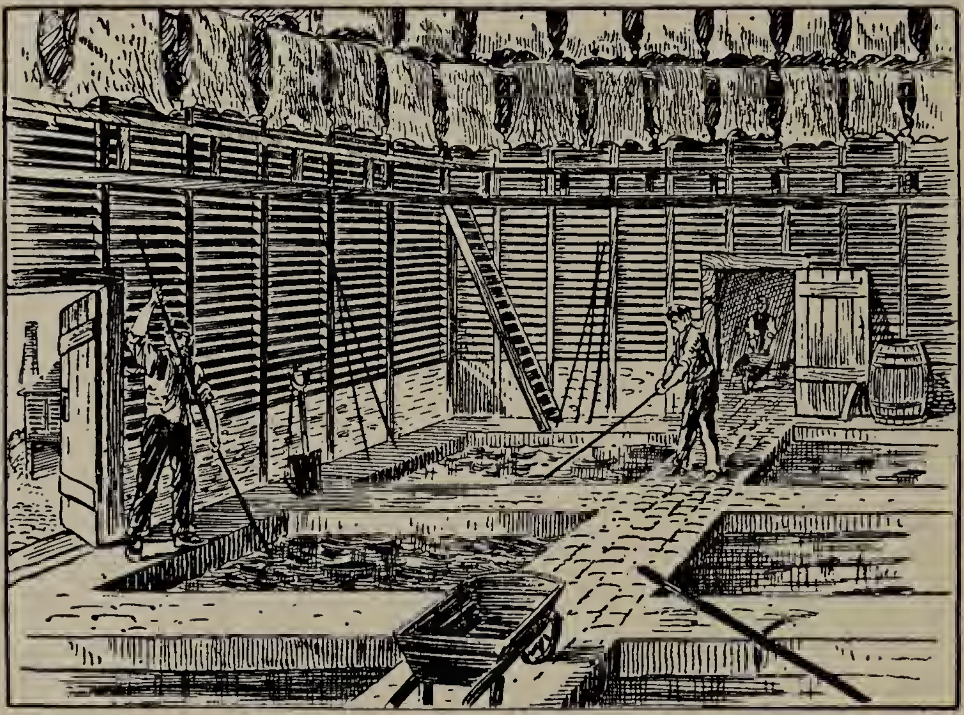
The next thing is to get rid of every particle of the lime, for that would be injurious. This is usually done by soaking the hides for about a week in tanks containing fowls' dung and water. This solution absorbs all the lime from the skins, and leaves them soft and supple.

They are now ready for the *tanning process.* The bark of many trees contains a peculiar substance called *tan* or *tannin.* The best tan is obtained from the bark of the oak or hemlock, but other kinds are sometimes used. A preparation is made by grinding the bark in a mill, and steeping the powder in water.

The prepared hides are thrown into the tanpits—great tanks in the ground—which are filled with the prepared bark-liquor, or *ooze,* as it is called; and there they are left to soak for four or five months. The object is to make the tannin of the bark unite with the gelatine of the skins. This converts the skins into actual leather. The longer they are allowed to remain in the tanpits the better, for it is necessary that every particle of the gelatine shall be acted upon by the tannin, if the leather is to be of good quality.

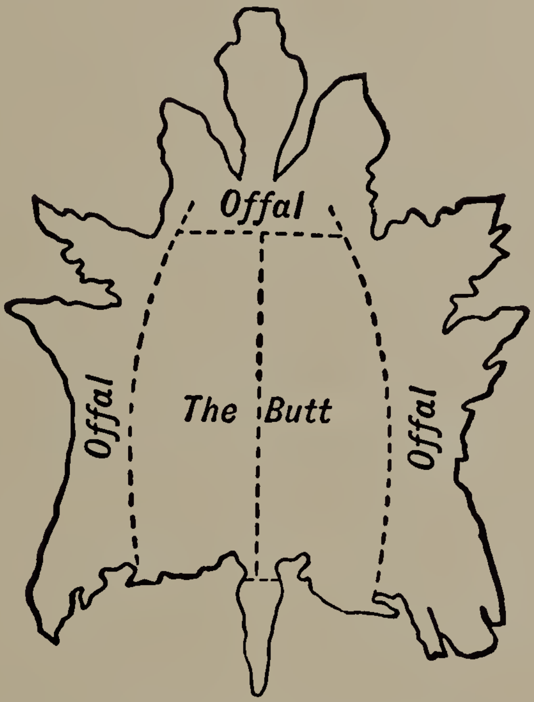
The hides, when sufficiently tanned, are taken out of the pits, washed and laid out to dry in open, airy lofts, after which they are hammered, and rolled between heavy rollers to harden them.

The thin skins, which are required for upper leathers of boots, are dressed with oil and tallow, and then rubbed and rolled with heavy rollers to give them a smooth surface. After this they are treated with a dressing of lamp-black and tallow, and rubbed and smoothed and polished again. This process is known as *currying*.



There is a great variety of quality even in the different parts of the same hide. The skin, as it is taken from the animal, is styled the *crop* or *full hide.* After it is tanned and dressed, it is cut up into the *butt* and the *offal.* The butt is the best portion of the leather; the offal consists of that part of the skin which covered the shoulders, neck, belly cheeks, and face of the animal. Thus in a single ox-hide we have five distinct qualities of leather, varying in value from fifty cents a pound to twelve cents.

Bull-hide, bullock-hide, and cow-hide are very thick, strong, and durable. They are mostly used for the soles of boots and shoes, and for harness-making. Calf-skin is usually employed for the best upper leathers for boots.



The hides of the animals while in the state of transition from the calf to the fully-grown ox are known as *kips*. They make a very valuable leather, almost as fine as calf-skin, but stouter and more durable.

The hide of the horse is remarkably thin, but when tanned and curried it makes a very valuable leather, which is used chiefly by the harness-maker. Pig-skins are tanned into a leather for covering saddles.

Our annual home products of hides and skins of all sorts are valued at a very great figure, but we import largely from all parts of the world, the total value of our imports being $30,520,177 for the twelve months ending June 1896.

Of this amount the South American States contribute by far the largest share. The United Kingdom stands next; but we also import hides from Mexico, Oceanica, the South African and Australian colonies, and from several countries in Europe. Buenos Ayres, the great South American seaport, ships annually about 3,000,000 hides; Monte Video, another port almost as large, exports about 1½ millions, and Brazil furnishes about the same number.

The vast, grassy steppes of Russia are the home of immense herds of horned cattle. It is estimated that upwards of 20,000,000 hides and skins of all sorts are obtained every year from these regions. Some of them are exported, but the greater part of the supply is tanned and dressed by the Russians themselves for their own use.

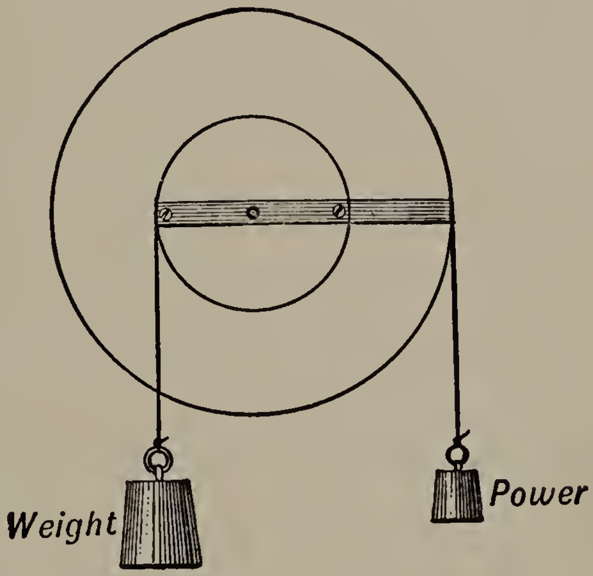
Lesson XXXII

THE WHEEL AND AXLE

"We have seen before," said Mr. Wilson, at the commencement of the next lesson, "how one machine gradually suggested another. I want to show you this morning how a very important machine grew out of the fixed pulley, just as the pulley itself grew out of the lever.

"I have here two circular wooden discs, with grooved circumferences, similar to the one I used before. The smaller of the two is, as you see, only about half the size of that; the other is much larger. I will fix both discs to the edge of the table, by means of a large nail, or a screw, in the usual way, placing the smaller one in front. I want both discs to revolve together, so I will fix them to each other with a peg.

"Now, on the right of the large disc or wheel, and the left of the small one, I will fix separate cords. Each cord shall be passed under its own disc, and round the grooved circumference, so that the end may hang from the outer side in each case. Notice that, when I pull the cord of either wheel downwards, the other rises upwards. In other words, our new machine is a lever of the first order. We want to see how it differs from the single wheel or disc. You will see this best if I draw with the chalk a horizontal diameter across the small front disc. The two radii of this diameter form the two equal arms of a lever, which act on the centre as their fulcrum. The cord of this wheel hangs and acts at the extremity of the left arm.



"I will now produce the chalk-line, towards the right, across the larger wheel. As the large wheel moves with the small one, the chalk line drawn across from the centre to the circumference represents a radius of the large circle. It is really the right arm of a long lever, and at its extremity, on the circumference of the wheel, the cord of that wheel hangs and acts.

"Now you shall pull the cord hanging from the larger wheel, and watch the chalk-line while you do it. The pulling of the cord depresses the line on that side of the centre, and, of course, raises the shorter line on the other side, because both wheels move together. We have, in fact, a lever of the first order, with arms of unequal length.

"Each wheel, as we have already seen, may be regarded as composed of a great number of levers, all acting on the centre, as their fulcrum; and the combination of the two wheels—a large and a small one—gives the advantage of unequal arms to each lever.

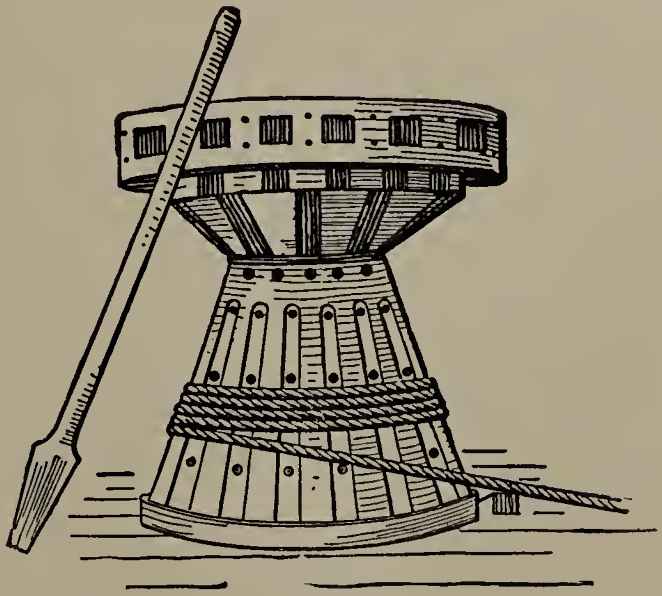
"We know, from the principle of levers of the first order, that a small weight acting at the extremity of the long arm will balance a large weight at the end of the short arm, and that the slightest additional weight on either will cause the other to move upwards. This is the whole secret of the wheel and axle.

"The radius of our large wheel is twice that of the small one; a power of 1 lb. will therefore support a weight of 2 lbs.; if it were ten times as long, the same power would support a weight of 10 lbs., and so on.

"Hence, the greater the difference between the size of the wheels, the greater the mechanical advantage. By making one wheel very small and the other very large, we get very great advantage of power.

"Now, before we leave our model, I want you to watch its working once more. We will first attach our 1 lb. and 2 lbs. weights to their respective cords, and so get a balance; and then I will add a very small weight to the cord on the larger wheel. The 2 lbs. weight at once begins to move upwards and the other down. But you notice that the former moves very slowly as compared with the latter, and it moves, moreover, through a smaller space. Here we have again an illustration of the principle that *gain of power*

means loss of speed; loss of power, gain of speed. The simplest and most familiar application of the wheel and axle is the windlass for raising the bucket



in a well. The axle, on which the rope attached to the bucket is wound, represents the small wheel of our model. The power is applied either to the ends of the spokes of a large wheel, or to a long handle attached to the centre of the axle.

"When the handle makes a revolution, it describes a large circle. The advantage, as regards gain of power, depends upon the size of this circle as compared with the axle.

"The capstan for heaving the anchor on board ship, opening and closing lock-gates, etc., is another application of the wheel and axle. In order to increase the power, the men work at the end of long spokes, which are fixed into the axis. The longer the spokes, the greater the mechanical advantage of the machine."

Lesson XXXIII

Waste and Repair

We know now that the blood is the vehicle by which oxygen is carried into all parts of the body, for the purpose of burning up or oxidising the worn-out, waste tissues. Those waste matters could not be removed from the system in their solid form. Oxygen, the powerful agent of combustion, burns them up, and converts them into soluble substances, which are readily absorbed and carried away in the stream of the blood.

But the blood is not merely the oxygen carrier. It has other duties beyond this. It brings material for building up again those parts of the body which have been worn out by their work. There is not only constant wear and waste going on, but constant repair as well. This explains why a person in good health varies so little in size and weight year after year.

All the materials, whether for making bone, brain, muscle, or any part of the substance of the body, are brought by the blood to the spot where they are wanted; and the blood gets them all from the food which we eat.

When we have not taken food for some time we begin to be conscious of a peculiar emptiness in the stomach; we feel weary and faint, and unfit for either work or play; we feel a great desire to eat—we are hungry. We go to our meal, and come away with renewed vigor, ready to resume our ordinary occupations.

When a person is in a healthy condition, this desire for food returns several times a day. He is said to have a good appetite. Indeed, if our appetite falls off, we know that something is wrong; we have to consult the doctor. If a person were kept without food, his body would shrink and lose weight, and he would gradually become unable to do any work with either mind or body.

So then *the body feeds on the blood,* and *the blood itself feeds on the food which we eat.* In other words, our food supplies new materials to the blood, and the blood carries them to rebuild just those identical tissues that have been destroyed with their work.

The food has actually to be converted into blood. This is the whole work of digestion. Digestion has to change the food we eat into blood fit to feed the body. The bread and butter, meat, pudding, potatoes, are solid substances, and quite useless for the purpose in that form. It is the work of digestion to change the nature of the food, so as to make it easily soluble. In this state, and in this state only, can it ever be absorbed into the blood.

The full force of this would be readily seen by putting some powdered starch and sugar into separate glasses of water. If the two were stirred with a spoon, the sugar in the one would entirely disappear, but the starch in the other would still be seen, and would, if left to itself, sink to the bottom. In the one case the water holds the sugar in solution; it has become, for the time, inseparable from the water. We could not pour out the water and leave the sugar behind. Not so the starch. This settles at the bottom, and we may easily pour off the water and leave the starch.

But in addition to this, if we tried our osmosis experiment with the two substances, there would be a marked difference. The dissolved sugar would readily pass through the membrane; it would be impossible for the water to pass and leave the sugar behind, and this is equally true of every dissolved substance. On the other hand, no amount of force or coaxing would send any of the starch through the membrane. This must be clearly understood now, as it will have an important bearing on the lessons which are to follow. The whole of our food must be dissolved, *for it can only pass into the blood by osmosis.* This dissolving of the food is the work of digestion.

Lesson XXXIV

LEATHER—SKINS

We have already dealt with the preparation of hides —that is, the skins of large animals, such as the ox, horse, buffalo, antelope, etc.—for the heavier, thicker kinds of leather. But besides these there are many varieties of thin light leather, made from the skins of the goat, kid, sheep, and lamb; such as are used for kid gloves, bags, purses, pocket-books, linings for hats, and a host of other purposes. These leathers are prepared, not by *tanning,* but by another process known as *tawing.*

For this purpose the skins, after being prepared in the usual way, are first soaked in a solution of alum and salt, and then in a liquor made of wheaten flour mixed with the yolk of eggs. The alum and salt by combining with the gelatine of the pelts does the work of the bark *ooze* in tanning, while the yolk of eggs and the flour give this kind of leather its peculiar softness and elasticity.

The consumption of eggs for this purpose is so great that it is no uncommon thing for some of the great leather factories in tawing to have at one time as many as 100,000 eggs in store, preserved in lime and salt.

The skin of the sheep is sometimes *tawed* whole; sometimes it is split into two distinct skins before the tawing process is begun. The unsplit or whole skin in its finished state is called *roan.* It resembles morocco, but is less expensive, and is largely used by bookbinders.

Sheep-skin leather is also extensively used in the manufacture of trunks and bags, pocket-books, purses, linings for hats, boots and shoes, cases for jewellery, musical instruments, men's braces, etc.

When it is split into two skins the *grain* or outer one is known as a *skiver,* the under one is called a *flesher.* The fleshers of sheep-skins are largely used for the manufacture of military gloves, and for wash-leather.

Wash-leather was formerly made from the skin of the chamois-goat; hence it is frequently styled *chamois, shamoy,* or *shammy leather.*

Large numbers of sheep-skins are converted into mats and rugs. For this purpose they are tawed with the wool on them. The process of preparation is very simple. All that is necessary is to carefully scrape away every little particle of flesh and fat from the skin, stretch it out flat upon a board with a few tacks, the woolly side downwards, and then rub the surface of the skin itself with a mixture of powdered alum and salt repeatedly for a few days.

The alum and salt are readily absorbed into the gelatine of the skin, and convert it into the new substance—leather. The best of the skins are afterwards treated to a dressing of the flour and yolk-of-egg liquor, to make them supple and pliant.

Parchment is made from the skin of the sheep, goat, and young calf. Rams'-skins supply parchment of excellent quality, but that made from lamb-skins is best. Vellum, a very white, fine, and smooth kind of parchment, used mostly for important documents, is prepared from the skin of the young calf.

The heavier kinds of men's gloves, known as *dogskin* gloves, are made from the skin of the South African sheep.

Lamb-skins are always tawed unsplit, as they are too thin to bear splitting. From them is made a soft white leather, known as *beaver*, which is used largely for making the cheaper sorts of white kid gloves.

Goat-skins are chiefly used in the manufacture of morocco leather. The skins for this purpose are dressed with *shumach*. The Moors of Northern Africa long held the complete monopoly in this manufacture; but the tanners of Europe have now not merely learned the art, but actually surpassed the Moors themselves in the quality of their production.

Morocco leather is used only for ornamental purposes, and is always dyed either red or bright yellow. An inferior *morocco* is made from sheep-skins. Kid-skins are always used for the best kid gloves.

After tawing the kid skins are stretched by hand and dried in a warm atmosphere. They are then worked about to render them soft and pliable, after which they are planed, and then polished by rubbing with a heavy glass disk. At last they are stretched on a marble slab and smoothed with a blunt knife. From a kid-skin thus treated material for thin gloves is commonly obtained.

The various parts of a glove are cut out by a machine having punches of different shapes and sizes, and the sewing is done by hand and by machines. Limerick, Ireland, carries on a brisk manufacture and trade in soft, delicate gloves—so thin and fine that it is a common thing to pack a pair of them in a walnut shell for sale.

We import immense quantities of foreign gloves, mostly from France—the French gloves being specially sought after, both for the quality of the kid and the excellence of the workmanship. Indeed, the glove manufacture in France is a very lucrative branch of industry. It is estimated to yield an annual output of more than 30 million pairs, worth from $15,000,000 to $20,000,000, and to give employment to about 90,000 persons.

Russia leather is well known by its pleasant smell, which, however, moths and other insects do not like. It is used for binding valuable books, and for making many varieties of articles for use and ornament. It is tanned with willow bark, and afterwards treated with a kind of tar made from birch bark; but the actual process of manufacture is kept a secret.

Lesson XXXV

SULPHUR

"I have this morning another common, well-known substance to talk to you about," said Mr. Wilson, as he showed the class a piece of roll-brimstone. "A very simple examination of this substance, which is known indiscriminately as sulphur or brimstone, will tell you that it is a solid body, of a lemon-yellow color, and that it has a faint odor but no taste.

"If we tap it with a hammer we shall learn that it is very brittle; and if we put it into water we shall prove that it is insoluble in water. We can, however, dissolve it in oil of turpentine. It takes fire when a light is applied to it, showing that it is highly inflammable, and it burns with a peculiar pale-blue flame and a suffocating odor.

"Now let us have an experiment. I will put some crushed sulphur in a test-tube and heat it gently over the Bunsen burner. The solid substance changes at first into a clear, yellow, limpid liquid, but as the heat is continued it becomes darker in color, and of the consistency of treacle; and finally it boils and passes off as vapor. While it is boiling we will introduce a small coil of fine copper wire into the mouth of the tube. The metal at once takes fire in the sulphur-vapor, and burns with brilliant effect. Now think of the combustion of bodies in oxygen and also in chlorine. You remember, of course, that we call the compounds formed by the burning—in the one case *oxides*, in the other *chlorides*.

"Our last experiment showed us the copper taking fire and burning in a similar way in the sulphur-vapor. The product formed by that burning is known as *sulphide of copper*. Most of the metals combine with sulphur to form *sulphides*. Indeed, most of the metallic ores are sulphides. Copper and iron pyrites, two common forms of the ores of these metals, are really sulphides. Sulphur is also met with in combination with mercury, forming a sulphide commonly called cinnabar. This is the chief source whence we obtain that useful metal. In one of our early lessons the method of separating the mercury from the ore was described.

"Most of the sulphur of commerce is obtained in the free state—that is, uncombined with other substances—from volcanic districts such as Sicily, Southern Italy, Iceland, and Mexico.

"Sulphur is frequently met with in the waters of mineral springs. The waters of Virginia owe their medicinal value to the sulphur which they contain.

"The roll-sulphur which I showed you first is obtained by pouring the melted sulphur into wooden moulds and allowing it to cool.

"The *flowers of sulphur* are formed by boiling ordinary sulphur, and causing the vapor from the boiling liquid to pass into a cold chamber, where it condenses, and settles upon walls and floor as a fine powder.

"Sulphur is largely employed in the manufacture of gunpowder and matches, and for many other purposes.

"I have now another experiment to show you. I will put a piece of sulphur in the deflagrating spoon, set it on fire by applying a red-hot wire to it, and lower it into this jar of oxygen which I have in readiness. The sulphur immediately bursts into a brilliant purple-blue flame, giving out intense heat, and the product of the burning is a suffocating gas. This gas is an oxide of sulphur. We call it *sulphur dioxide.*

"I will next pour some blue litmus infusion into the jar containing the sulphur di-oxide, close the jar with my hand, and shake it up.

"Now, without removing my hand, I will invert the vessel in this bowl of water, and if the hand be then taken away, the water will rush up into the jar with great violence, and the blue litmus coloring-matter will change to a bright red.

"Sulphur di-oxide is so soluble that water will dissolve nearly fifty times its volume of this gas. This is why the water rushed up into the bottle.

"If you dip your finger into the solution and put it to your tongue you will find that this dissolved oxide has a sour taste."

Lesson XXXVI

PLANTS USEFUL FOR FOOD

SUGAR

Sugar is one of the most important products of the vegetable kingdom. The juices of many plants contain sugar, each variety having its own special characteristics. The various sugars are arranged in three groups —*grape-sugar*, *cane-sugar*, and *manna*, or *leaf-sugar*.

The first of these—grape-sugar—takes its name from the white, crystalline, sugary substance found in the inside of raisins and currants, which, as you already know, are dried grapes. This white substance is really sugar; we call it grape-sugar. It is the source of the sweetness in the raisins and the currants. But fruits in general, as well as the grape in particular, owe their sweetness to this same kind of sugar—grape-sugar. The apple, pear, plum, gooseberry, cherry, etc., have at first a sharp, sour taste, and gradually pass from sour to sweet as they ripen. This is owing to the gradual formation of grape-sugar in them. Even when fully ripe most of them are a little sour; and it is the mixture of sour and sweet which gives fruit its pleasant flavor. This grape-sugar of the fruits yields wine when fermented. We have frequently had occasion to notice the conversion of starch into sugar by the saliva, in the work of digestion. The kind of sugar thus formed is this same grape-sugar which is found in fruits.

By mixing some starch in water with a little sulphuric acid, and boiling the mixture in a shallow dish over the spirit-lamp, we may easily effect this conversion for ourselves. When the liquid has cooled it will be found to have acquired a sweet taste. The acid will have converted the starch into sugar—grape-sugar. The saliva, you may remember, is an acid fluid too, and has a similar action on the starchy matters of the food. We could, by adding a little lime to the boiled solution, separate the acid, and then if the liquor were boiled down, we should get actual sugar.

Potato, wheat, barley, rice, corn, or sago starch can be readily made to yield sugar in this way. The sugar obtained from starch is known as *maltose*, and is made into beer by the process of brewing.

Manna-sugar is a peculiar and distinct product, differing from both grape- and cane-sugar in many respects. It is obtained from the sap of a variety of plants. In some it exudes from the surface of the leaves, and is hence known as leaf-sugar; in others it is obtained by making incisions in the stem. It is produced in very small quantities, and only in a few parts of the world. It is chiefly used for medicinal purposes.

A species of ash, which grows in Sicily and Calabria, yields a valuable kind of manna-sugar. It is obtained by making cross-cut incisions in the stem. The sap, exposed to the air, hardens as it flows, and concretes into a solid gum-like mass round the slits in the bark. When fresh gathered it is very nutritious, and enters largely into the food of the people. It soon acquires, however, a slight purgative property, and this, while it unfits it for food, renders it valuable for medicinal purposes. The manna ash tree is also found in Asia Minor, Turkey, Greece, Hungary, and sometimes as far north as Switzerland.

We have already dealt at some considerable length with the varieties of cane-sugar, their preparation and properties. It will be quite unnecessary to do more now than call attention once more to the fact that these sugars are not all of them the product of the sugar-cane. The class known as cane-sugars include, in addition to that, beetroot-sugar, maple-sugar, corn-sugar, and palm-sugar.

Sugar has become almost a necessary of life to us. It is estimated that we consume, on the average, no less than 70 lbs. of sugar per head of the population in the United States each year. We are by far the largest consumers of sugar in the world. In the year ending June 1896, 3,708,874,766 lbs. were imported into this country. The total yearly production from the sugar-cane all over the globe is said to be upwards of 5000 millions of pounds, and by far the greater part of this comes from Cuba, and other West Indies, East India, the Hawaiian Islands and Germany.

Think of the millions of men in various parts of the world who are employed in cultivating the plants, extracting and preparing the sugar, and conveying it to this and other countries; to say nothing of the traders and others through whose hands it must pass before it reaches the actual consumer. Thousands of ships are employed in carrying this one article of commerce.

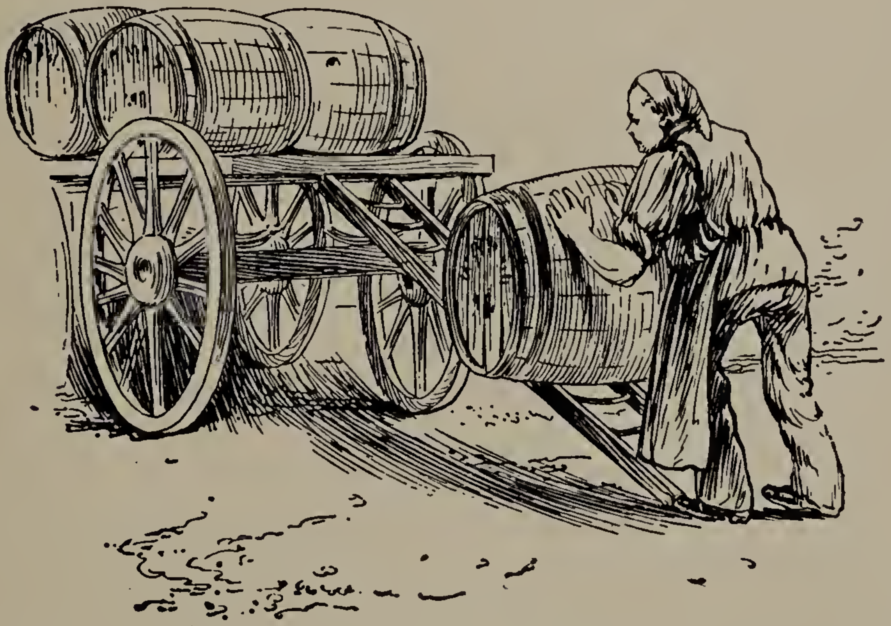
The preparation and sale of beetroot-sugar, too, is largely increasing every year. We import, as a matter of fact, more beetroot than actual cane-sugar, but it is not all consumed at home. Much of the sugar we import is sent out of the country again as a manufactured article.

The topmost shoots of the date-palm yield a juice which, when boiled down, gives a brownish, raw sugar, commonly known as East India *date-sugar*, *palm-sugar*, or *jaggery*. The juice is obtained by piercing the tender shoots, so as to cause the juice to flow. It is produced by the populations of India and other tropical regions where the palms grow, and mostly for their own exclusive consumption.

Lesson XXXVII

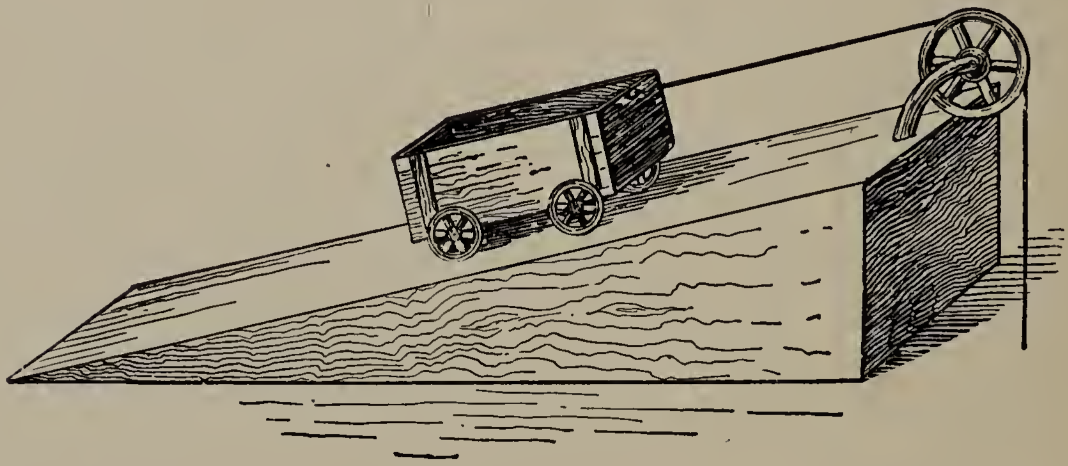
The Inclined Plane

"This morning on my way to school," said Mr. Wilson, "I saw some brewer's draymen unloading great heavy barrels from their wagon, by sliding them down a sort of slanting ladder to the ground. When they had got them to the ground they lowered them into the cellar in the same way. Besides this I saw them raise other barrels, first from the cellar to the ground, and then from the ground to the wagon, by rolling them up the same ladder. This slanting ladder is a machine—very simple, and at the same time very useful. By means of it the men were able to move those heavy bodies with ease from their awkward positions. We call it the inclined plane. Let us see what we can learn about it.



"Here is a smooth, polished board. We will lay it on the table, so that it rests in a horizontal position, and then place on it one or two objects, also having a smooth, polished surface. The objects, whatever they are, rest on this horizontal plane, showing no tendency to move.

"Now we will rest one end of the board on this block of wood. It is a plane still, but, instead of being horizontal, it slopes; it is, in fact, an inclined plane. I want you to notice how the same smooth objects act when we place them on the board now. They, one and all, roll quickly down the slope. We will next change the smooth polished board for one made of rough deal, incline it at the same angle, and place the same smooth objects on it as before. They do not move as quickly now; some of them, indeed, do not move at all, but remain at rest on the slope.



"The rough inequalities on the surface cause a rubbing or *friction* between the objects and the board, and it is this friction that retards the movement of the objects, and actually brings some of them to a standstill. The same things rolled rapidly down the smooth board, because there was less friction. Indeed, in considering the inclined plane, we must for the present think of the surface as being perfectly smooth, so as to cause no friction, although practically this is never quite true.

"Let us glance for a moment in another direction. The slope of a hill is, of course, an inclined plane. Now, suppose I set one of you boys the task of taking to the top of a hill a load too heavy for you to lift, how would you act? I think, if it were a round body that would roll, you would roll it up the hill; if it were something with a flat surface, such as a box, you would probably attach a rope to it, and drag it up. What kind of hill would present the easier task—one with a steep slope, or one with a gentle slope? You would find it much easier to roll or drag the load up the gentle slope than up the steep one.

"I want to show you now the reason for this, and to make clear to you what mechanical advantage the inclined plane gives. Let us return to our smooth, polished plane.

"I will adjust the plane so as to make its height exactly half the length of its slope, and that will give us an incline of 30°. To the top of the slope a small pulley shall be fixed, and I will attach one end of the cord which passes over the pulley to some smooth object standing on the plane. I have chosen for our object this little toy truck, which runs on smooth, polished wheels; and I have loaded the truck to make it weigh exactly 2 lbs. Now, Fred, you shall hold the cord, while I attach to the other end of it a 1 lb. weight. When that is done we will leave the truck to take care of itself; and we see that the 1 lb. weight is sufficient to balance it on the slope. A half-ounce weight more hung on the cord will make the truck travel up the inclined plane.

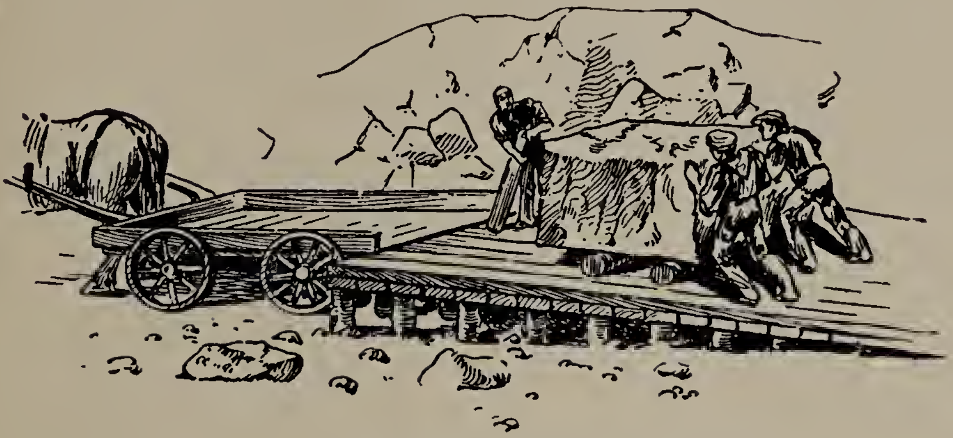
"We may alter the inclination of the plane now, and we shall find that as we vary the slope so the power will vary. The little truck will not be supported by the same power on different slopes. Thus, if we make the height one-third the length of the slope, the truck will be supported by one-third its weight; if the height be one-fourth the length, it will require only one-fourth its weight to support it.

"In other words, the longer we make the slope as compared with the height, the greater is the mechanical advantage. It is important to remember that we have made use of the pulley only to enable us to measure the force required. Whether the body be pushed upwards from behind, or pulled up by means of a cord, the force necessary to accomplish it is the same in each case.

"We will next glance at a few practical applications of the inclined plane.

"We have already had something to say about the drayman's ladder. Next time you see one, notice how smooth its working surfaces are. You are now prepared, of course, to tell what kind of ladder is most advantageous to him—a long or a short one—and to give your reasons for what you say.

"We often see an inclined plane used for transferring a great block of stone into a cart. The rough surface of the stone, in addition to its weight, would, however, prevent it from moving even on the inclined plane. Hence, in order to overcome some of the friction, three or four rollers are placed under the block, and, as these roll forward, they carry the block with them, the hindermost one being transferred to the front from time to time, as it is disengaged.



"In the construction of bridges a great deal of thought and care must be given to the length of the approaches on either side. These approaches slope upwards towards the middle of the bridge; and the slope must be made sufficiently long in comparison with the height, so as not to cause too great a strain on the horses which will have to draw heavy loads over the bridge.

"The horse travels with its burden along a level road with comparative ease, because the weight rests upon the wheels of the cart, and it has only to overcome the friction between the wheels and the rough surface of the road. As soon, however, as it begins to mount a hill, the weight is thrown behind the wheels, and there is now, in addition to the friction, another force to contend against, namely, the force of gravity, due to the weight of the load; and it is plain that this must increase with the increase of the slope.

"The road up a steep hill is, for the same reason, usually made to wind round and round the hill, in order to give a longer slope, and so render the ascent easy."

Lesson XXXVIII

BONES

The bones of almost all animals are serviceable in some way to man. Indeed, the position which bone holds among the economic products of animals is by no means an unimportant one. Bone enters largely into many varieties of manufacture; and so great is the demand for it, that in addition to their home supply from slaughtered animals, foreign nations import cargoes every year from many parts of the world. English annual imports of bones from all sources amount to upwards of 100,000 tons, and are valued at about £700,000 sterling. The bones of commerce are chiefly those of the horse, ox, buffalo, elephant, giraffe, and hippopotamus.

We use bone in its natural state for knife-handles, spoons, brushes for teeth and nails, combs, fans, buttons, paper-knives, etc. The bones usually employed for these purposes are the shank and buttock bones of oxen. It is estimated that in Sheffield, England, no less than two million shank-bones are worked up in this way every year. The manufacture of bone buttons is a very important and extensive industry, and gives employment to immense numbers of work-people. Birmingham and Sheffield turn out bone buttons in ton-loads every year.

The fresh or green bones, as they come to the hands of the manufacturer, contain a large amount of fat, and before they can be of any use to him this must all be removed. The fat is extracted by boiling the bones. They are usually boiled for about twenty-four hours, and the fat which rises to the surface is skimmed off when cool. The hollow shank-bones of the ox are carefully boiled by themselves, and the skimmings from them yield a valuable fat, which forms the material for the manufacture of butterine, and such compositions as take the place of butter. The fat from other bones, which is coarser and of inferior quality, is sold to the soap-makers, and is used for common soaps.

Bones are also largely used in the manufacture of artificial manures. Our investigations into the nature and composition of bone have shown us that in addition to animal or organic matter—ossein—it contains two-thirds of its weight of mineral matter. It is this mineral matter that makes the bone dense, hard, and rigid—the very material for the framework of the body of the animal, providing support, protection, and means of locomotion.

We have seen, too, how a bone behaves when it is placed in a clear, red fire. The whole of the organic matter in it burns away, leaving a white brittle substance, which the fire will not consume. This is the earthy or mineral matter of the bone. It is known as bone-ash, or bone-earth, and consists chiefly of phosphate of lime. Bone-ash is obtained in this way by burning bones, and is prized by the farmer as a very useful manure for his land.

You remember, no doubt, that by steeping a bone in dilute muriatic acid, we are able to dissolve all this mineral matter out of it, leaving only the tough, flexible, gristly ossein behind. When the steeping is over, all the mineral matter of the bone is in a state of solution in the liquid itself. This will help you to understand the preparation of another very valuable manure, known as *super-phosphate of lime.* The bones for this purpose, instead of being burned, are merely crushed into small pieces and put into dilute sulphuric acid. The acid, of course, dissolves all the mineral matter out of the bone, the ultimate product being the valuable super-phosphate of lime.

Animal charcoal, a substance largely used in the arts, is made by burning bones in closed, air-tight retorts for twelve hours, the gases being allowed to pass off as they are formed by the burning, so that nothing is left behind but the carbon of the bone. This is afterwards crushed into small grains, and is known as animal charcoal.

Animal charcoal is employed in the sugar-refineries. The syrup of the raw sugar is filtered through this charcoal, which extracts all its brown color and leaves it white. The powdery dust formed by crushing the charcoal is known as bone-black, and is used in the manufacture of blacking.

Now let us think once more of those great factories where bones are made into knife-handles, spoons, buttons, and other articles of use. Of course the bones must be sawn, cut, carved, and shaved in various ways in the preparation of such articles; and the workman makes cuttings, chips, scraps, shavings, and saw-dust, just as he would with other materials.

None of this, however, is wasted. All is collected for further use.

These scraps of bone are soaked in dilute muriatic acid, which dissolves out all the mineral matter and leaves behind only the animal matter of the bone—the tough, flexible ossein. This is first washed and cleansed in lime-water, and afterwards carefully boiled. Ossein when boiled yields a new substance—*gelatine or jelly.* This jelly becomes a valuable article of food, very rich in tissue-forming properties. It is first flavored with orange, lemon, vanilla, or some such flavoring, and then poured while warm into bottles, and left to cool. These are the jellies we see in bottles in the grocers' shops.

Lesson XXXIX

DIGESTION

The sole purpose of taking food is to make blood, and the great thing to remember is that the food can only be converted into blood after it has been dissolved or digested. This work of digestion commences in the mouth.

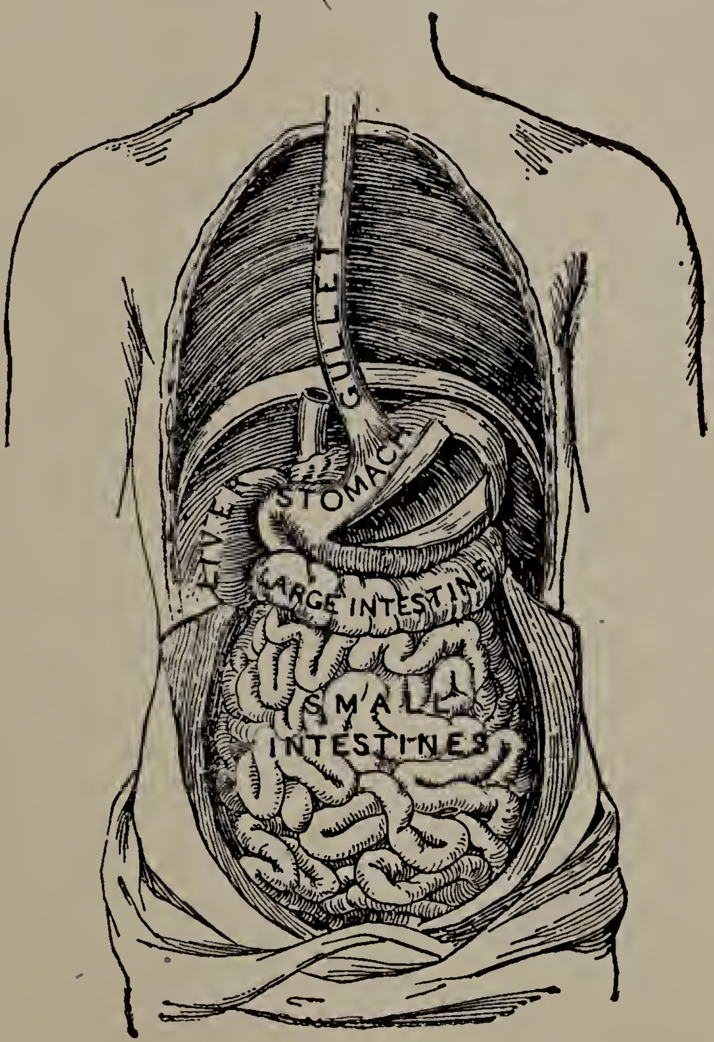
The mouth is provided with a double row of teeth, which act the part of a mill in crushing and breaking up the food. While this crushing work is going on, a fluid called *saliva* oozes out from the lining membrane of the mouth, and moistens the food. This saliva is a thin, watery fluid, which has the power of changing starch into sugar.

Starch, you remember, is one of the most important constituents of all plants. Our vegetable foods—such as bread, beans, peas, rice, potatoes—owe their value in a great measure to the starch which they contain. Nevertheless, it is a strange thing that the starch itself is absolutely useless as food until it has been acted upon by the saliva in the mouth.

Our lesson on the repairing work of the blood taught us that all food, which is to be of any service, must be dissolved, as only dissolved substances can pass by osmosis through a membrane, and so reach the blood. The starchy parts of our food, therefore, being insoluble, could not in that form be of any value. The saliva acts upon the insoluble starch, and *changes it into sugar,* which is soluble. It is the sugar itself, in a dissolved state, which is taken into the blood, and all starch reaches the blood in this way. So then the starchy portions of our food are being digested as we chew them, and hence we may see the necessity for due care and deliberation at our meals. Never eat in a hurry, but allow ample time for the flow of sufficient saliva to properly moisten the food so that it may be well masticated before it is swallowed. Food swallowed in great lumps can be of no use except to give pain. When the work of mastication is completed the food is swallowed, and passes down into *the gullet.* The lower extremity of the gullet expands into a large bag or pouch, shaped something like a bagpipe. This is *the stomach.* It lies across the upper front part of the abdomen, immediately below the diaphragm. The diaphragm itself is pierced with a hole to allow the gullet to pass through and join the stomach. This bag or pouch is very strong and muscular, and is constantly contracting and expanding in such a way as to cause whatever is in it to be rolled and churned about from side to side.

The inside of the bag is crowded with multitudes of tiny tubes, which are constantly pouring out into the bag itself a peculiar fluid—*the gastric juice.* From three to four quarts of this fluid are poured into the stomach of an adult in the course of the twenty-four hours.

It is plain that the object of this large quantity of gastric juice, and also of the constant churning process, is to continue the work which was begun in the mouth. The gastric juice, like the saliva, acts as a solvent for the food, or, at all events, for some of it. It will not dissolve starch-food, and it will not dissolve fat. It acts upon lean meat, and upon those parts of the bread, pudding, peas, beans, and such things which the saliva will not dissolve. In other words, gastric juice is the solvent for all proteid matters in the food.



The mass of food in the stomach then contains the starchy matters that have been acted upon by saliva, and the proteid matters which the gastric juice has dissolved. Both these are ready to pass into the blood.

The inner lining of the stomach is a close network of blood-vessels, which branch out into the finest of capillary tubes; and in these tubes the blood is always coursing along, while just outside their thin walls is the great cavity of the stomach filled with food, some of which is digested and in a state of solution.

You know that, when two liquids are separated by a thin membrane, they pass readily through it by osmosis. Thus it happens that osmosis does the rest of the work in the stomach. Those portions of the food which are dissolved pass into the blood by osmosis through the delicate walls of the capillaries.

The lower end of the stomach leads out through a somewhat narrow pipe into the *intestines or bowels.* These form a long tube, which, if stretched out, would measure between five and six times the length of the whole person. They are divided into two distinct portions, the small and the large intestines.

That part of the bowel which joins the stomach is known as the small intestine. The tube is about five-sixths of the entire length, and is folded and doubled many times upon itself. The large intestines begin where the small intestines end, in the groin near the right hip. The tube then passes up the right side, crossing the abdomen just below the stomach, and then turns downwards again, finally opening externally at the lower extremity of the trunk.

Near the junction of the small intestine with the stomach lies a great organ—the liver, which has important work to do in connection with digestion. It prepares a greenish-yellow, slimy-looking fluid—*the bile*, and pours it into this part of the small intestines. This bile is an alkaline fluid, and has the power of dissolving fatty, oily matters.

The same opening which admits the bile into the intestine also admits another little tube from an organ called the pancreas. This tube brings a fluid, known as *the pancreatic juice*, which resembles in its properties both the saliva and the gastric juice.

Now let us see what all this has to do with the work of digestion. The whole of the food is not dissolved in the stomach. All that remains in an undigested state passes out into the small intestine. There it receives bile from the liver, to dissolve the *fats*, and pancreatic juice from the pancreas, to complete the work of digesting or dissolving. The walls of the intestines are strong and muscular, and as they contract, they force the stream of food onward, the fluids dissolving it as it goes.

Lesson XL

PHOSPHORUS

In commencing the next lesson Mr. Wilson showed the class the bottle labelled phosphorus. "We have frequently," he said, "had occasion to employ the contents of this bottle during our experiments. We will now try and learn something about the substance itself."

He took one of the sticks of phosphorus from the bottle, and allowed the class to see that it is a pale yellow, almost transparent, solid substance. He cut it with a knife as easily as he could have cut a piece of wax.

As he cut it, and while they were examining it, he called attention to the fumes of greenish-white vapor surrounding it like a little cloud. As soon as it was taken out of the water small wreaths of this smoky vapor began to rise from it. This, he explained, was due to the rapid oxidising of the substance, which was taking place even at the ordinary temperature of the room. A very slight increase of warmth—even the warmth of the hand—would be sufficient to cause it to burst into actual flame. He showed them that for this reason he wore a glove, as it is not safe to hold phosphorus in the naked hand. Even while he was speaking he let fall a little piece on a warm plate lying on the table, and in an instant it took fire.

"This great inflammability of phosphorus," he said, "is its chief characteristic, and shows us clearly enough why it is necessary to always keep the substance in water.

"Now watch this little experiment. I will put a small piece of dry phosphorus on the table together with a little powdered potassium chlorate, and strike them with a hammer." It burst into flame and exploded with a loud report.

"It is this last property of phosphorus," he continued, as soon as the boys had recovered from the shock, "which makes it of such great use in the manufacture of lucifer matches.

"In one kind of lucifer the paste containing the phosphorus is put on the end of the match itself. These matches will ignite when rubbed on any rough surface, and are, of course, dangerous. Many accidents have happened through carelessness in using them.

"In the 'safety' match the phosphorus paste is put on the box and not on the match. There is no danger of the match igniting until it is rubbed on this phosphorus rubber.

"Phosphorus is never met with in the free or uncombined state. It is chiefly found in combination with other elements, forming phosphates. Phosphate of lime is one of the most important of these; it is one of the materials of certain volcanic rocks. These are the rocks which by crumbling down produce our fertile soils. The plants which grow in such soils absorb the phosphorus compounds from them to help in building up their own material. These plants become the food of man and animals.

"All the bony structures in the animal consist largely of phosphate of lime, which has been obtained in this way. The bones owe their hardness and rigidity to the phosphate of lime which they contain.

"You, no doubt, remember that we have several times, in our lessons in physiology, dissolved this phosphate of lime out from bone by soaking it in dilute hydrochloric acid. In those experiments our business was rather with the animal matter of the bone than with the mineral matter dissolved out from it. I have now, however, a bone in soak, and we will examine the liquid itself. It is quite clear; we can see nothing in it. Now, watch while I pour some ammonia into it, and you will see that the phosphate of lime will be precipitated to the bottom from the clear solution.

"The chemist always prepares phosphorus for his purpose from bones. The bones are burned to a white ash in a clear, open fire. This burning, as you know, gets rid of all the animal matter of the bone; the white ash left behind is the earthy or mineral matter, and is known as *bone-earth* or *bone-ash.* It is this bone-ash which yields the phosphorus.

"Just one little experiment before we close.

"I will cut off a small piece of phosphorus, dry it carefully in blotting-paper, place it on this metal plate, light it, and cover it with the bell-jar.

"Violent combustion at once begins, and the oxygen in the jar is rapidly consumed. In order that the whole of the phosphorus may be consumed, I will raise the jar a little from time to time to admit more air. All this time the jar is filled with dense white fumes, and at last the combustion ceases—the piece of phosphorus is all consumed.

"Now let us watch those fumes. We shall see them gradually condense and fall on the plate, as a soft, white, snow-like powder. This powder is an *oxide of phosphorus.*

"Now that the fumes have all gone, we will remove the bell-jar, and pour a little water into the plate. The moment the water is put into the plate a violent hissing takes place.

"This oxide of phosphorus has a powerful affinity for water. The energy with which the water sucked up the white powder caused that hissing.

"I will now add a little of the blue litmus solution, and you will see that the effect is the same as we have seen before in the oxides of carbon and sulphur. The blue litmus turns red, and if we dip the finger into it, we shall find again that this dissolved oxide has a sour taste."

Lesson XLI

IVORY

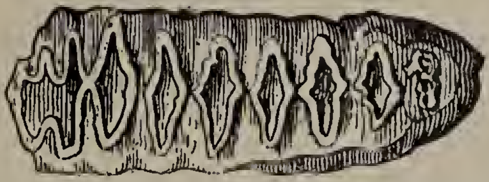
Ivory is a substance resembling bone, and, like it, of considerable importance in the arts and manufactures. The closeness of its grain and the high polish which it is capable of taking are sufficient to distinguish ivory from bone. A still more remarkable difference, however, is seen by a careful comparison of the two substances. If, for example, some polished articles of ivory and bone be examined side by side, the former will show a number of beautiful, regular, curved markings on the surface, but the bone has no such marks. These curves may be readily seen, as they are of a slightly different shade of color from the rest of the substance of the ivory. They cross each other, something like the curves on the back of an engine-turned watch-case, forming small lozenge-shaped spaces between them. No specimens of bone—indeed, no other animal substance of any kind—has these markings. Hence this is a sure test for distinguishing ivory from bone.

The readiness with which ivory can be cut, carved, and turned; the beauty of its hard, white, polished surface; and its great durability in all climates—render it specially suitable for many purposes in the arts, both useful and ornamental. It is chiefly employed for making knife-handles, backs for brushes, billiard-balls, chessmen, paper-knives, fans, combs, pianoforte and organ keys, and a large variety of fancy and ornamental articles. Cut into thin plates, it is also used in bookbinding as covers for books, and for writing-tablets.

The ivory of commerce is furnished by the teeth and tusks of various animals. Those of the elephant, hippopotamus, and walrus yield the best quality and the largest supply. Among these elephant ivory holds the foremost place.

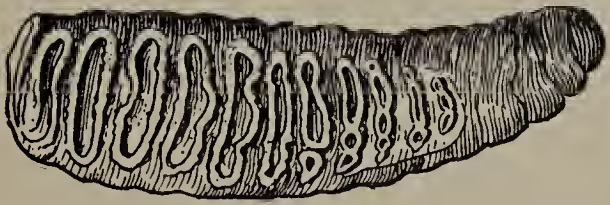
The elephant, being a herbivorous animal, has largely-developed molar teeth in both jaws for crushing its food; but the most striking feature of its dentition is presented by the two enormous tusks which project from the upper jaw. Incisors or cutting teeth like those of the horse would be useless to an animal that feeds as the elephant does; hence they are always wanting.

The molar teeth of the elephant are of little commercial value, because they contain, in addition to the hard solid dentine, a large proportion of more loosely-constructed bony matter, known as cement, which has a tendency to crack, and so renders the ivory less durable. They are sometimes used for making knife-handles and small thin plates for writing-tablets.



MOLAR TOOTH OF THE AFRICAN ELEPHANT.

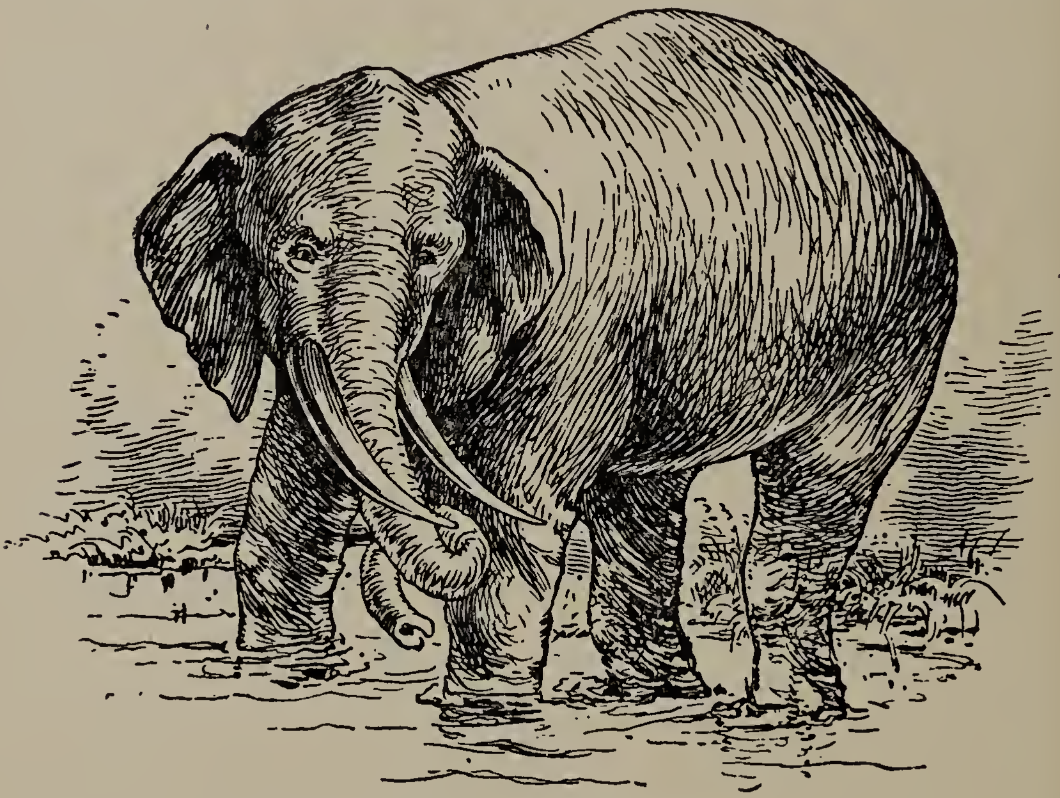
There is a remarkable difference in the structure of the molars of the African and Asiatic elephants. In both of them the hard enamel of the tooth appears in ridges on the crown. In the tooth of the African elephant these ridges assume a kind of lozenge-shape; in the Asiatic animal they stretch transversely across the crown of the tooth from edge to edge.



MOLAR TOOTH OF THE ASIATIC ELEPHANT.

The tusks of the elephant are the largest teeth to be met with in the animal kingdom. They grow to their enormous size because of the absence of any teeth in the lower jaw to oppose them.

In most of the mammalia (including man himself) the first set of teeth are shed in due course, and their place is taken by a new set. The renewal occurs but once during the life of the animal; and the teeth do not grow after attaining a certain size. We may therefore say that these teeth are of limited growth. Contrast such teeth with the incisors of the rodents, which grow as long as the animals live, and the enormous tusks of the elephant will cease to be a matter of wonder. The tusks of the elephant, hippopotamus, wild-boar, and walrus, and the long spiral, horn-like tusk of the narwhal, are alike in this respect; they are endowed with perpetual growth, for they continue to grow as long as life lasts.

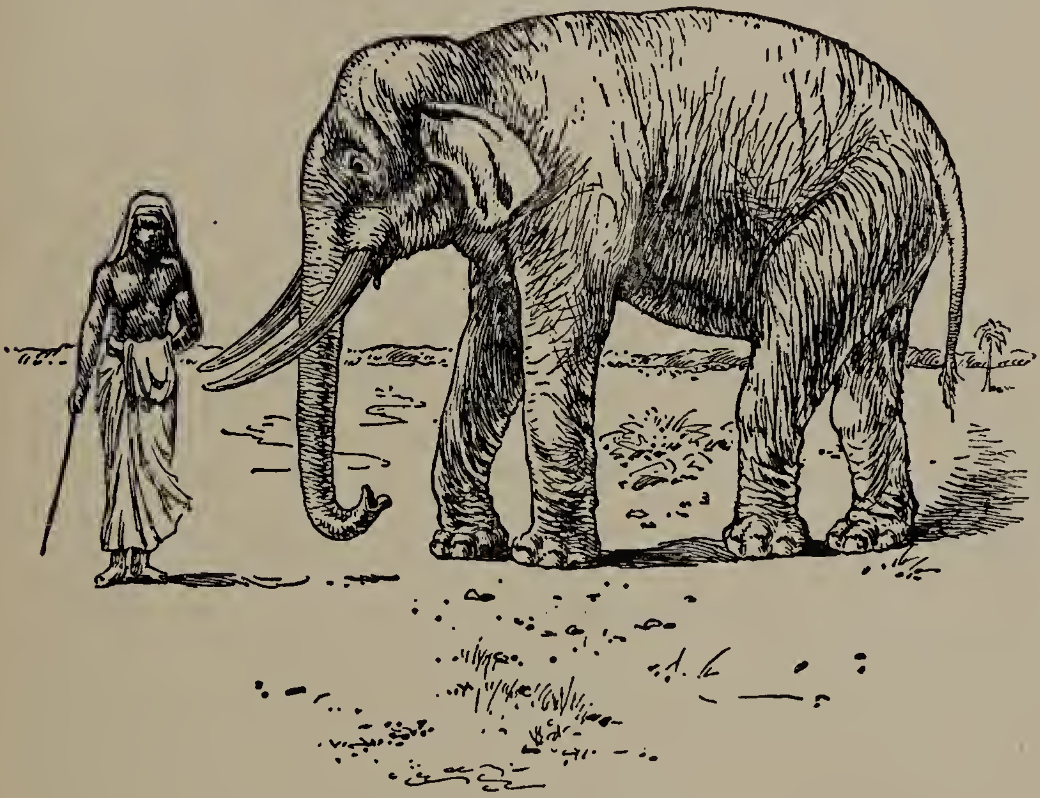


AFRICAN ELEPHANT.

The African is much larger than the Asiatic elephant; the female as well as the male is furnished with tusks, and the tusks attain immense proportions. A single tusk will sometimes weigh from 150 to 175 lbs. and measure 10 feet in length.

The tusks of the Indian elephant are smaller; they usually weigh from 60 to 80 lbs. each. The elephants of Ceylon and Siam furnish very beautiful and highly-prized ivory, but the tusk does not weigh more than 25 or 30 lbs.

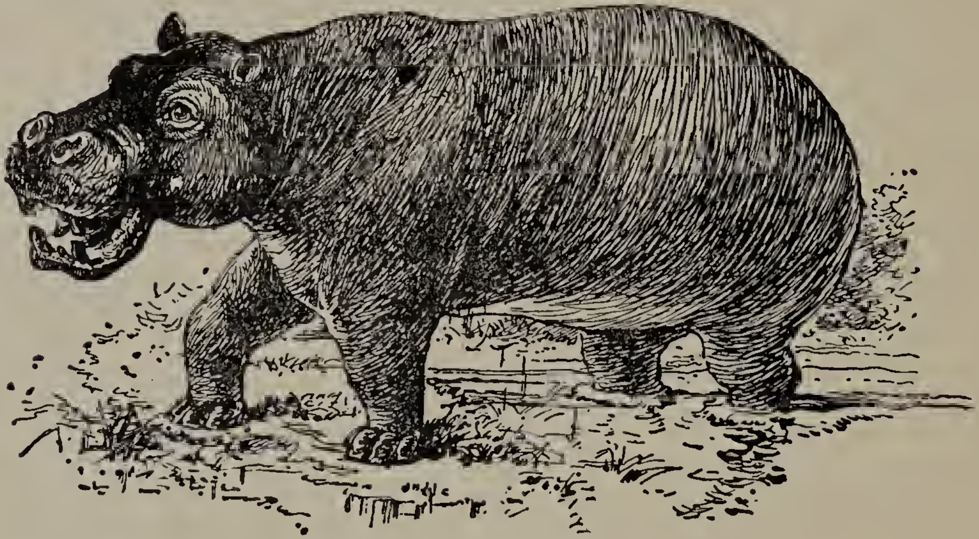
Wild elephants live together in vast herds, and are hunted and killed for the sake of their ivory tusks. It is estimated that thousands of elephants are slaughtered annually to supply the ivory which is an important article of commerce. The elephant uses his tusks in uprooting trees, to get at the young herbage growing on the upper branches. They are also very formidable weapons of attack and defence.



INDIAN ELEPHANT.

Sir Samel Baker, the great African explorer, gives a vivid description of the havoc which he once saw wrought in a mimosa forest by a great herd of wild elephants. These trees grow from 16 to 20 feet in height, and the animals uproot them easily, using their tusks as crowbars and levers. He found the place a complete wreck, the trees not only torn up, but stripped of their leaves and tender green shoots, and even their bark; while the vast herd could be seen in the distance leisurely making off after their meal.

The quality, and consequently the value, of ivory varies considerably. The best, hardest, whitest, and closest-grained ivory is obtained from near the pointed end of the tusk; the base of the tusk is somewhat hollow and spongy. The largest tusks are the most valued, as they can be worked to greater advantage. Tusks that weigh a cwt. or upwards are classed first in value, and fetch as much as $300 per cwt. Smaller tusks weighing from 35 to 50 lbs. are worth about $200 per cwt. The smallest tusks, below 18 lbs. in weight, are known as *scrivelloes.* They are mostly used for cutting billiard-balls.



THE HIPPOPOTAMUS.

For hundreds of years vast quantities of fossil-ivory of the now extinct mammoth have been dug out of the frozen soil in Siberia and Alaska. It is estimated that about 20,000 lbs. of it finds its way into the Russian markets every year. As many as ten fossil tusks have been dug out in one spot, many of them weighing from 200 to 300 lbs. each.

In spite of the removal of such enormous quantities of fossil-ivory each year, the store does not seem to materially diminish, for in many places the tusks are found lying about in heaps.

The tusks of the hippopotamus yield a very highly-esteemed ivory, which is much harder and whiter than elephant ivory. It keeps its color, too, better than some kinds, which are apt to turn yellow. This ivory was very much in demand till late years by dentists for the manufacture of artificial teeth, and fetched as much as $7·50 a lb. It is not used for this purpose now; it has been replaced by other substances.

The long curved tusks of the walrus, which are the canine teeth largely developed, yield a useful kind of ivory, although it is of less value than that of either the hippopotamus or the elephant.


HEAD OF WALRUS.

Lesson XLII

THE WEDGE

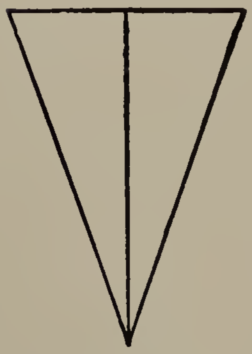
"The thing that must strike us most as we are becoming acquainted for the first time with the mechanical powers," said Mr. Wilson, "is the easy, natural way in which one machine has in every case suggested the next.

"The last machine we studied was the inclined plane. There is just one point to remember now about that contrivance. It is employed to raise heavy bodies by actually pushing or dragging them up its slope, the plane itself remaining at rest.

"I have here a piece of hard wood, cut in the form of an inclined plane. I want you to take it in your hand, Fred, insert its thin edge under this large box on the table, and push it forward. What have you done? You have raised the box on the inclined plane, but the work has been done this time, not by pushing or pulling the box up the slope, but by forcing the inclined plane under the box. It is the inclined plane itself that moves, and not the body which we wish to raise.

"We have here clearly a new machine. Let us examine it.

"Here are two such inclined planes exactly the same size. I will place them together base to base. The two, joined in this way, form a wedge. I have also an actual wedge all in one piece. We have only to draw a chalk line on one of its triangular sides, from the apex, perpendicular to the base, to show that it might be easily separated by the saw into two inclined planes exactly similar.



"The wedge is, in fact, simply a pair of inclined planes, or, as we might say, a double inclined plane.

"Our next business is to learn how to make use of the wedge as a machine for accomplishing certain work.

"Let us turn our attention to this large cupboard, and suppose that it is necessary to raise the cupboard a few inches from the floor. It is too heavy to lift; how shall I do it?

"Some of you will probably suggest the pulley, others the wheel and axle. Now, either of these might do very well if we wanted to lift it some distance, but no machine will accomplish what we want now so well as this simple little wedge.

"You shall take the wedge in your hand, Fred, insert its thin edge under the cupboard, and push it, as you did the little inclined plane under the box on the table. What is the matter?"

"It will not move, sir," said Fred; "I cannot force it under the cupboard."

"No, Fred, you are quite right. It will not move with all your pushing. Now take this hammer, and strike the wedge a few smart blows with it. Does the wedge move now?"

"Yes, sir; the blows of the hammer have driven the wedge between the bottom of the cupboard and the floor, and as the wedge moved under, it lifted the cupboard. The heavy body has been raised by the moving of the wedge."

"Quite true, Fred; and if we compare the small exertion of striking the blows with the great weight of the body you have raised, we shall see that this little machine gives great mechanical advantage.

"There is a point in connection with the wedge worthy of notice. As the power is always applied to a wedge by a blow with a hammer, and not by pulling or pushing, it is not easy to calculate exactly the mechanical advantage with this machine as we have done with others.

"I want you to notice, too, that the cupboard still remains raised up, just where the wedge carried it. Why does not the weight of the body, pressing downwards, force the wedge out? Perhaps I had better tell you. It would do so if the wedge and the bottom of the cupboard itself were perfectly smooth; in other words, if there were no friction.

"It is the friction between the two that grips, or holds the wedge in its place, every time the blow of the hammer has sent it a little farther in. If it were not for this friction, the wedge would rebound and fly out after the blow had been struck.

"One of the commonest uses of the wedge is for splitting great blocks of wood. Axe-heads, knives, chisels, nails, planes—indeed, most cutting implements—are applications of the same principle, for they are all wedges, thin at one edge and thicker at the other."

Lesson XLIII

BEVERAGES—INFUSED DRINKS

Water is the natural drink of man and animals; but man in every part of the world concocts for himself artificial drinks of various kinds. These are nearly all of vegetable origin; they differ in the mode of preparation. Among the commonest artificial drinks are tea, coffee, cocoa, beer, wine, and ardent spirits. We prepare beverages from the first three of these by steeping them in boiling water. We make infusions of them, drawing out their flavors and properties into the water itself. These, therefore, we may call infused beverages, and they are always taken hot. The cup of tea is an infusion of the leaves of the tea-plant; the cup of coffee is an infusion of the coffee-bean or berry; and the cup of cocoa or chocolate is an infusion of the cocoa-nib or seed. In either case leaves, berries, and seeds have to be roasted and specially prepared before they are fit for use.

Beer, wine, and spirits are also prepared as infusions, but these infusions after being made are fermented. Hence they may be called fermented beverages. They are usually taken cold.

To us American people tea is one of the most important of these beverages; but the consumption of tea is not limited to our people. The Russians and the Dutch are large consumers of tea, and so are the people of Great Britain. Indeed, tea forms the daily drink of more people than all the other beverages put together. Probably not less than 500,000,000 of the human race depend upon tea, in some form, as their daily bererage. Under the head of tea we include infusions made from the leaves of many varieties of plants in different parts of the world. The tea with which we are familiar is the leaf of the tea-tree, originally a native of the hilly parts of Bengal and China. It is commonly known as China tea.

In South America a kind of tea, known as maté, or Paraguay tea, made from the leaves of a species of holly, is the universal drink of all classes of the population.

In North America another kind of tea, known as Labrador tea, is made from the dried leaves of a plant that grows wild in those regions. It is the daily beverage of the native population.

The Arab tribes of Northern Africa make a very pleasant drink, possessing many of the qualities of China tea, from the dried leaves of a plant which is grown very extensively in those parts. It is known as Abyssinian tea.

Various other infusions, such as Mexican tea, Tasmanian tea, etc., are made from the dried leaves of plants, all of them resembling in some respects the tea with which we are familiar.

All the tea used in our own and European countries came originally from China. The tea-plant of China has, however, of late years, been introduced for cultivation into India and Ceylon, and now the greater part of our supply comes from these countries. The most striking feature in the tea-market of to-day is the daily-growing favor in which Indian teas are held, and the gradual falling off of the supply from China and Japan.

Since 1885 Ceylon has given up the cultivation of coffee, and turned its attention to tea; and the Ceylon-grown tea is now making great headway in public estimation. The total import of tea to our country in the twelve months ending June 1896 were 93,998,372 lbs. Of this amount China sent 49,178,277 lbs., while Japan fell a little below with 38,169,652 lbs.

The total value of their tea was $12,704,440; of the Chinese tea, $6,788,802; of the Japan, $4,863,721.

In the island of Sumatra the coffee-tree is grown exclusively for its leaves, which are gathered, dried, roasted, and otherwise prepared for the purpose of making tea—coffee-tea—the beverage universally drunk by the native Sumatrans.

The beverage known by the general name of coffee is prepared from the seeds of various plants. Each variety of seed, however, requires the same treatment. They must be roasted and ground before they are fit to be infused in water.

Coffee, in some form or other, is the beverage of more than 100,000,000 of the human race.

Most of the coffee of commerce comes from the Arabian coffee-tree, a tree indigenous to Abyssinia, where it grows like a wild weed. From Abyssinia the tree was first transplanted into Arabia and Persia; and it has, in later times, been successfully introduced for cultivation into several countries in both the Old and New World. Most of our coffee now comes from Central America, Jamaica, and Brazil. Till 1885 Ceylon supplied nearly all the coffee that came to this country. But in that year the Ceylon coffee plantations were stricken with the ravages of a disease which killed off nearly all the trees, and since then the cultivation of coffee has ceased in that island. The tea-plant has been introduced in its place, and the coffee-tree has found a new home in the Western Hemisphere.

The total imports of coffee into this country in the twelve months ending June 1896 were 580,277,222 lbs.

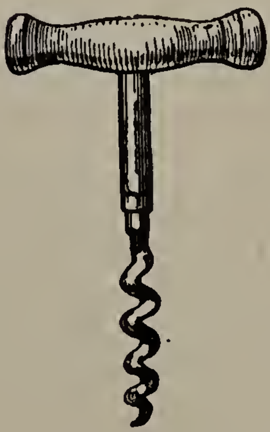
The cocoa-tree is, as we have already learned, a native of America. The Spaniards, when they first settled in Mexico, about the year 1500, found the tree growing there, and a beverage made from its seeds in common use among the natives. It is still grown almost exclusively in America and the adjoining islands. In the island of Demerara there are whole forests of these trees.

The consumption of cocoa in the United States has nearly trebled itself during the last few years. We annually import upwards of 25,000,000 lbs. Part of this is for home consumption; the rest, after undergoing various preparations, is sent out of the country again as a manufactured article.

Lesson XLIV

The Screw

"In our lesson on the inclined plane we showed how the principle of the machine is utilised in making a road over a hill. The road is led round and round the hill, rising gradually all the way. Such a road is really an inclined plane; and, as it winds round the hill in the form of a spiral, we may call it a spiral inclined plane.



"An ordinary corkscrew will give a good idea of what is meant by this name—spiral inclined plane. Or you may illustrate it for yourselves. Cut a piece of thick white paper into the shape of the section of a long inclined plane, with a slight ascent. Ink the sloping edge, and then wrap it round and round a pencil, or a small round ruler. The ink-marked edge of the inclined plane passing round and round the central axis will represent a spiral inclined plane. To give it a simpler name, we commonly call it a screw. The screw is another important mechanical power, derived, as you see, directly from the inclined plane.

"Examine for yourselves a few screws, such as the carpenter uses in his work. Trace the spiral inclined plane in each of them. We call it the worm or thread of the screw, and the distance between the threads we call the pitch. Sometimes the threads are very close together, and we say the screw has a fine pitch; sometimes they are wide apart, and then we say the screw has a coarse pitch. The central cylindrical part is called the axis, and the round upper portion the head, of the screw. We know that in the inclined plane the ratio which the power bears to the weight or resistance depends upon the ratio between the height of the plane and its length. If we want a small power to overcome a great resistance, we must make the length of the slope as great as possible in comparison with the height.

"Applying this knowledge to the screw as a machine, we can easily calculate the ratio between the power and the resistance, if we first measure the pitch, and then find what is the length of one turn of the screw, *i.e.* what is the length of the thread once round the screw.

"Suppose, for instance, the pitch of a screw to be $\frac{1}{16}$ of an inch, and the length of the thread once round it to be 2 inches. Then, as the length of the inclined plane is 32 times the height, any given power applied to the screw will overcome a resistance 32 times as great.

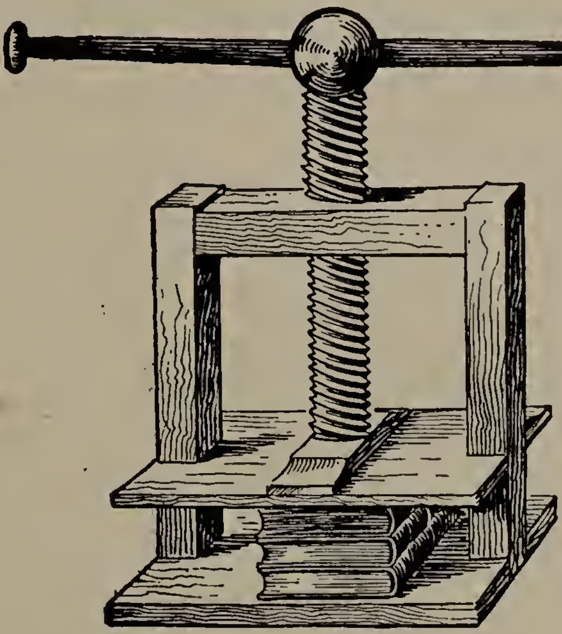
"If you insert a corkscrew into a cork, or a common screw into a piece of wood, you will see that they penetrate the substance because thread after thread of the spiral inclined plane moves downwards. The screw, like the wedge, is a movable machine—a movable inclined plane.

"But the screw, besides its simple uses in the direction we have mentioned, becomes also a most useful and powerful machine for pressing substances together. When used for this purpose, it must be provided with a nut. This nut is a hollow cylinder, on the inner surface of which is cut a hollow spiral groove of exactly the size to receive the spiral thread of the screw. The nut itself being fixed, holds the screw fast.

"Of course, when a common screw enters a piece of wood, or a corkscrew penetrates a cork, the instrument cuts its own nut or groove in the substance through which it passes. This is why the threads of these screws are provided with a sharp cutting edge. All other screws have blunt edges. We have already made it clear that the mechanical advantage of the screw depends upon the ratio that exists between the pitch and the length of the slope. Now follow me a little farther. How do we force the screw into the wood? With the help of a screw-driver. What enables us to push the corkscrew into the cork? The handle at the top.

"Here is a picture of a screw-press at work. The workman forces the screw down through its nut by turning the long handle at the top.

"Remember that, in every case, the screw-driver, the corkscrew handle, and the handle of the screw-press are all levers. In addition to the mechanical advantage of the screw itself, these levers give the power an immense assistance.



THE SCREW-PRESS.

"This may be easily calculated by a reference to the screw-press. Imagine a screw-press with a pitch of $\frac{1}{4}$ inch, and worked by a lever, which at each revolution sweeps a circle of 15 feet. Now 15 feet = 180 inches = 720 quarter inches. That is to say, the length of the slope is 720 times as great as its height. Hence the man, by exerting muscular force of 20 lbs. on the end of the lever, would produce a pressure of 20 × 720 = 1[illegible],400 lbs., or upwards of 6 tons."

Lesson XLV

HORNS

If we were to set about making a list of the horned animals we should find that nearly all of them belong to the order of "ruminants." Probably the first thing to strike us would be the great difference between the horns of the ox and the corresponding appendages of the stag. Both are horns, but they differ in structure as well as in their external appearance.

BULL'S HEAD AND HORNS.

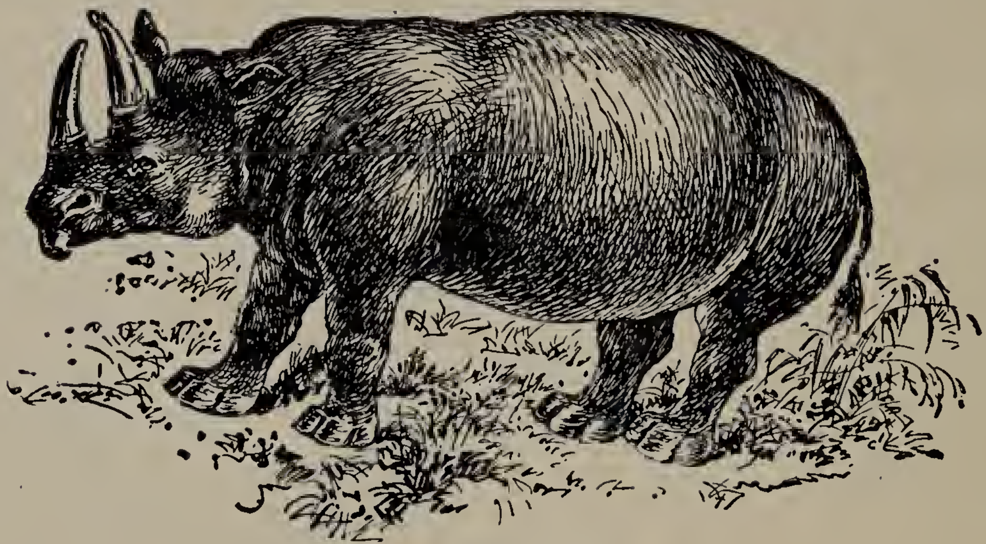
The bullock's horn is hollow, curved, broad at the base, and tapering to a point; it is very hard, tough, and elastic, and has a smooth, shiny appearance. It is really a hard, strong, protecting covering for a bony core, which grows out from the frontal bone of the skull. The core itself is part of the actual skull bone, and is enveloped with a very tender, sensitive skin containing a close network of nerves and blood-vessels.

The horny material of which this covering sheath is made is the same kind of substance as that which forms the claws of mammals, the talons and beaks of birds, and our own finger-nails.

Oxen, sheep, goats, and antelopes have these hollow, horny horns. Some of the antelopes have straight horns, but in all the other members of the group the horns are more or less curved like those of the ox, and some are twisted. These hollow horns make their appearance early in the life of the animal, and continue to grow as long as it lives. They vary in size in different animals; in some cases they measure as much as 6 feet from tip to tip.

HEAD AND HORNS OF ANTELOPE.

Certain antelopes of America shed their horns periodically; but none of the other animals do so, and hence, with this exception, we may describe them as *permanent horns.*



THE RHINOCEROS.

STAG'S HEAD AND ANTLERS.

The rhinoceros has the same kind of horny horn, but instead of being hollow it is solid, and there is no inner core.

Passing next to the horns of the deer, we find at once that they are altogether different from these hollow horny horns. They consist of a number of spreading branches, and are usually called antlers in preference to horns.

If the antlers of the common stag and those of the fallow deer and reindeer be compared, it will be seen that in the former the branches are rounded like the branches of a tree, while in the latter they are flattened out.

These antlers are hard, solid bone, and not horny matter. They are parts of the frontal bone of the skull grown out, but without any external covering sheath of horny material. Antlers of this kind are common to all the deer family, but, with the exception of the

REINDEER'S HEAD AND ANTLERS.

STAG'S ANTLERS IN SUCCESSIVE YEARS OF THEIR GROWTH.

reindeer, only the males have antlers. In every case the antlers are shed in the spring of each year, and new ones take their place. Hence these are sometimes called *deciduous horns.* During the first year there are no actual horns, but only a pair of short rough knobs, covered with a hairy skin. The horns make their appearance in the second year, and are then single, straight, and pointed. These fall in due course next spring, and the third year another pair, having two antlers or branches, take their place. The fourth year's growth have three antlers; the fifth have four; the sixth, five; the seventh, six. In the fully-grown deer the antlers are very large, thick, and wide-spreading; but the period of growth never exceeds ten or eleven weeks.

The true horny matter of the permanent horns is a very different substance from the bone of the antlers of the deer. A piece of cow's horn readily softens in boiling water, and becomes so plastic that it may be easily cut and moulded into various forms, and even welded together. The substance of the antlers is actual bone, resembling in almost every particular the ordinary bone in the body.

Each of these has its uses. The horny horns, and especially those of the ox family, are used for making combs, drinking-vessels, shoe-lifts, knife-handles, buttons, umbrella-tops, etc.

Buttons are usually made from the solid tips of the horns. They are first softened in boiling water, and then pressed into the required shape. Rams' horns are sometimes made into snuff-boxes in Scotland.

The antlers of the deer family are mainly employed in making handles for carving-knives and forks, pocket-knives, and many varieties of ornamental articles.

The supplies of horn to English manufacturers average about 5000 tons, and are valued at about £160,000 sterling. Most of the supplies come from India, South Africa, the East Indies, the United States, South America, and Australia.

From British India and the Straits Settlements they get on an average 2500 tons of horns, mostly those of the ox and buffalo, and this is estimated to represent the slaughter of no less than two million head of these cattle annually.

Nearly one-fifth of English imports of ox and buffalo horns are used in the manufacture of combs; the annual value of horn combs manufactured in that country is said to reach £400,000 sterling. The cutlery works of Sheffield use up annually for knife-handles, etc., about 400 tons of foreign stag-horns, besides a probable 100 tons from English deer forests and those of the Continent.

Lesson XLVI

ABSORPTION

Our lesson on digestion made clear to us the fact that all food, if it is to be of any service to us, must enter the stream of the blood, and it can only do so by *osmosis* through the walls of the blood-vessels themselves. We learned further that only dissolved substances are capable of passing through a membrane in this way; hence the whole purpose of digestion. Digestion is simply the work of so dissolving the food as to render it osmotic.

Starch is insoluble, and therefore has no osmotic force. The starchy matters of the food are converted into sugar by the action of the saliva; sugar is soluble and, of course, readily osmotic; and, as the food-stream passes along the alimentary canal, this dissolved sugar is greedily sucked up, by direct absorption, into the network of capillary vessels, which closely line its walls.

It is exactly the same with the proteid matters of the food. The lean parts of meat, together with what is left of the bread and pudding, peas and beans, after the starch has been removed, form a substance resembling *albumen* or *white of egg.* If some "white of egg" were put into a bladder and immersed in a vessel of water, it would be seen that no exchange takes place. The substance cannot pass through a membrane in that state. It is the work of the gastric juice to dissolve all these proteid matters, and, when dissolved, they are readily taken in, by direct absorption, through the walls of the blood-vessels.

It still remains to account for the fatty matters of the food. They leave the stomach in an undissolved state, for neither the saliva nor the gastric juice has any effect upon them. They can be dissolved only by an alkaline fluid; and this the liver supplies in the shape of bile. It is the bile that dissolves the fatty, oily portions of the food, and so renders them osmotic.

But the food-stream, as it passes out from the stomach into the intestines, contains not only these undissolved fats for the bile to act upon; some of the starches and proteids remain undissolved. This explains why, side by side with the bile duct, another little channel opens into the intestine, bringing from the pancreas a fourth dissolving fluid, known as the pancreatic juice. This fluid combines in itself the properties of both saliva and gastric juice, and completes the work upon all starches and proteids which have escaped the action of those juices in the stomach. As these substances are dissolved, and thus rendered osmotic, they are at once sucked up into the blood, as before, by direct absorption, all along the intestinal canal.

But the intestines themselves have a wonderful part to play in the absorption of the dissolved food. The inner surface of the small intestines is not smooth, like the outside of the tube, but is covered with a multitude of tiny thread-like projections, set close side by side, like the pile of velvet. It is estimated that there are no less than four million of those little hanging threads in the walls of the small intestines. They are called *villi*. They might be compared to a multitude of tiny tongues hanging down into the tube. They are being constantly bathed by the stream of dissolved food, as it passes along the intestinal canal. These little tongues suck up from the stream the dissolved fats which it contains.


INNER SURFACE OF INTESTINE, SHOWING VILLI.


VILLUS, SHOWING THE LACTEAL.

Each little *villus*, small as it is, is really a very complicated structure. It has, running through its centre, a tiny tube, which forms at its extremity an exceedingly fine network of still smaller tubes. This tube is not for the purpose of carrying blood. It is called a *lacteal*. The name lacteal comes from the Latin word *lac*, meaning *milk*. It signifies *milky*-

looking. The name is given to these vessels because of their white, milky appearance an hour or so after a meal. This white, milky appearance is actually due to the minute particles of fat, which they have absorbed from the intestines after the bile has dissolved and broken them up.

The work of these tiny tubes, the lacteals, is to absorb the digested fatty parts of the food. All the fat which enters the blood is carried to it through the lacteals. They gradually unite into larger vessels in the walls of the intestines, and these at last form a great trunk or pouch called the thoracic duct.

The thoracic duct is a tube about 18 inches long, and about the size of an ordinary goose-quill. It lies along the front of the spinal column, and extends upwards to the root of the neck. It forms a sort of reservoir or receptacle for the dissolved fats, which are sucked up by the lacteals and poured into it. At its upper extremity it opens into a great blood-vessel known as the left sub-clavian vein. Thus, the fatty matters, taken up by the lacteals, at last reach the blood, and the work of digestion is completed.

Lesson XLVII

BEVERAGES—FERMENTED DRINKS

The sweetening principle of all fruits is known as grape-sugar. If the juice is squeezed out of some fruit, and then left to stand for a time in a warm temperature, there is a natural tendency in the grape-sugar which it contains to undergo a remarkable change. During this change the surface of the liquid becomes covered with a film, resembling yeast, and two new substances are formed—alcohol and carbonic acid gas. We speak of the change as fermentation. The presence of the alcohol in the juice can be easily detected by its peculiar, sharp, biting taste.

If the juice were allowed to stand for a sufficient length of time, it would continue to ferment, and more and more of the grape-sugar would be converted into alcohol. The juice would become actual wine. This is the whole secret of fermentation. As the juice ferments, its grape-sugar becomes converted into alcohol.

It is no part of our business to follow up the process of wine-making. Properly speaking, the name *wine* is generally used in a restricted sense for those drinks made from the fermented juice of the grape; but wine is made from most fruits.

There are many varieties of wine, according to the kind of grape and the mode of preparation. The wine countries of Europe are France, Spain, Portugal, Germany, Italy, Hungary, Greece, and Turkey; and in all these the cultivation of the vine and the manufacture of the grape into wine constitute most important national industries.

From France comes Champagne, Médoc, Burgundy, and Bordeaux. Spain is famous for Sherry and Malaga; Portugal for Port. The wines of Germany are produced in the basin of the Rhine, and are commonly known as Rhenish wines. Moselle is also a German wine. Madeira, a wine resembling Sherry, comes from the island of that name; and the chief of the Hungarian wines is Tokay.

Some wines are bottled while the fermenting process is going on. They still contain the carbonic acid gas; and it is this gas in the wine which causes it to foam when uncorked, and gives the wine its brisk taste. Such wines are known as sparkling wines. Others are not bottled until the work of fermenting is completed. In the preparation of these wines the carbonic acid gas is allowed to pass off before they are put into the bottle, and they do not continue to work and foam. These are known as still wines.

The juices of the apple and pear are fermented, and made into a kind of wine. That made from the apple is called cider; that from the pear is perry.

Most of the palms yield a sweet juice, which if allowed to ferment will produce an alcoholic liquor. Toddy is a kind of wine made from the juice of the topmost spathe or flower-shoot of the cocoa-nut palm. It is made and consumed in large quantities in all countries where this palm grows.

A somewhat similar wine is made from the date-palm. It is known as date-wine, and is highly esteemed by the people of the deserts where this tree grows.

You remember that the starches can be made to yield a kind of sugar, called maltose. This starch sugar, like the grape-sugar of fruits, will ferment if dissolved in water, but only after some yeast has been added to the solution.

This constitutes the difference between wines and beers. Wines are made from grape-sugar, which ferments spontaneously; beers are made from sugar, which requires yeast to make it ferment. In both cases the fermentation splits up the sugar into alcohol and carbonic acid gas.

Barley is the starch grain usually employed for brewing purposes, although corn is rapidly coming into use. The grain is first converted into malt by the maltster. He soaks it in a tank of water for two days, and then lays it out evenly on the floor of the malt-house in a warm temperature. After about a fortnight the grains are seen to be sprouting. They are then, when in this state, thrown into an oven or kiln. The heat stops further growth, and the starch is converted into sugar. When in this condition the grain is called malt. We have nothing to do here with the process of beer-making. It will be enough for us to know how the barley grain is converted into malt.

A HOP GARDEN—PICKING TIME.

Hops are grown largely in this country for the purpose of brewing. They give the beer its bitter aromatic flavour, and also prevent it from turning sour. The hop gardens of England extend into fifteen counties, and occupy no less than 71,789 acres. Kent is the chief county for hops. A hop garden in the flowering season, when the plants are in their beauty, presents a picturesque sight, and is sometimes called the English vineyard.

Spirituous liquors are made by the process of distillation. If a fermented liquid is boiled in a closed vessel, the alcohol which it contains, as well as the water, will assume the vapor form and pass away into the cooler to be condensed. But this will take place only when the boiling point is reached. The boiling point of alcohol is 172° Fahr, that of water 212° Fahr.

In distilling alcoholic liquors, therefore, the aim is to keep the liquid in the boiler at or near the boiling point of the alcohol itself, but below the boiling point of the water. The alcohol vaporises and passes away into the condenser, and the water is left behind.

In this way wine is distilled and made to yield brandy; fermented molasses is distilled and made to yield rum; and the liquor of malt treated in a similar way gives whisky.

It must be carefully borne in mind that our purpose in dealing with these intoxicating drinks here is merely to point out the materials from which they are made, and to give a general notion of their preparation. We have nothing to do with them in themselves. Whatever good they may have done, it is certain that they have done untold mischief, and that man is wisest who has nothing to do with them.

Lesson XLVIII

WATER AS A MACHINE

"We have lately been discussing certain contrivances which we call machines. Each of these machines is employed by man for the purpose of turning to the best account the various natural forces. You remember, of course, that we defined a machine to be *any contrivance for transmitting a force from one point to another, or for altering the direction or intensity of the force.* Now, I want to introduce to you another machine, and a very important one—I mean water.

"As we are going to think of water as a machine, it is clear that it must possess certain properties peculiar to itself, which enable it, like other machines, to accomplish certain work. To be a machine, as we now understand machines, it should be able to transmit a force from one point to another; it should be able to alter the direction of the force; it should be able to increase the intensity or magnitude of the force. Water can do all these things; and it does them because of two properties which it possesses in common with all liquids.

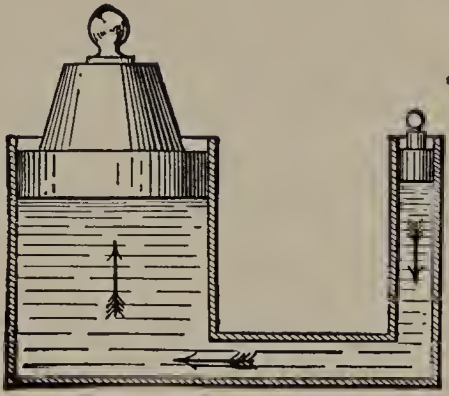
"One of the important discoveries which our earlier lessons led us to make with regard to water is that it is incompressible. You no doubt remember our experiment with the pop-gun and the squirt. We filled each of these with water, and, after closing the hole firmly with the finger, tried to force the piston down. With all our trying it refused to move, because water will not be compressed, or squeezed into smaller space. I want you to keep this fact well before you now. If a vessel of any kind is filled with water, no amount of pressure will force that water into a smaller space.

"Another important truth which we learned in those early lessons was that water presses equally in all directions. I remember I showed you this by means of a hollow india-rubber ball, which I first pierced all over with small holes, and then filled with water. When I squeezed the ball, jets of water were forced out on all sides.

"Suppose we repeat the experiment with this wooden pop-gun. I have already drilled some small holes all round the end of it, and I will now fill it with water. I have only to press the end firmly against the palm of one hand, and force the piston down with the other, and a jet of water will rush out through every hole. The pressure applied to the piston rod in one direction has been transmitted by the water in every direction. It is because water is incompressible, and because it transmits pressure equally in all directions, that we are able to use it as a machine.

"But to be an effective machine it must also alter the intensity or magnitude of the force. Let us see whether it does this.

"Imagine, if you can, two tubes, one small, the other very large, with a connecting pipe between them. If we poured water into either one of those tubes, you know that it would flow into the other, and the level in both would be the same, because water always finds its own level. Imagine each tube provided with a close-fitting piston, resting on the top of the water; and let the under surface of the small piston be exactly 1 square inch, and that of the other 100 square inches.



"Now, if liquids transmit pressure equally in all directions, it is clear that whatever pressure was applied to the small piston would be transmitted by the water to every square inch of the surface of the larger piston. That is to say, if a lb. weight were placed on the small piston, we should expect to find that every square inch of the surface of the large piston resting on the water would be pressed upwards with a force of 1 lb.; the entire upward pressure on the piston being 100 lbs.

"Now, as a matter of fact, if we had two such piston-fitted cylinders, a weight of 1 lb. on the small piston could only be balanced by 100 lbs. placed on the large piston. This tells us that the water on the under side of the piston is pressing upwards with a force of 100 lbs., and it derived that pressure from the 1 lb. weight placed on the small piston. Hence we see that water is actually a machine. It is able to transmit a force from one point to another; it is able to alter the direction of the force; it is able to increase the intensity or magnitude of the force."

Lesson XLIX

Tallow and Offal of Animals

The fat or tallow of animals, especially of those whose flesh is used as food, forms an important article of commerce. It is obtained by boiling down the carcases in huge boilers; the fat, of course, floats on the top, and is drawn off into coolers. Tallow is used now mostly in the manufacture of soap. Formerly large quantities were made into candles, but since the introduction of solid paraffin very few tallow candles have been made.

Our home consumption of tallow amounts to many thousand tons annually, but we export, in addition to this, to many parts of the world, the total value of our exports being from $2\frac{1}{2}$ to 3 million dollars. Most of our exported tallow goes to Great Britain, France, Germany, and other European countries. The first-named country formerly drew from Russia its largest supplies, but of late years the trade in Russian tallow has declined.

Till recent years Australia reared its sheep and cattle almost solely for the sake of the wool and hides, there being little demand for the flesh. Whole carcases were boiled, 300 or 400 at a time, in huge vats or boilers, 11 or 12 feet high. The fat was drawn off for tallow; the flesh was used for feeding pigs, or put on the land as manure. In New South Wales and Victoria the number of carcases of sheep alone boiled down for tallow annually averaged $1\frac{1}{2}$

millions. The rise of the Australian trade in frozen carcases as food for Europeans has now caused a corresponding fall in the supply of tallow from these countries.

Under the head of offal are included all the waste or refuse parts of the carcase, as well as certain parts which are used as food—*e.g.* the head, tongue, feet, heart, liver, kidneys, lungs, tripe, gut, and bladder.

The tripe-dressers of London and other large towns carry on an extensive and flourishing trade in the preparation and sale of offal as food. Some parts of it are highly esteemed as delicacies; others form cheap and wholesome food for the poor.

Calves' heads form a nutritious dish which is regarded as a luxury. Ox-tongues are also largely in demand as a delicacy. We export immense quantities of canned beef products to Great Britain, Germany, France, other European countries, and Africa.

The feet of oxen, when boiled, yield gelatine—a very wholesome food. Calves'-foot jelly is much esteemed as a delicacy for invalids. There is a large amount of fatty oil in the foot of the older animal, which must be extracted before it is fit for food. The fat extracted is the useful oil known as neat's-foot oil.

The accumulation of animal refuse in the slaughter-houses and meat markets of our large towns was formerly a source of great danger to the community, and various means were adopted to destroy it, or get rid of it in some way before it could work mischief. Now every part of it is applied to some definite purpose, and provides a remunerative source of employment and profit.

The blood of the slaughter-houses, instead of being allowed to run away into a drain as useless, is now put to various uses, either as food or in the industrial arts. The blood of pigs and sheep is used for many purposes, and in Sweden the poorer classes of the population live on a very wholesome bread made of the blood from the slaughter-houses mixed with wheaten flour.

Blood is largely used in the arts in the form of blood-albumen. One kind of blood-albumen is obtained from the clot after the blood is allowed to stand for some time; another is derived from the *serum* or liquid part of the blood. The first of these is used by calico-printers to produce the color of the particular kind of cotton cloth known as Turkey-red.

It is estimated that upwards of 6000 tons of blood are used annually for this purpose. That derived from the blood-serum is employed by dyers as a mordant for fixing or *biting in* the colours in woollen fabrics.

Dried blood is used to clarify wines and syrups, and it also forms a valuable manure for the land.

The intestines of animals are prepared for various purposes, and are thus the source of large and important branches of manufacture. The delicate membrane of the small intestine of the ox is the material from which gold-beaters' skin is made. One London maker alone is said to use up the gut of no fewer than 10,000 oxen every week for this purpose. Other parts of the gut are made into strings for musical instruments, lashes, and whip-cords, and skins for sausages.

Cow-hair is used for mixing with mortar for plastering purposes, but not so much as formerly, because it can find (at least the best part of it) a better market. Large quantities of it are now made up into cheap imitations of sealskin for ladies' jackets, etc. The best of the hair for this purpose realises from $50 to $55 per ton. The coarser, rougher hair is used for stuffing chairs and sofas, and in making felt for roofing purposes. It is also made into ropes, as well as carpets and other textile fabrics.

Glue is made from all sorts of refuse animal matter, including the fleshings (*i.e.* the parings of the hides from the slaughter-houses and tanneries), the refuse parts of the hoofs and ears of horses, oxen, and sheep, and the cuttings and scrapings of the horns of animals. Almost any animal offal and garbage, useless for other purposes, is available as a material for making glue. The dried sinews, the inner bony core of the horns, even old worn-out leather (if it is first deprived of its tannin)—all are made to yield glue.

Size is a weak solution of glue allowed to cool and clarify. Scraps of vellum or parchment, old kid gloves, and rabbit skins are used as materials for making gelatine and size.

The process of glue manufacture is simple. The fleshings are soaked in lime-water to cleanse them; after which they are washed, and then boiled. The impurities rise to the surface and are skimmed off during the boiling, and the clear liquid is then run away into moulds and left to dry and harden.

When the glue is sufficiently solid it is cut into thin slices by wire in the same manner as soap. These slices are again subdivided by a wet knife, and spread upon drying frames.

Gelatine is used for stiffening straw hats and for dressing silks and other fabrics. It is also used as an article of food.

Size is chiefly used for mixing with whiting and color in whitewashing and coloring ceilings and walls.

Lesson L

Acids

"I have here a bottle containing a liquid which has long been familiar to us by name, for we have made frequent use of it in our lessons," said Mr. Wilson at the next meeting of the class. "We know it as *spirit of salt,* or *muriatic acid.'*

"I think we are now in a position to make it teach us something new," he continued; and he poured some of the liquid into a test-tube, and added a little blue litmus solution.

"The color, you see," he went on, "instantly changes to red. Now, Fred, dip your finger into the liquid, and put it to your tongue."

Fred did so, and found that it had a sharp, strong, sour taste. "We have met with these same characteristics before," continued Mr. Wilson, "in the dissolved oxides which we examined. The solutions of the oxides of sulphur and phosphorus had the same sharp, sour taste, and they both turned the blue litmus into a bright red. The carbon di-oxide was sour too, although only very slightly; but it also changed the blue color of the litmus.

"There are many substances, besides those we have examined, which have the same characteristics. The chemist has one name for them all. He calls them acids. In our every-day language the word *acid* calls up in our mind some sharp, sour taste, such as that of vinegar or unripe fruit. It comes from a Latin word *acidus*, which means *sour*. Many substances possess this peculiar sharp taste, and when the name acid was first used by the chemist, it was limited to such bodies. They all have the same effect, too, in turning the blue colour of litmus into red.

"But it is now known that, although most acids are sour to the taste, there are some which are not sour. To the chemist, therefore, this sourness is a mere accident in spite of the name. Acids are now distinguished entirely by their action on vegetable coloring matter. Any substance which can change the natural blue color of litmus into a red is said to be an acid, whether it be sour to the taste or not.

"We are now in a position to give the proper names to those substances which we have till now called dissolved oxides. Carbon di-oxide when dissolved in water is *carbonic acid*. Sulphur di-oxide similarly becomes *sulphurous acid* when it is dissolved in water. The oxide of phosphorus, which we produced and examined, became *phosphoric acid* when it was dissolved in water.

"These acids and many more like them were produced by the combustion of some substance in oxygen. There are other acids which are not formed in this way, and these are not oxides; they contain no oxygen at all. The spirit of salt or muriatic acid which we examined just now is one of them. It is also sometimes called hydrochloric acid, but this is not really a good name, for spirit of salt is really a solution of hydrochloric acid, and not the acid itself.

"Hydrochloric acid, by its very name, of course, suggests that it is composed of two bodies—hydrogen and chlorine—with which our lessons have made us familiar. We will prepare some now, and see what we can learn about it.

"I have here some common salt, which has been fused in an iron ladle over a very fierce red fire, then allowed to cool into a solid mass, and afterwards broken up into pieces with a hammer. We must first weigh a certain quantity of this fused salt, and put it into a flask. Then we must weigh an equal quantity of oil of vitriol, and pour over the salt.

"I ought to tell you that oil of vitriol has another name—sulphuric acid, but this is not the same as the sulphurous acid I mentioned a little while ago. It is one of the most powerful of acids, and like those we have examined, it has a sharp taste and turns blue litmus red.

"You see by this time there is a sort of action going on between the salt and the acid. If I now apply the flame of the Bunsen burner gently to the bottom of the flask, a gas will be rapidly given off. This gas is the hydrochloric acid we want.

"Hydrochloric acid is heavier than air; we therefore collect it by displacement. All that is necessary is to guide the delivery tube into the jars as they stand, with their mouths open, on the table. The heavier gas will sink to the bottom of the jar and drive the air out at the top. As they fill we will cover them with the glass discs, and set them aside till we require them. Now to learn something about this new gas.

"We will take one of the jars, with the glass cover still closing the mouth, and invert it in this bowl of water. Notice what happens when I slide the disc away under the water. The water rushes rapidly up into the jar, dissolving the gas which it contains. There is a very strong affinity between this gas—hydrochloric acid—and water. Water will greedily dissolve 480 times its own bulk of this gas. You remember I told you that muriatic acid, or spirit of salt, is simply hydrochloric acid in solution.

"I am now going to perform the same experiment again, but I will color the water with blue litmus this time. When the jar is inverted, and the disc removed, the water rushes up as before, but as it enters the jar it changes from blue to red. Now you can see why we call the gas an acid. You saw, moreover, that I prepared the gas from common salt. Hence you will not be surprised now at the name *spirit of salt*."

Lesson LI

PLANT-FIBRES FOR SPUN AND WOVEN GOODS

Materials for an immense variety of textile fabrics, as well as for rope and cordage of all kinds, are provided by the fibres of the cotton, flax, hemp, and jute plants.

The woolly down from the pods of the cotton-plant yields such materials as calico, nankeen, muslin, fustian, hosiery, and lace.

Fustian is the common name for a large number of heavy materials, used principally for working men's clothing, such as corduroy, moleskin, fustian, velveteen, velveret, and beaverteen.

Hosiery includes, not only stockings, as the name denotes, but all those textile fabrics made by a kind of knitting or chain-stitch, altogether different from the regularly crossed threads of the warp and woof in woven goods.

COTTON-TREE.

Cotton supplies materials for clothing man in all parts of the world. Indeed, the cotton-plant may justly take its place among the most valuable of Nature's products. It is by far the most abundant and important of all materials used for textile fabrics.

The cotton-plant grows in most of the hot countries of both the Old and the New World. There are three varieties of the plant—the tree, the shrub, and the herb.

The cotton-tree grows to the height of 15 or 20 feet, and yields the finest and most valued cotton. It grows on the shores of Florida and the adjoining islands; and is sometimes known as *Sea Island cotton.* It is also called *long-staple cotton,* from the length of its fibre.

COTTON-PLANT.

The cotton-tree grows also in India, China, and North Africa. The Hindoos make from it a fine, silky cloth for turbans.

The cotton-shrub is a woody, perennial plant, about the size of our currant-bush.

Most of the cotton grown in the United States of America is of the herbaceous variety. The plant is an annual, and grows from seed sown in March or April. It attains the height of about 2 feet, bears bright green leaves, and blooms in June.

The flower is very like the hollyhock, and when it falls it leaves behind a pod about the size of a walnut, containing seeds embedded in a loose, white, woolly down—the cotton of commerce. The pods are picked in the autumn by women and children, who go through the plantation from plant to plant, with bags or baskets slung round their necks. It is estimated that in England alone no less a sum than £100,000,000 sterling is sunk in the manufacture of cotton goods. There are not less than half a million looms at work in English cotton centres; and in a busy time 10,000,000 yards of cotton cloth can be turned out in one day.

LEAVES, FLOWERS, AND PODS OF COTTON-PLANT.

Some idea of the number of persons employed in the manufacture may be formed from the estimate that between 30 and 40 millions sterling are paid annually in wages and the cost of working. In 1886 they imported 671,026 tons of raw cotton; and the same year they exported cotton yarn alone to the value of 11½ millions sterling, and cotton goods to the value of 57 millions sterling, besides what they retained for their own use.

Before the cotton-down is fit for the manufacturer the seeds must be removed. These seeds are about the size of grape-seeds, and contain much oil. This oil is expressed, and forms an important article of commerce—cotton-oil. It is used for burning in lamps, for oiling machinery, for soap-making, and as a substitute for olive-oil. The residue, after the oil is removed, forms a valuable oil-cake for feeding cattle.

The textile material provided by the flax-plant comes from the bast-fibres of the inner bark of the stem; and is manufactured into linen, duck, diaper, damask, sheeting, towelling, huckaback, drill, check, drabet, and sail-cloth.

The rougher and commoner fibre is made into sacking, and a mixture of flax with cotton gives the useful fabric —union. The plant yields another product besides the bast-fibres of the stem. Its seeds form a valuable article of commerce. When pressed they yield linseed-oil and oil-cake for feeding cattle.

FLAX-PLANT.

The mode of cultivation depends entirely upon the special kind of product in view. Warm climates produce the finest seeds; temperate climates the best fibre for the manufacturer.

The flax-plant is extensively grown in the north of Ireland. The bast-fibres of the hemp-plant are used for making rope and cordage, canvas, sacking, sail-cloth, floor-cloth, and other coarse, strong fabrics.

Lesson LII

Furs

Fur is Nature's covering for the animals which inhabit the colder regions of the world; and the more rigorous the climate, the more beautiful the fur-skins which it produces. Man, even in his primitive state, soon learned to set a high value on these skins as a clothing for himself, and in process of time he discovered a means of so dressing them as to prevent them from rotting, or the hair from falling off.

The inhabitants of very cold countries dress themselves to-day entirely in fur, or line their other clothing with it. We in this country regard fur, because of its costliness, as a luxury for winter ornament; only the wealthy part of the community can afford to look upon it as a necessary article of clothing.

The fur-bearing animals include members of both the Carnivora and the Rodentia. The vast majority of them are wild animals, which are hunted and trapped in the most solitary regions of the earth, remote from the haunts of man. Their skins yield many varieties of fur, from the simple rabbit-skins worth two or three pence, to valuable furs which have been known to realise as much as $500 each.

Among the most beautiful and costly of these furs are the skins of the fox, racoon, bear, badger, wolverine, skunk, polecat, marten, stoat, mink, otter, and seal.

Many varieties of foxes are killed every year for the sake of their fur, and all of them are highly prized.

Silver-fox is a rich, soft, handsome skin of thick dark fur, with long silvery-white overhair. A single skin will sometimes fetch as much as $100. Black-fox, another variety, is one of the most valuable furs which the world produces. It is rarely met with now, and consequently is even more expensive still; the price

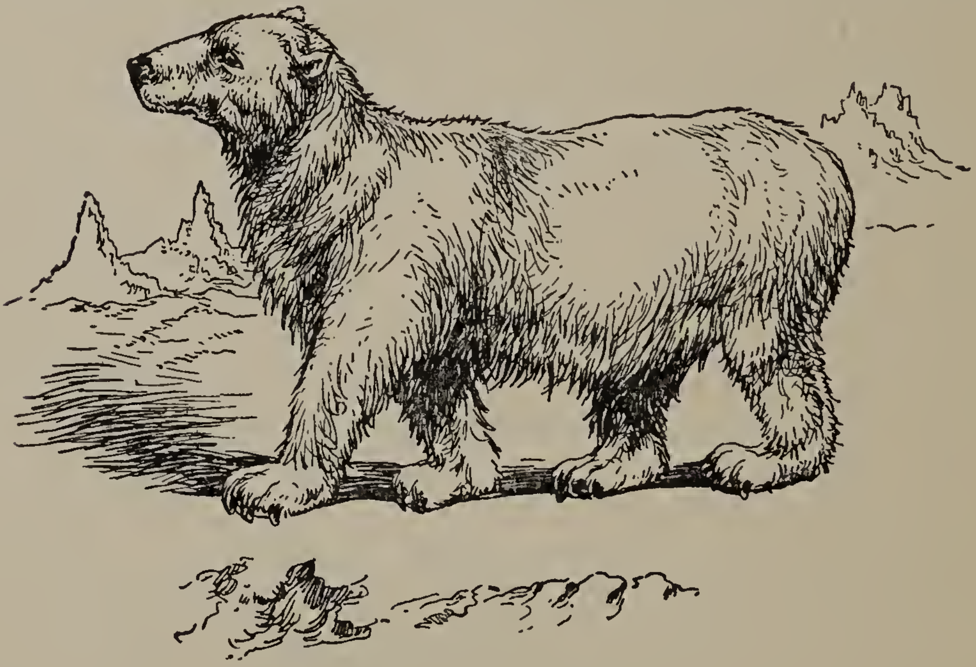
THE SILVER-FOX.

THE RACOON.

asked for a single skin frequently being no less than $200. The red-fox, grey-fox, kitt-fox, cross-fox, and Arctic fox are among the other varieties. The last named animal changes color in winter from a dark gray to pure white, and in this condition the skin is taken and prepared for the market. Most of the polar animals are more or less liable to this change.

The skin of the racoon furnishes a handsome grayish-red fur, much used in Germany and Russia as an inside lining for travelling coats.

Bears are found in many parts of the world, although their numbers are slowly and surely thinning before the steady march of settlement and civilisation both in Europe and North America. Their skins all afford thick handsome furs. The black, brown, and grizzly bears belong to the forest and mountain regions, the last named being a powerful and ferocious beast peculiar to the Rocky Mountains. The polar bear is a sea animal; it inhabits the floating masses of ice,



THE POLAR BEAR.

in the frozen seas of both the Eastern and Western Hemispheres.

The American badger has a very soft, fine fur, fully 3½ inches long. It is of a dark purplish-brown

THE AMERICAN BADGER.

color, tipped with white, and mottled with black rings here and there. The fur of the European badger is coarser; it is mostly used for artists' brushes.

THE WOLVERINE.

The wolverine, or glutton, is about the size of the badger. It has a soft, close, fur coat, about an inch thick, with stiff overhairs fully 4 inches in length. It is much in request for muffs and victorines.

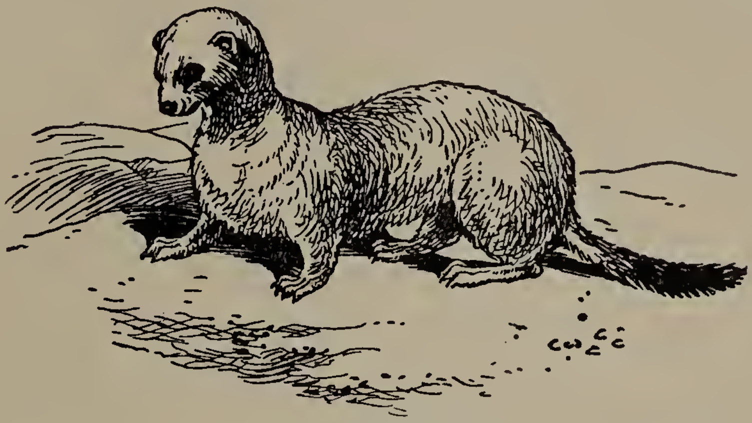
The skunk, or American polecat, has a long, soft, rich black fur, which for ladies' apparel rivals many of the higher priced furs. During its lifetime this animal has the power of emitting a most offensive fluid from a small bag near the root of the tail. This is its mode of defence against its enemies, and a very good one it is, for no animal can endure the nauseous stench. In preparing the skin for the market great care is necessary to avoid breaking the bag; and to ensure the rest of the fur being fit for use, a narrow strip is cut out along the middle line of the back.

THE SKUNK.

The weasel family is a numerous one, its members being small animals very similar to the polecat. Among the weasels the stoat or ermine is highly prized for

THE WEASEL.

its fur. In summer the fur is a bright, reddish-brown, but it changes to a pure white as winter comes on. This fur is much in demand for state purposes, for it has been adopted from very early times by royalty and nobility to adorn their robes of state. It is this fact alone which has given to ermine a value considerably above its merits as compared with many other kinds of fur.



THE ERMINE.

The martens are closely allied to the weasels, and they too form a numerous and widely distributed family. The most valuable of them as regards its fur is the Siberian sable. In the summer the fur is reddish-brown with gray spots, but in the winter it

THE SABLE.

changes to a full, dark brown. Its fineness and the soft rich lustre of its surface render it one of the most costly and beautiful of the furs. It can rarely be worn except by wealthy persons, because, in addition to its beauty, the difficulty of procuring it adds to its value. The animal is only to be met with in the coldest and most out-of-the-way, rugged places, and the trappers have to endure every hardship of hunger and cold, and at the same time to be constantly on their guard against wild beasts. No less than $100, and even $200 must often be given for a single skin.

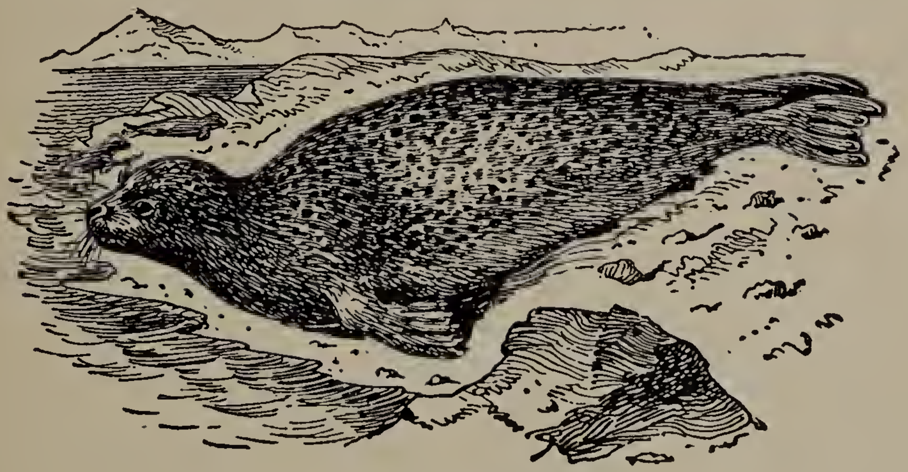
The mink is a North American animal whose fur is unrivalled for its beauty and durability. It is of a chocolate brown color, very fine, short, and dense, with strong, stiff overhairs. It is rapidly rising in estimation, and it is not so expensive as many skins are. A very fine specimen may often be bought for $5.

The sea-otter was formerly to be met with on the Pacific shores of North America in thousands, but the

THE SEA-OTTER.

numbers have decreased considerably. The fur is jetty black and soft as velvet, the skin of the male being immeasurably superior to that of the female. A single skin has been known to fetch as much as $300, and even $500; but the value has declined of late years. Still the animal is scarce, and consequently the fur is uncommon.

The seal is undoubtedly, from a commercial point of view, the most important among the Carnivora. There are several varieties of the animal to be met with in almost every part of the world. The flesh of one kind is used as food, another yields seal-oil from its blubber, and another is the fur-seal. We have to concern ourselves now only with the last-named variety.



THE SEAL.

They live in millions on the rocky islands of the seas which they frequent. A seal breeding-ground, or *rookery*, as it is called, is a sight worth seeing. About June the bull seals begin to arrive thousands strong, and shortly after they are followed by the females. This is the season for taking the seals. In many places, owing to the indiscriminate slaughter that was allowed to go on, the animals have entirely disappeared, and now the annual take is strictly limited by international law. Only the young male seals may be killed. The females and their cubs must not be molested on any account, and the number to be killed in any one season is limited.

The mode of killing them is simple. The hunters manage to stalk them so as to get between them and the water as they lie resting on the rock. Then they drive them landwards, frightening them with tremendous yelling and shouting, and kill them with a single blow on the head with a heavy, sharp-edged club.

THE ROOKERY.

The most extensive seal-fisheries are prosecuted around the shores of Newfoundland, Labrador, and Greenland, and in the neighbourhood of Behring's Straits; but there are important fishing grounds among the islands of the Southern and Antarctic Oceans.

All the skins we have mentioned, and many other varieties, are known as fancy furs, or dressed furs. The skins or pelts are dressed and prepared by a sort of tawing process with the fur on them. The alum and salt used in the tawing convert the skin itself into a kind of kid leather, thereby arresting all tendency to putrefaction, and at the same time fixing the hairs.

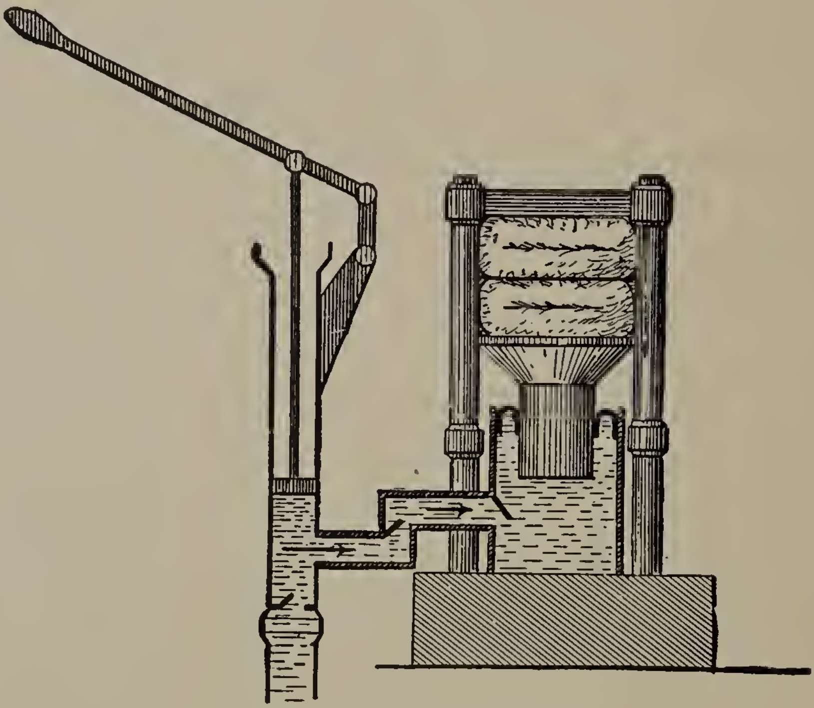
Some of the commoner kinds of furs, such as those of the rabbit, hare, coypus, cat, and musk-rat, are used for felting. For this purpose the fur is removed from the skin, and beaten and pressed till it becomes matted or felted together. This is the material of which felt hats are made. As a branch of the fur trade it forms a thriving industry in England, France, Belgium, Germany, and other countries.

Lesson LIII

THE HYDROSTATIC PRESS

When we were discussing water as a machine, I illustrated the water pressure by means of two tubes, a large and a small one. That will now help us considerably to a right understanding of the contrivance known as the hydrostatic press. The name is a long one, but it will be easy to understand if you remember that it is derived from two Greek words: *hudor*, meaning *water*, and *stasis*, meaning *standing*. It represents the power of standing water. The machine is also known as the hydraulic press. It consists essentially of a small force-pump, connected by means of a pipe with a large and strong cylinder, fitted with a piston. The pump itself, like all other force-pumps, consists of a barrel, fitted with a solid piston, and having in its floor a valve opening upwards. The piston-rod is moved up and down by a lever handle.

As the piston rises and exhausts the air, water rushes up the suction-pipe from the reservoir into the barrel. At the next descent of the piston, the water is pressed downwards, and effectually closes the valve in the floor of the barrel. But the water will not be compressed, and hence it finds its way out of the barrel by the only available channel—through the pipe, and so into the large cylinder.



THE HYDROSTATIC PRESS.

The pipe itself, moreover, is provided with a valve, also opening outwards, and this prevents any return of water into the barrel of the pump. The consequence is that each stroke of the pump-handle forces more water into the large cylinder, and this water presses upwards upon the great cast-iron piston in it.

This upward pressure of the water causes the piston, or ram, as it is called, to rise vertically. The larger the surface of this piston, as compared with that of the little piston of the pump, the greater will be the force of the upward pressure.

The top of the ram is broad and flat, and above it is placed an immensely strong iron plate, supported on stout iron pillars.

The great use of the hydraulic press is to pack wool, cotton, hay, and other light but bulky articles into smaller space. If any of these objects be placed on the top of the ram, the pressure of the water will force them upwards against the iron plate, and so compress them into a much smaller bulk.

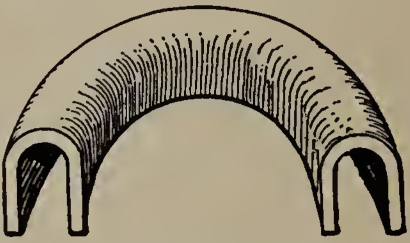
Bales of cotton and wool are, in this way, so closely compressed that they have to be bound with strong iron bands, to prevent them from expanding and bursting during the voyage. The object of the pressing is, of course, to enable the ship's hold to carry more cargo than it otherwise would.

The hydraulic press is also used in raising heavy bodies, such as immense masses of iron plates, and other metallic work used in building. Thousands of tons are raised in this way with comparative ease.

The most marvellous illustration of the powers of this machine is seen when immense ships are raised by its means bodily out of the water, and held suspended there, while the workmen examine and repair the under parts of their hulls.

Much use is also made of this machine in warehouses, hotels, workshops, and great public offices, in the elevators, by which people and goods are easily and quickly carried from the very basement to the highest story of the building. Very few public buildings can now be found without their hydraulic elevators.

If you turn next to the picture of the press, you will see that the ram is smaller than the cylinder in which it works. When this machine was first invented it was of comparatively little use, because as the force, applied at the pump-handle, sent more water in, it caused a corresponding overflow at the top, between the ram and the sides of the cylinder, so that the force was lost.



THE BRAMAH COLLAR.

An English engineer, Mr. Bramah, invented a clever contrivance for overcoming this difficulty. It is known as the Bramah collar. It is made of leather, and is cut in the form of a hollow ring or circle. The leather ring is first well soaked in oil to make it perfectly impervious to water, and then bent down on both sides. You will best understand the arrangement by glancing at the picture of the collar supposed to be cut in two. The cut edges resemble the letter U inverted. This leather ring, or collar, as it is called, fits close to the sides of the cylinder and the ram; and the water as it rises fills the hollow space.

As more water is sent by the pump into the cylinder, it presses with increasing force against the inner sides of the collar. This pressure holds the leather firmly to the sides of both the cylinder and the piston, and effectually closes the opening, so that there can be no overflow—none of the power is lost.

Since the invention of the collar the machine has been styled indiscriminately the hydrostatic, the hydraulic, and the Bramah press.

Lesson LIV

FUR AND THE FUR TRADE

Siberia and British North America are the two great fur-yielding regions of the world. They form immense hunting-grounds for almost every variety of fur animal. They give constant employment to large numbers of adventurous men, who in their trapping and hunting are exposed to great risks and dangers.

The Siberian trappers are usually bold, hardy peasants, whom the rigor of the climate drives to adopt this life of hardship and danger. In North America, although many hundreds of white men are employed as fur-hunters, the hunting and trapping are mostly in the hands of the Indians, who barter the skins they obtain for blankets, biscuits, and a variety of articles for use and personal adornment.

Siberia provides by far the largest share of the fur trade of the world. Among its fur-bearing animals are the sable, marten, beaver, fox, squirrel, ermine, wolf, bear, lynx, badger, sea-otter, and seal. The richest and handsomest furs are obtained from the eastern part of Siberia.

It is said that China alone imports annually from Siberia nearly three million squirrel-skins, irrespective of other furs. Turkey and Persia are also large importers of Siberian furs. The winter, of course, is the season for fur-hunting, because then the coats of the animals are at their thickest and best. All through the winter the hardy, intrepid hunters are scattered over the wildest and most solitary parts of the country, collecting the furs. After the break up of the winter they bring their collections to certain towns, where annual fairs are held for the sale of the furs and other commodities.

Among the most important of these towns are Nishni Novgorod on the Volga, Archangel on the White Sea, and Yakoutsk on the Lena in Eastern Siberia; each of which acts as a central depot for the fur trade in its own part of the empire. The Emperor of Russia derives part of his private income from a tribute which is paid by certain Siberian tribes in the shape of the most costly of furs. Such furs are, as a consequence, never allowed to appear in the markets.

The fur trade of North America was entirely in the hands of the Hudson Bay Company till the year 1860; but since that time it has been taken up by several other traders.

Victoria, in Vancouver Island, is the chief depot for the Hudson Bay traders, who confine their operations mostly to the North-West Provinces, Hudson Bay, and the Rocky Mountains. New York, Boston, St. Louis, and Montreal are the chief centres of the fur trade for the eastern part of the continent.

The principal fur-bearing animals of America are the sea-otter, common otter, and seal; black, red, white, and silver foxes; the panther, wolf, beaver, racoon, bear, wolverine, badger, musk-rat, lynx, ermine, and marten.

The furs sent out annually from British Columbia form the most important and valuable of its exports.

The estimated total collection of furs from all the fur-producing countries of the world in a single season does not fall far short of 30 million peltries, their total value being upwards of $15,000,000. This, of course, takes no account of rabbit-skins and others that are used for felting purposes, for such skins are not styled peltries. Of these France is estimated to produce no less than 80 millions; England, 30 millions; Australia, 20 millions; Belgium, probably 15 millions; and Austria and Germany another 20 millions.

The trade in peltries gives employment to three distinct classes of people. First there are, as we have seen, the trappers, who collect the skins; then there are the wholesale dealers, to whom they sell them at the great trading centres; lastly, there are the furriers, or fur-dressers, who prepare the skins for the market.

The pelts, as they are taken by the trappers, are simply rubbed and salted to arrest putrefaction, and in this state they are brought in to the depot. At the depot they are cleansed and cured, and then packed in large casks for shipment mainly to European countries, where they command high prices, and yield large profits to the traders. London is a great centre of the fur trade.

The value of the fur, of course, depends upon the condition of the skin. If the pelt is torn, through the struggles of the animal in the trap, or riddled with shot, or badly stretched and dried, it loses materially in value. On the other hand, it is a remarkable thing that so little is really wasted, even in a so-called spoilt pelt. The smallest clippings, cuttings, and remnants are pieced together with marvellous skill, so that it is often difficult to see that they have been joined.

Many skins owe their elegance and value to the length and fineness of the overhair; but we have only to examine a lady's seal-skin jacket or muff side by side with some other fur article to see a striking difference. The seal-skin fur has a close velvet-like softness, without any of the long, loose hairs such as we see in most other furs. The skin as it is taken from the seal and put into pickle for the London furrier has stiff coarse overhair, which almost conceals the real fur beneath; but in the work of preparation all the overhair is carefully removed.

For a long time each hair was plucked out singly by hand. At last, however, some one discovered that the roots of these stiff coarse hairs were more deeply embedded in the skin than those of the true fur; and a curious method has since been adopted for removing them. The pelt is first stretched out flat with the flesh side uppermost, and part of the skin is pared or shaved off with a sharp, flat knife. In cutting away this under surface of the skin those deeply-embedded hair-roots are cut through, and it is an easy matter then to pull out the long overhairs. No one but an expert would be able to recognise a seal-skin as it leaves the hands of the furrier, if he could have seen it in its greasy, salted state when it was taken out of the pickle cask.

SECTION OF FUR, SHOWING THE OVER-HAIR.

Lesson LV

BASES, ALKALIES, SALTS

"You, no doubt, remember a very interesting experiment, in which a piece of the metal, potassium, thrown into a basin of water, takes fire spontaneously, and burns with a beautiful purple flame, as it floats about on the surface," said Mr. Wilson.

"Oh yes, sir," replied Will. "You showed us that experiment to prove the strong affinity of potassium for oxygen. The metal burned by robbing the water of its oxygen."

"I remember too, sir," said Fred, "you explained that as the metal took away some of the oxygen from the water, a certain amount of hydrogen was set free. This hydrogen, being a very inflammable gas, burns with the potassium on the surface of the water. The potassium, oxygen, and hydrogen enter into combination, and form a new substance, caustic potash, which dissolves in the water as it forms."

"Those are two excellent answers, my lads, and they prove that you follow each lesson carefully, step by step.

"Yes, the potash is in the water after the experiment, although we cannot see it, because it is in a state of solution. Let us have the experiment again now. This time, however, I want to prove to you that the potash is really in the water. I have therefore colored the water in the basin with red-cabbage infusion. As soon as the piece of metal touches the water it bursts into flame as before; but what else do we see? The reddened water has changed at the same time into a bluish green.

"Potash is a substance which is used for many purposes, and it is usually sold in sticks. It has a very greedy affinity for water, so that it must be kept bottled up close.

"I have a stick of the substance here. Of course, if I put some of it into water it will dissolve immediately. We will make a solution, and see what it will tell us.

"Let us first pour a little of the potash solution, slightly diluted, into a test-tube, containing some red-cabbage infusion. The color instantly changes to a bluish-green, just as our water changed in the basin. This proves conclusively that the combustion of the potassium on the water just now produced potash. We could not see it, but we saw its effect on the red coloring matter of the water.

"I have here some litmus, which has been reddened by an acid. Notice that when I pour a little of our potash solution on it the original blue color of the litmus is at once restored.

"Lastly, Fred shall pour a few drops of the potash solution into the palm of his hand and taste it. It has an intensely acrid taste—a taste like that of common washing soda—and produces a strong caustic or burning sensation on the tongue. This is why it is sometimes called caustic potash.

"This substance—potash—is a sample of a great many bodies, which have the same peculiar acrid taste, and the same power of changing vegetable reds to blue or green.

"Any substance which has this acrid taste, and is able to turn vegetable red to blue, the chemist calls a *base.*

"Many of the bases resemble caustic potash in being soluble in water. These have another name. They are called *alkalies.* That is to say, an alkali is a base of a special kind. It is soluble in water, and it gives to the water a soapy taste and feel.

"Here is some olive-oil. I will pour a little of it into a test-tube, add to it some of the potash solution, and shake it up for a minute or two. If you now pour some of the mixture into the palm of your hand, you will at once notice its soft, smooth, soapy feel. In fact, we have made soap.

"I think now you are clear as to the nature of an *acid,* a *base,* and an *alkali.*

"I have now another acid for you to examine. It is called nitric acid, and is one of the most powerful of all. I will dilute a little of it and put it into a test-tube. Diluted as it is, it has a very sour taste, as you may easily test for yourselves.

"You of course can tell me what will happen if I dip this blue litmus-paper into the dilute acid? The color will instantly change to red, as it does with all acids.

"Now, let us turn again to our solution of potash. I dip the reddened litmus into it, and the blue color is immediately restored like magic. This, you know, is the usual characteristic of a base.

"I want you to watch carefully the next step. I will mix the acid and the base together, and then test the mixture, as before, with litmus. This time the liquid has no effect upon either to change its color. The blue litmus remains blue, and the red remains red.

The liquid is neither an acid nor a base. It is neutral to both the blue and the red litmus.

"Perhaps we can learn something more about this liquid. Let us see. If a little of it be poured on a watch-glass, and allowed to evaporate, we shall find, when all the water has disappeared, that the surface of the glass will be covered with crystals of a new body. This substance—the product of an acid and a base—is called a *salt*. The name of this particular salt is *nitre* or *salt-petre*."

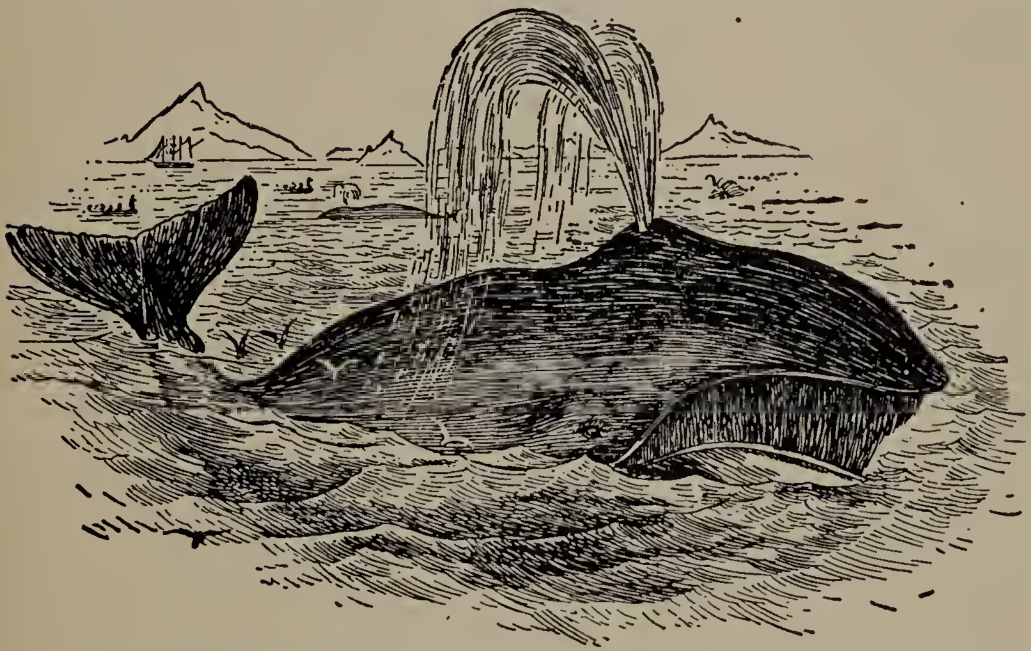
Lesson LVI

THE WHALE AND ITS PRODUCTS

The cetaceans, or whale-like animals, which include the whale itself, the porpoise, the dolphin, the dugong, and the manatee, although they live entirely in the water, are all mammals. They bring forth their young alive, and nurse them just as the land mammals do; they are lung-breathing animals, and their blood is warm.

Nature, as we have seen, provides her various creatures with some sort of coat to prevent this bodily heat from being too rapidly dissipated, and modifies that covering to suit the requirements of each animal. The fur-animals of the frozen regions of the world are a striking example of this beneficent provision; and some of them, such as the white bear, the otter, and the seals, which spend much of their lives in the icy water, have especially thick warm furs.

The animals we are about to consider now, however, never leave the water, and they are provided for in a different way; a thick coat of fur would not do in their case. Their skin is bare and naked on the outside, but immediately beneath it (in fact, forming part of it) is a thick under-coat of fat. Fat is a bad conductor of heat, so that the under-coat of fat performs the same office for these creatures as the thick fur covering does for the land mammals. It keeps their blood warm in those icy seas. But it does more than this; for being lighter than the water, it helps to keep the animals afloat.



THE BALEEN WHALE.

It varies from 8 inches to 20 inches in thickness, according to the habitat of the animal. In the right whale of the frozen Arctic seas it is thickest, and is known as blubber; in the South Sea whale it is comparatively thin. The seals, because they live partly in the water, have a thin layer of this oily fat under their fur coat.

There are two kinds of whales—the baleen whale, which has no teeth, and the sperm whale, which has formidable teeth or tusks in the lower jaw.

The former class includes the Greenland, or right whale of the North Polar Seas; the South Sea or black whale of the Southern Ocean, especially round the Australian coasts and the extremities of Africa and America; and the Pacific or American whale of the north coast of America, round the neighborhood of Behring's Straits. These whales are all very different in shape and size; the most valuable is the Greenland whale, an enormous creature, the largest of all the animals in the world, sometimes reaching 80 feet in length.

These whales have no teeth; but they have, hanging down from the upper jaw, on each side of the tongue, an extensive row of about 300 flat plates or blades of baleen or whalebone. These baleen plates are at right angles to the jaw-bone, and hang parallel to each other. They form, as they hang from the roof of the mouth, a transverse arch, the inner edge of each plate being fringed with stiff but flexible hairs. When the mouth is shut the fringed edges of the baleen plates rest on the upper convex surface of the tongue.

The largest of the baleen plates springs from the middle or highest part of the roof. These are sometimes from 12 to 15 feet in length; each plate is usually from 10 to 12 inches wide at the root, and about half an inch thick. The plates diminish in size as they near the front of the mouth, those in the front being only a few inches long. One of the largest plates usually weighs 7 lbs., and the total yield of whalebone from a large whale is about one ton.

The baleen whales, having no teeth, are unable to kill and devour other large inhabitants of the sea, in spite of their own enormous size. Their throat is so small that it would be impossible for them to swallow any creature larger than a herring. Their food, in fact, consists of very small animals—for the most part the small soft-bodied animals which exist in myriads in every sea.

Think of the enormous number of such small things it must take to supply one meal, and then think of the manner in which it captures them. Picture to yourselves this powerful creature cleaving its way with headlong speed through the water, with its immense cavernous mouth wide open. This mouth, with its fringed baleen plates, is a trap to catch thousands and thousands of the small prey as the whale rushes through the water.

The baleen whales are hunted and killed for the sake of their blubber and baleen plates.

Whalebone was till late years largely used for the ribs or stretchers of umbrellas. Nowadays steel frames are mostly used, but whalebone is still employed for the best carriage umbrellas. It is also much used, split into fibres, as a substitute for bristles for coarse brooms and brushes. It is used in thin narrow slips to strengthen women's stays and corsets. Whalebone softens when heated, and becomes plastic. In this state it is moulded into a variety of articles, such as knobs for walking-sticks, whip-handles, etc.

When a whale is caught the blubber is all removed from the carcase for the sake of the oil which it contains. The blubber of a full-grown whale will yield 100 tuns of oil. It is known in commerce as train-oil or whale-oil.

The sperm whale or cachalot of the Eastern Archipelago (that is the seas between Australia and Japan) is a very different animal from the baleen whale. It is sought after mostly for the sake of a very valuable oil—spermaceti—which is obtained from the head. The oil obtained from the carcase itself is known as sperm oil.

THE SPERM WHALE.

The head is of enormous size—half as large as the entire body, and is said to weigh 35 tons. It has formidable teeth in the lower jaw, but no baleen plates. The teeth are from twenty to twenty-five in number, and vary in size, some of them weighing as much as 30 lbs. The oily matter of the head is contained in a triangular-shaped hollow, which is known as the sperm case. About 400 gallons of oil are usually obtained from a single head.

This enormous mass of oil makes the head very light, and, in fact, acts as a kind of float to keep the nostrils above the water.

Spermaceti is used mostly for making candles, but its use for this and other purposes has greatly diminished during the last quarter of a century. The introduction of petroleum and vegetable oils has had the effect of driving this and other animal oils out of the market. The consequence is that the whale fisheries have gradually declined, both as regards our own and foreign ports, while France has given them up altogether. Peterhead and Dundee in Scotland are now the only British ports which send out whalers.

In our country New Bedford and San Francisco are the principal whaling ports. In the twelve months ending June 1896 our exports in whale oil amounted to only 82,676 lbs., while our exports of other fish oils were 761,449 lbs.

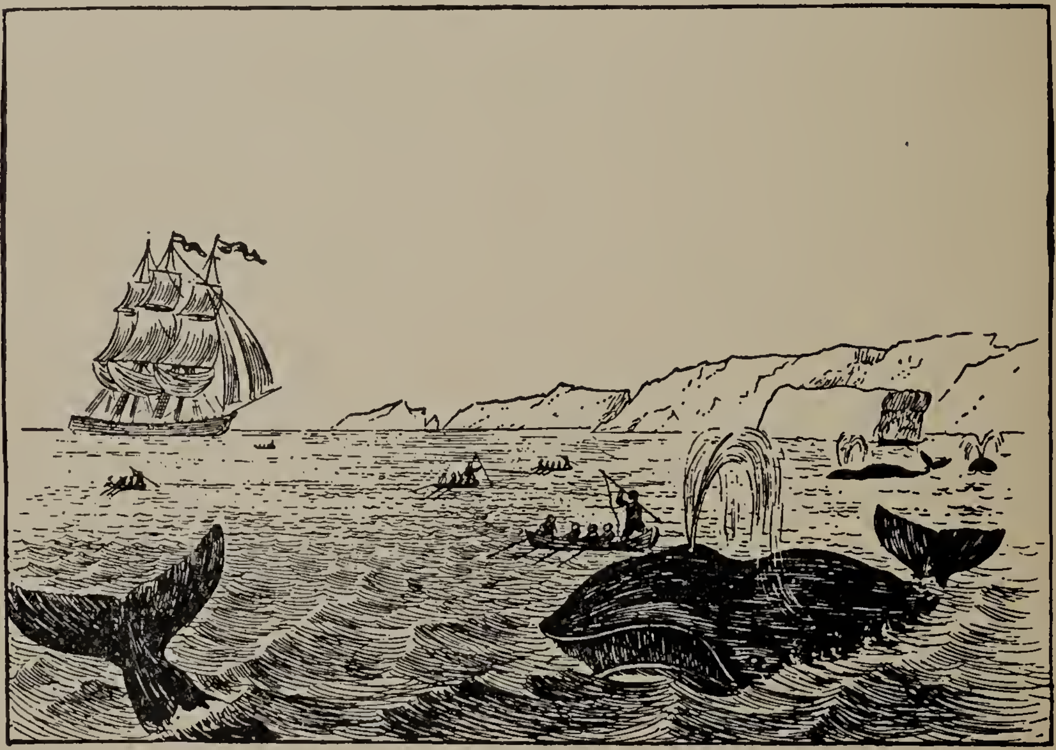
Lesson LVII

The Whale Fishery

The chase and capture of the whale, from the very conditions under which the bold, hardy whaler attempts it, is perhaps fraught with more danger and attended with more peculiarly exciting adventure than any of man's struggles with the lower animals.

The ships themselves are strongly built and specially fitted up for the work. They usually carry six or eight large whale-boats, of a peculiar form—head and stern alike. This peculiarity of structure enables them to be rowed backwards or forwards at a moment's notice, without the trouble or the delay of turning. Each boat is provided with two harpoons and half a dozen lances. The harpoon is attached to the end of a long, thin, but exceedingly strong rope, which is kept carefully coiled up in a tub in the bow of the boat. Each boat's crew consists of five or seven men, according to its size; one of them is the harpooner, the others do the rowing.

Arrived at the scene of action, the ship cruises about with a man constantly on the watch till a whale is sighted. The animals, although able to stay under water nearly half an hour, usually come to the surface to breathe about every ten minutes. Their presence is at once shown, because the moment they come to the surface they commence to blow, throwing up from their blow-holes a stream of water several yards high. The look-out man immediately gives the alarm, and everything being in readiness, the boats are lowered with extraordinary rapidity, and at once set out in chase of the beast.



The whale after blowing eight or nine times descends again, and the harpooners, standing in the head of their boats, have to keep a sharp look-out as he comes up once more to breathe. The danger is that the huge creature may rise beneath the boat itself, and with one whisk of his massive tail shatter it like a piece of match-wood, hurling the men into the water. The harpooner watches, and the men continue to row on until he is within striking distance. Then as the huge carcase rises above the water, he takes the harpoon in his right hand and the rope in his left, and with unerring aim hurls the weapon with all his force into it; at the same moment shouting the order, "Stern all."

This is the signal for the men at the oars, who instantly back water, so as to row backwards out of the way of the whale. The animal, as soon as he feels the harpoon, darts downwards, as a rule, into the depths of the sea. He carries the harpoon of course with him, for it is deeply embedded in his flesh. The harpoon is attached to the rope in the tub, and such is the awful speed of his descent, that the men have to keep the side of the boat and the rope itself drenched with bucketfuls of water to prevent them from taking fire through the friction.

The wounded animal keeps up this headlong rush through the water for about twenty minutes, and it sometimes happens that the men have to hitch on a second line, before he finishes his maddened career.

Up he must come at last, however, to breathe, and as he comes the rope slackens, and they again wait for him.

Immediately he rises, and while he rests exhausted on the surface to take breath again, he receives another harpoon and perhaps one or two lances, and down he goes as before. As he descends he lashes the water with his huge tail, and the men sheer off to give him a wide berth. They then rest on their oars and wait for his return to the surface, which usually takes place sooner than before, for he is exhausted by this time and weakened with the loss of blood.

When he next comes up he usually spouts blood instead of water, and the men row close up to him and despatch him with lances. In his death struggles the great beast lashes the water into foam with his tail, and dyes the sea all round him with his blood, but at last all is over, and the huge carcase floats on the surface of the water.

Several of the boats now make fast their lines to the body of the whale, and row towards the ship with it in tow. Arrived alongside the ship, they fasten the carcase to it with chains, and prepare to remove the blubber. A crane is hoisted over the side of the vessel, and at the end of the chain which hangs from it is a strong sharp hook. Some of the men work the crane; the rest, who are provided with spiked boots to prevent them from slipping, get on to the whale, and with sharp spades prepare to cut into the blubber. As soon as a great piece is cut all round, the hook is lowered and fastened firmly into it, and then the signal is given to the men at the crane, and the whole piece is literally torn away and hoisted into the ship.

After all the blubber is removed in this way the men turn their attention to the whalebone, every blade of which is carefully cut away, and the rest of the carcase is then sent adrift probably as food for the bears and fishes.

The ship is fitted with appliances for draining the blubber and boiling the oil, as well as with barrels to receive it when it has been boiled; and for some few days every man is busy. The blubber is cut up into small pieces and left to drain, and when no more oil will flow from it, it is gently heated in large boilers. In this way the blubber is made to give up all its oil, which is first strained and then stowed away in the casks prepared for its reception.

In the case of the sperm whale the spermaceti is obtained by making an opening in the "sperm case," and dipping out the contents with buckets. It is carefully boiled, and when purified separates into a kind of wax-like substance—the spermaceti of commerce—and a fine oil.

The sperm whale is even more formidable than the Greenland whale. In the first place, these whales usually swim in shoals, and it is no uncommon thing for a whole shoal to come to the assistance of one which has been attacked by the harpooner. In such a case the boat's crew is as good as doomed. The whales will even attack the ship itself, and they have one invariable method of attack. They swim off to a distance and rush with headlong speed against the side of the vessel, butting it with their massive head. Their huge teeth, too, are very formidable weapons of attack. They bite the boat in two, or smash it up in pieces. These teeth furnish ivory, but the ivory is not of such value as either elephant or walrus ivory.

Lesson LVIII

SILK AND THE SILK-WORM

The untutored savage, throughout all time, has clothed himself with the skins of mammals, and adorned his person with the feathers of birds; but it would never dawn upon him to look for his clothing to the insect race. That to him would appear an absurdity; and yet silk, the most beautiful of all fabrics, is the product of an insect—the silk-worm.

The silk-worm is the grub or caterpillar of a peculiar kind of moth, which feeds on the leaves of the mulberry tree. The moth came originally from China. It has a thick-set, hairy body, with short, stout legs and large cream-colored wings marked with dark stripes. The female is bigger than the male, and altogether different in appearance. She dies as soon as she has laid her eggs, which are smaller than grains of mustard-seed, and from 250 to 400 in number; the male does not long survive her.

The favourite food of the silk-worm, as we said just now, is the leaf of the mulberry tree. People, therefore, who rear silk-worms provide a constant supply of fresh mulberry leaves, and the mother-moth lays her eggs on the leaves. The grub, when hatched, emerges from the egg in the form of a little black worm, not more than a quarter of an inch in length; but there is plenty of food at hand, and it feeds and grows quickly. While growing it casts its skin as it becomes too small, and another skin takes its place. During its growth the silk-worm moults, or casts its skin, four times. The first moult takes place about eight days after it leaves the egg; the second, third, and fourth at regular intervals of about five days each.

After the last moult it feeds voraciously on the mulberry leaves and continues to grow for about ten days longer, when it may be said to have reached its full size as a caterpillar. It is then about 2 inches long; its body, which is of a grayish cream color, is supported upon sixteen legs, and consists of twelve ringed segments, from the last of which projects a sort of horn. It now ceases to feed, and after fixing itself to some light object, such as a twig, a bit of straw, or a piece of paper rolled up, it commences to send out, from two small holes under its jaw, a fine, yellow, gum-like substance, which hardens into a silky thread or fibre on exposure to the air. With this the worm completely envelops itself as in a ball.

SILK-WORM, COCOON, CHRYSALIS, AND MOTH.

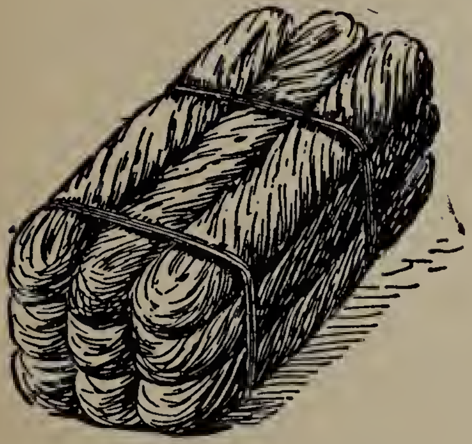
The first day is usually spent in forming a loose, flossy covering for the outside of the ball. This it afterwards coats with gum, so as to make it into a kind of outer skin. Inside that, during the next three days, the silk-worm spins a firm ball of fine, strong, yellow fibre, which is the silk of commerce. The whole forms an oval ball, about the size of a walnut, and is called a cocoon.

The creature—whatever it is—of course occupies the centre of the cocoon. It is not a silk-worm, it is not a moth. It is a lumpy, oval ball, covered with a dark red, shiny skin or shell; but if it were removed from the cocoon, it would be to all appearance lifeless. It is the silk-worm chrysalis. It has taken the first stage of that wonderful change, which is peculiar to the life-history of all insects—from the grub to the pupa or chrysalis; and if left alone it would pass from the pupa to the perfect insect.

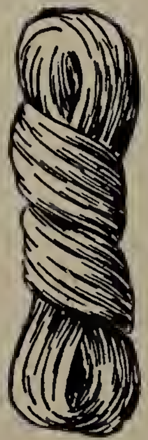
Many grubs, when about to enter the pupa or chrysalis stage, envelop themselves in a kind of silky covering, which they spin with material from their own bodies. The destructive rose-maggot may always be met with in the spring, curled up in a leaf of the tree, in a loose, flossy covering of its own spinning. Most caterpillars prepare for the chrysalis stage in the same way, but only the silk-worm caterpillar spins a silk which is of use to us.

After from ten to fifteen days the chrysalis would, if left to itself, give ample proof that it is not lifeless. During its imprisonment in the cocoon it undergoes wonderful changes, and at the end of the time emerges from the ball, not as a grub, not as a chrysalis, but as a winged moth able to fly in the air. It is found that the cocoon from which the moth has been allowed to work its way out does not yield such good silk as one that has not been broken through. Hence in silk-producing countries the chrysalis is always killed, by throwing the cocoons into boiling water or steaming them. The hot water, too, softens the gum on the cocoon, so that the loose outer skin is easily pushed aside to allow the inner ball of fine silky fibre to be taken out. Of course some of the cocoons are left for the moths to emerge from them in the natural way, in order that there may be eggs for future hatching.

The process of unwinding the delicate, silky thread of the cocoon without breaking it is one that requires extreme care. As the silk-worm commenced its spinning operations from the outside, the first step in the unwinding is to find the outer end of the thread. This done, the rest is easy with care. The thread is unwound by means of a rotating wheel, each cocoon usually yielding from 300 to 500 yards of silk. It is estimated that 250 cocoons weigh 1 lb., and as it takes 12 lbs. of these cocoons to produce 1 lb. of silk, it therefore follows that a single lb. of this raw silk is the result of the work of 3000 silk-worms.



A CHINESE BOOK OF SILK.



A HANK OF SILK.

From the reels the silk is made up into bundles or hanks, and is known as raw silk. A number of these hanks are usually bound together to make what is known in the trade as a "book." In this state it is shipped to the manufacturer to be spun into thread and woven into various fabrics.

The raw silk, however, requires careful treatment before it is fit for the spinning machine. It must first be washed and then *thrown*. The *throwing process* consists of twisting several of the delicate threads together to make one sufficiently strong to be spun into yarn for weaving. It is then known as *thrown silk*. The word *thrown* comes from the Anglo-Saxon word *thrawan*, which means *to twirl or twist.*

The silk-worm will not thrive in our cold latitudes. The principal silk-producing countries of the world are China, Japan, India, Persia, Turkey, Italy, and the South of France. China, as we have already observed, was the original home of the silk-worm, and to-day that country provides by far the greatest supply—more than all the rest put together.

We import annually from 10 million to 12 million lbs. of raw silk for our home manufactures, but a great supply of silk comes to us in the form of manufactured goods, mostly from France.

The silk manufacture is not one of our great industries. Yet we have important centres of activity in the various branches of the trade.