
HOLY BIRD

Reading enables us to see with the keenest eyes, to hear with the finest ears, and listen to the sweetest voices of all time.

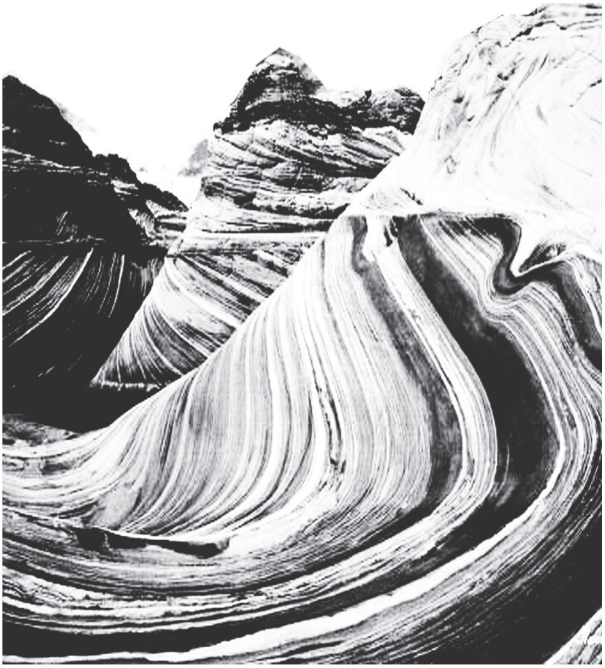
—James Russell Lowell

西方原版教材与经典读物·科学系列

SCIENCE READERS

科学读本⑤

〔美〕文森特·默奇（Vincent Murche）/著



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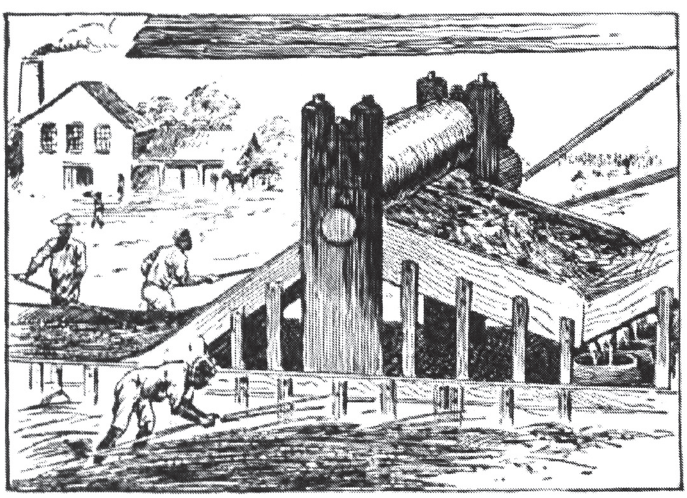
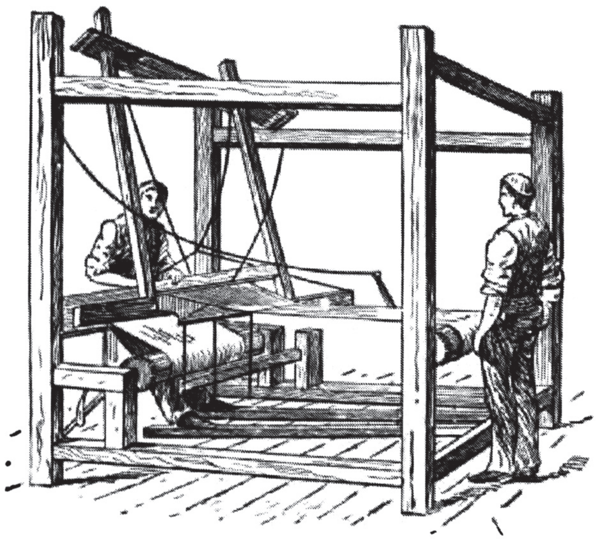




Lesson 01

Matter

Our young scientists are still eagerly pressing onward in their search for knowledge, under the careful and sympathetic guidance of their teacher, Mr. Wilson. Step by step they have been advancing through the various stages, beginning with simple facts, either such as were evident to their own observation, or such as could be shown by simple experiment. In this way they have acquired a rich store of scientific facts, and they are now, in the higher stages, learning to offer simple explanations of these facts, and to familiarize themselves with the proper names for the various objects and operations with which they come in contact.

Last year's course made this very evident, and it will become more so as they proceed to higher subjects. Both boys have still a scientific institute as their goal, where they mean to make their mark some day.

"I remember," said Mr. Wilson, "I began last year's course by introducing a new word—matter. We have since then used this word, rather than speak of a substance, an article, or a body, I will now try and help you to form a clearer conception of what we mean by it. This brick lying on the table shall give us the start.

"Without taking it up, I want you to tell me all you can about it. You will, of course, begin by describing its shape, size, and color. But how did you gain this information? Your eyes told you. You learned it through the sense of sight.

"Now take the brick in your hands and shut your eyes, and you will learn something more, through another sense—the sense of touch. This tells you that the body is hard and rough. A blind man could tell that.

"But let us leave the brick and turn our attention to these two bottles. Each contains a clear liquid. The liquids are totally unlike each other, but neither of the above senses can tell us this. How can we find out? Here we have to rely upon another sense—the sense of smell—to distinguish the two bodies; this tells us that one is water, the other paraffin oil.

"We might take a piece of salt and a piece of sugar, cut to exactly the same size and shape, and it would be impossible to tell one from the other, by either of the senses to which we have already appealed. We put our tongue to each, and we learn at once what we want to know, but this time through another sense—the sense of taste.

"I think I have shown you enough to make the rest of my explanation simple. Everything around us which appeals to us in this way, through one or more of our senses, we call matter.

"By the name matter, then, we mean every substance that exists, every substance about which we may learn through our senses. The air around us is matter. We know that it has an existence, for although we can neither see, smell, nor taste it, we can hear it when it is in motion, and we can feel it as it rushes through our mouth and nostrils in the act of breathing.

"Suppose I now show you a little experiment. I have here a small piece of gun-cotton, which is a highly explosive substance. I place it in the palm of my hand and apply a lighted taper. The result is a sudden flash; the substance burns so rapidly that every particle of it disappears, and yet the hand scarcely feels the heat.

"What has become of the gun-cotton? It has not been destroyed; it has simply been converted into another form, and has passed away in the air as an invisible gas."

"That reminds me, sir," said Fred, "of what we learned about the burning of the candle, the coal-gas, and the lump of coal. These things are not destroyed in the burning. They are simply changed into other forms."

"Yes, my lad, you are quite right," said Mr. Wilson. "The candle contains matter in the form of tallow and wick. These substances, as well as the coal, are formed of hydrogen and carbon. The burning simply uses them to form new substances. It uses the hydrogen to form water-vapor, and the carbon to form carbonic acid gas, both these new substances being at once absorbed into the air around.

"Nothing is destroyed. The coal and the tallow are changed into new forms. That is all.

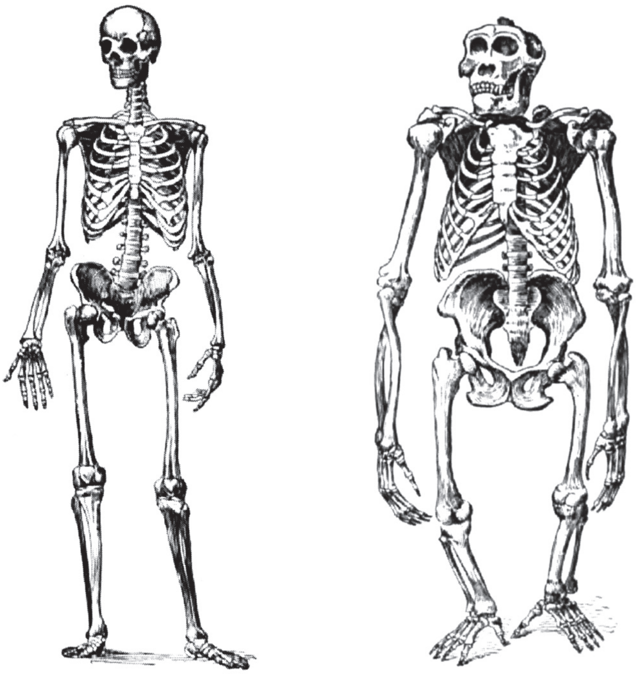
"What happens when we dissolve substances in water? These substances disappear; they seem to be destroyed. But we know they are there still, for we can recover them easily by evaporating the water.

"It is just so with every kind of matter that exists. We may grind it into powder, dissolve it in water, and even burn it, but we cannot get rid of it—we cannot destroy it. We merely change its form; for matter is indestructible."

Lesson 02

Man and Brute

Step by step our lessons have made us familiar, in some degree, with the build of the human body, and, through it, with the general structure of the various members of the brute creation. We are now in a position to carry our investigations a little farther, taking still the human body as the type, and following up, as we meet with them, the various adaptations of it to suit the requirements of each



animal. Let us commence with the head, which, as you know, consists of two distinct parts—the skull and the face.

The skull or cranium is formed of eight plates of bone, firmly joined together at their edges, so as to make an oval box to lodge and protect the brain. There is a round hole in the base of this bony box, through which the spinal cord passes into the canal provided for it, and on either side of this aperture is a smooth bony projection, by which the skull rocks on the topmost vertebra of the spinal column. These projections are termed condyles.

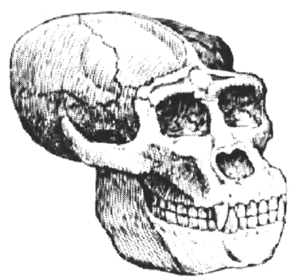
Turning next to the face, we find that it consists of no less than fourteen distinct bones, all of them, except one—the lower jaw—firmly and immovably fixed to each other and the bones of the skull. These fourteen bones provide five large cavities for lodging and protecting the sense organs of sight, smell, and taste.

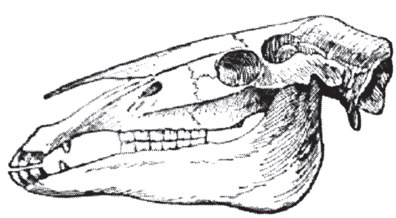
So far, the structure of man and of all mammals is on similar lines. But man stands immeasurably above any of these creatures. "Endowed with an intellect capable of indefinite improvement, he exhibits but little of that instinct which guides the operations of the lower animals. His knowledge is the result of observation, and is matured by thought; his power of speech and the capability of writing are faculties entirely his own, whereby he can communicate his ideas and transmit to posterity the results of his experience. By no means highly gifted as relates to his bodily strength, his swiftness is very far inferior to that of most animals of his size. Possessing neither strength of jaw nor canine fangs, he is destitute of offensive weapons, and his body being not even clothed with hair, few creatures are, in this respect, left so utterly defenseless, nay, in addition to these disadvantages, he is, of all animals, the longest in acquiring even that strength which is necessary for the supply of his simplest wants, and yet this very feebleness is to him an advantage, compelling him to have recourse to that intelligence with which he has been so highly endowed. Absolutely dependent upon parental care for his support, he must necessarily derive from that source the education of his intellect, as well as of his physical powers, and hence is established an attachment as durable as it is sacred. The very length of his pupilage necessarily gives birth to habits of family subordination, which ultimately lay the foundation of all social order, and tend to multiply indefinitely the advantages derivable from that mutual co-operation, whereby he has succeeded in subjecting or in repelling the attacks of inferior animals—in clothing himself so as to defy the inclemencies even of the most rigorous climate, and in spreading his race over the surface of the earth.

"Nevertheless, in reviewing the grand scene of nature, the supremacy of the human race seems to be manifested in nothing more strikingly than in the privilege conferred upon mankind of studying the Creator's works, and learning the great lessons they are so well calculated to teach.

"Of all the countless creatures that now throng the busy scene of life, or that successively have faded from existence, not one has been permitted to inquire from whom or whence it received its being. Man alone has been taught to recognize his Maker's hand, which formed all living things, each in its separate sphere, and still upholds and guides the wondrous system He Himself created."

So then it is man's intellectual power which raises him to this lofty height, utterly unapproachable by the rest of





God's creatures. In man the brain-case is developed; in the lower animals, on the contrary, the development is in the direction of the face, and not of the skull. The face is always disproportionately large as compared with the skull.

That this is no mere chance accident may be readily seen by comparing the heads of a man, a gorilla, and a horse. If a tape were passed round a person's head, so as to cross the eyebrows and both ears, and the two ends were then tied at the nape of the neck, it would show roughly the proportion between skull and face, and give some idea of the enormous brain capacity in man.

Turn from this to examine the heads of any of the lower animals, and the contrast is at once sharp and striking. Even in the great apes, and they make the nearest approach to man, it is the head, quite as much as the hand, that stamps them as a distinct creation.

Let us try to find the reason for this special development. The face is designed mainly as a lodgment for the sense organs of sight, smell, and taste. These sense organs mean to the brute creation the main part of their existence. The keenness of sight, smell, and also of hearing is as necessary to the hunted as to the hunting animal—in the one case to give the signal of danger, in the other to guide the hungry prowler to its prey. What then is more natural than that these sense organs and of course their bony lodgments should be developed at the expense of the rest of the head? Length of face, for instance, means a corresponding development of the nasal cavities, with greatly increased capacity for the spread of the nerves of smell. In every animal that depends upon its sense of smell either for its safety or its food, we find an elongated face.

Then next as regards the mouth. Feeding being the chief business of these creatures' lives, it is quite natural to look for a special development of the organ of taste to guide them in the choice of their food, and of the jaws and teeth to masticate it.

Moreover, with many of them, the mouth, jaws, and teeth are not merely feeding organs, but weapons of attack and defense. In either case the animal depends upon them for its very existence. The brain, such as it is, has no other duty than to act as overseer to these special organs; here we have in a nutshell the reason why there is special development of the face at the expense of the skull or brain-case.

Just one other thought, and that was the only reason for mentioning the condyles at the base of the skull. Man walks erect. He is the only one of God's creatures to whom this attitude is natural. Is this an accident? Let us see. The head rocks to and fro on these condyles, which fit into corresponding hollows in the top of the Atlas vertebra. In no other animal do we find these condyles placed so far forward as in man. If we examine the various types of animals from man downwards, we find the condyles nearer and nearer to the back of the skull. The consequence is that the weight of the head does not rest directly on the spine, as it does in man, but upon the muscles and ligaments which bind the two together.

Lesson 03

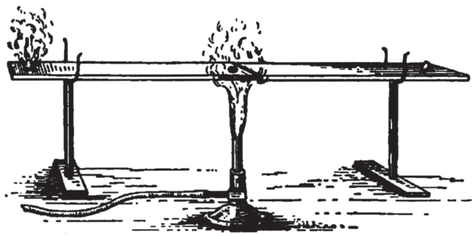
Conduction of Heat

"We have already learned something about heat and its effects on various bodies—solids, liquids, and gases," said Mr. Wilson. "Our next business will be to inquire how heated bodies part with their heat—that is, how heat passes from one portion of matter to another. I want you to come and take the poker out of the fire, Fred. That's right. But why did you drop it? Hot, was it? How can that be? The part that was in the fire is of course red-hot, but you held the handle, and that was out of the fire. Let us see what it means. Hold one end of this copper wire in your hand, keeping the other end in the flame of the Bunsen burner. Tell us what happens."

"The end that I hold in my hand is getting hot, sir."

"Yes, Fred, it is, and it will soon be so hot that you will be glad to drop it. The fact is, in both cases the heat from the fire and the burner travels along the metal, from particle to particle, one particle first getting hot itself and then heating the next, and so on, until it reaches the opposite end.

"I will now show you a very interesting little experiment. I have here a long strip of copper and another of iron joined, end to end, by means of a rivet. I will fix them so



that the joined part is in the flame of the Bunsen burner, and on the opposite ends I will place a small piece of phosphorus. In a short time the phosphorus on the copper takes fire, but that on the iron will remain much longer before it ignites.

"Now, what do we learn from this? We learn that heat travels along the particles of both the copper and the iron, but that it travels more rapidly along the former than the latter.

"Let us go a little farther. I will place this tin dish on the stand over the Bunsen burner, and put a piece of bone and a thin strip of copper into the dish. Both are receiving the same amount of heat, and it is only natural to expect that one will be exactly as hot as the other. Now, Fred, take them out of the dish, the bone first, and then the copper. Tell us what you observe."

"The bone is not heated at all, sir, except in the very spot where it rested on the dish."

"Quite right, Fred. You can easily pick up the bone. Now take the piece of copper out. Ah! you drop that quickly enough, don't you? The copper, you see, is not heated in one spot only, but the whole of it is hot. The heat travels rapidly along the particles of copper, but very slowly indeed through the bone.

"Copper and iron carry, or conduct, the heat from particle to particle of their substance. We say that these metals are good conductors of heat, and that heat travels along them by conduction. The bone conducts heat so slowly that we usually call it a non-conductor. There are some bodies which, although not actually non-conductors, have such small conducting power that we arrange them in a class by themselves as bad conductors.

"In classifying bodies according to their conducting power, we find that dense substances are generally the best conductors; light, porous ones the worst.

"Conduction may be said to be confined to solid bodies, liquids and gases being very bad conductors of heat.

"The metals are the best conductors of all, but they differ very much one from the other. They stand thus in the order of their conducting power: silver, copper, gold, brass, tin, iron, lead, platinum, and bismuth—silver being the best. Among the bad conductors are marble, stone, brick, glass, earthenware, sealing-wax, leather, wood, linen, cotton, and straw.

"The non-conductors include bone, horn, feathers, down, fur, wool, flannel, silk, hair, cork, india-rubber, and air."

Lesson 04

Tea

"We can see, from all we have learned hitherto, how greatly we are indebted to the vegetable world for our daily food," said Mr. Wilson. "Of course the greater part of all the articles that appear on our tables at meal-time are in the form of eatables. I have here, however, a most important article of daily consumption, although it is not for eating, but drinking. We take it as a beverage. It is tea. Tea is so common an article in every home that it will not be necessary for me to describe it to you now. We will rather confine our attention to its peculiar properties.

"Take a few grains of tea in your mouth, and taste them. They have a pleasant aroma and flavor, and if you keep them long enough in your mouth you will notice a peculiar astringent taste.

"We will now put some of the tea into this cup, and pour on it some boiling water from the kettle. The water at once begins to assume a straw-colored tint, then becomes brown, and the more tea there is in the cup the darker the liquid will be. We say that we have made an infusion of tea. That is, the tea has not merely colored the water, but the water has actually drawn from the tea its peculiar properties.

"Take the cup of tea in your hand, and smell it, and you will at once detect the peculiar odor or aroma which you noticed in the dry tea, except that it is stronger now as an infusion. You shall taste it as soon as it is sufficiently cool, and you will notice that the infusion has the flavor of the dry tea as well as its odor.

"Now that we no longer want the liquid infusion, we will pour it away, and see what we have left in the cup. We have a heap of brown leaves. Each little grain of tea has uncurled and opened out, and we now see that it was nothing but a leaf rolled up.

"I will select two or three of the most perfect of the leaves, and spread them out carefully on this sheet of blotting-paper, so that we may examine them at our leisure.

"The leaves are lance-shaped—that is, long and somewhat oval, with sharp-pointed ends. They vary in length; some leaves are two, some three, and others four inches long. They have serrated or saw-like edges—that is, the edges of the leaves present something of the appearance of the edge of a saw. I have pointed out to you similar leaves in our earlier lessons, among them being those of the rosebush, basswood, appletree, and strawberry plant. These leaves are the product of an evergreen plant, commonly known as the tea-tree, although it is scarcely correct to call it a tree. It is rather a bush or a shrub. It is never allowed to grow more than three or four feet high. It bears long pointed leaves, of a

bright, deep green color. with jagged saw-like edges, and being an evergreen, the leaves are the same color at all seasons of the year. It has beautiful white flowers, with yellow stamens, and these are succeeded by the fruit, a kind of dry pod, containing three seeds.

"The tea-plant is supposed by some to be a native of Bengal, but it first came to the notice of Europeans in China and Japan, where it is not only extensively cultivated, but even grows wild among the hills. It will not grow except in a warm climate, and it flourishes best on the hilly slopes, provided the soil be rich and deep.

"The plants are usually placed in rows about five feet apart, so as to enable the pickers to walk between them when the leaves are ready to be gathered. In its general appearance a tea-plantation is said to bear some resemblance to a garden of gooseberry or currant bushes.

"Let us now leave the plant itself, while we consider the value of tea as a beverage. "We all know what a refreshing effect a cup of tea has upon us when we are tired and weary. Indeed, nothing seems to do us so much good, and yet no one has, hitherto, been able to prove satisfactorily the precise action of tea on the body. It contains a volatile oil, which is supposed to act upon the nerves with a soothing, quieting effect, while at the same

time it stimulates their action and produces a feeling of exhilaration, and, in addition to this, by assisting the work of respiration and perspiration, it tends to cool the body. This, however, is only the case when tea is drunk in moderate quantities, for it produces the opposite effect of sleeplessness if taken in large quantities.

"In making tea, it should never be boiled, because boiling carries off the volatile oil (its most valuable constituent). The proper way is to first warm the teapot with a little hot water, then put in the tea, the quantity depending upon the number of persons who require to take it, and then pour boiling water on it.

"A cosey, made of some non-conducting materials, such as wool or feathers, will, by keeping the heat in, help to draw the tea quickly. Even this may become injurious, however, if used carelessly. The tea should never be allowed to stand a long time, for after a while it draws from the leaves a peculiar substance called tannin, which is very injurious to the work of digestion. In these days of tea-drinking, people should know that tea taken in excess, or badly prepared, becomes in its way as great an evil as any other abused beverage."

Lesson 05

Solids, Liquids, and Gases

"Suppose we begin our new lesson, boys," said Mr. Wilson, "with one or two experiments.

"I have here a piece of wash-leather. I will pour a small drop of mercury into it, and squeeze it between my fingers and thumb. The squeezing, you see, breaks up the one drop of mercury into thousands of very tiny drops, and forces them through the pores of the leather. I have purposely let some of them fall on my coat-sleeve; you can see the little silvery balls shining out from the dark cloth. Now I will pick up two or three of these tiny balls with my knife, and spread them over this piece of black cloth, just as one spreads butter on bread. Come and find them now, Fred."

"I cannot see them now, sir."

"No, Fred, you cannot see them with your naked eye, but look for them through this magnifying glass, and tell me what you see."

"There seem to be thousands of tiny drops; I could not see one of them before. But did they all come from those two or three little balls, sir?"

"Yes, Fred, they did. But you have seen something of the same kind before."

"Oh, I remember, sir. You boiled a few drops of mercury in a test-tube. We saw it boiling, and you told us that it was passing off as vapor, but we could not see it till we called in the help of the magnifying glass. We then found, all round the cool upper part of the tube, an immense number of silvery balls, which our eyes were not sharp enough to see, and you told us that each of these little balls was made up of untold numbers of still smaller globules, so small as to be invisible even to the most powerful microscope."

"That's right, Fred," said Mr. Wilson. "And now what have we learned? We have learned that mercury can be split up into extremely small particles, so small as to be absolutely invisible. It was only after condensation had united millions of them into the form of little tiny balls that the magnifying glass was able to detect them. This means, of course, to say that the mercury is made up of these tiny particles, and what is true of mercury is true of every sort of matter. Matter of all kinds is made up of extremely small particles, which are called molecules.

"This being the case, how do we account for the fact that matter is not all alike? Why should there be solid, liquid, and gaseous bodies?"

"This is due to the force of cohesion, sir," said Will. "In all solid bodies the molecules are held together by this force, so that each individual molecule has its own particular position, from which it cannot be moved unless this force of cohesion be first overcome."

"Quite right, Will," said Mr. Wilson. "What this force of cohesion really is, we don't know; we only give it this name because the word cohesion means the act of holding together. This we do know, that if there were no such force, the molecules of all matter would fall asunder. Instead of solid bodies, there would be nothing but impalpable powder, and in place of liquids, nothing but vapor.

"This force is not equally strong in all solids. We can break a piece of lead more easily than a piece of steel, a brick more easily than a piece of marble. Cohesion is stronger in the steel and marble than it is in the lead and brick respectively. In liquids the force of cohesion is slight as compared with that in solids. The molecules have no fixed position, but are free to move about, and roll and tumble one over another.

"In a solid the molecules are bound so firmly together that we are unable to move a single part of it without moving the whole body, but in a liquid we can set in motion some of the particles, and leave the remainder at rest. This freedom of movement among the molecules of a liquid explains why it flows when unsupported.

"But let us notice next the manner in which different liquids flow. I will pour this water from one tumbler into the other, and then I will do the same with some oil, molasses, and tar. Why should the molasses, tar, and oil flow slowly as compared with the water? The force of cohesion is stronger in them than in water; the particles take longer to separate. It is easier, for the same reason, to thrust one's hand into a basin of water, than into a basin of molasses.

"In gases there is no force of cohesion, but rather a repelling force. The molecules of a gas are constantly trying to separate farther and farther from each other. This explains why gases can always be compressed into a smaller space than they once occupied."

Lesson 06

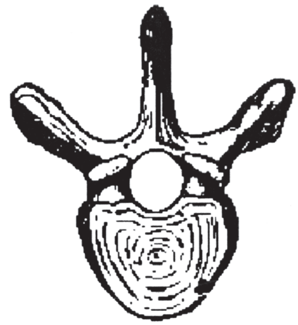
Bones and Joints

We have already inquired into the nature of the head, and the various modifications in its structure, which are met with in all mammals, from man downwards.

Let us now proceed to examine the rest of the bony skeleton.

Our earlier lessons have shown us that the most important part of that skeleton is the vertebral column. It is the possession, or otherwise, of this backbone, with the rest of the internal framework, which constitutes the first great line of separation into vertebrates and invertebrates.

Taking again the human skeleton as our starting-point, we find that the vertebral or spinal column is made up of thirty-three separate bones or vertebras. There are seven vertebrae to form the neck; twelve to form the back; five to form the loins; five to form the sacrum, and four at the lower extremity. That is to say, the number of bones was originally thirty-three. The five vertebrae of the sacrum are separate bones only in the child. They are united into one solid bone in adult age. In the same way the four lowermost vertebrae, although separate bones in the child, become welded into one in the adult.



Each vertebra consists of a thick solid part, which is called the body, and of processes or projections, which serve to bind the whole chain of bones together. The body and these processes enclose between them a hollow ring. When the vertebrae are in position the body of one rests on the body of that below it, the rings are all one above the other so as to form a continuous canal, and the processes too are all in line. The ends of the middle or spinous processes can be felt down the back.

In man, and in all mammals, the "body" of each vertebra is flat, and covered with a thick pad of cartilage.

Let us now look at the vertebrae of the neck—cervical vertebrae, they are sometimes called. There are seven of them. We cannot pass them by without a glance at the two topmost of these bones.

The first is the Atlas vertebra, so called because it holds or supports the head, as the fabled Atlas of old was said to support the world. The smooth condyles at the base of the skull rock upon corresponding hollows on the upper side of this bone. The nodding of the head is accomplished in this way by a hinge joint.

But we must examine this Atlas vertebra further, and then we shall find that it differs from all the rest, in having no body. In place of the body there is a hollow ring, and

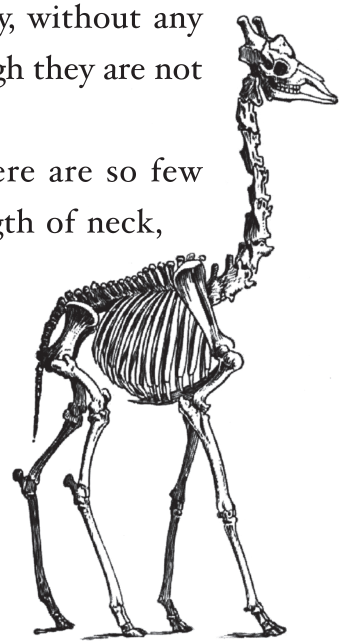
ATLAS VERTEBRA.

AXIS VERTEBRA.

into this ring fits an upright peg or projection from the second vertebra, which is called the Axis vertebra.

The turning of the head from side to side is brought about by the Atlas bone turning round on this peg, as on a pivot, and carrying the head round with it.

It is a remarkable fact that in all mammals the number of the neck vertebrae is seven. The giraffe, with its long craning neck, has seven vertebrae; elephant, with its very short neck, has seven; and the whale, whose head seems to be joined directly to the body, without any neck at all, has also seven, although they are not much thicker than a wafer.

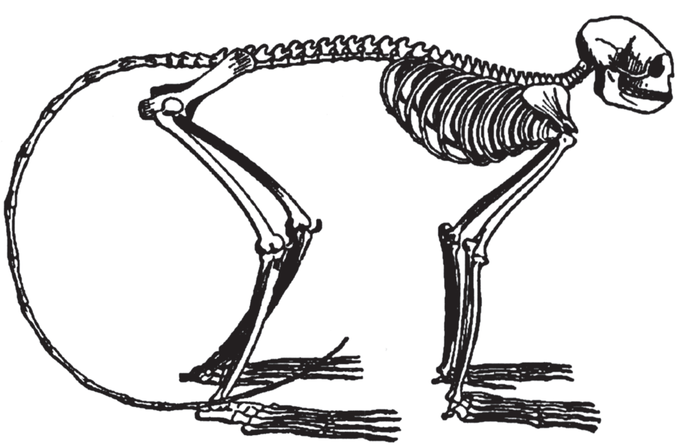


Seeing that in the giraffe there are so few joints for such an enormous length of neck, it is easy to understand why the movements of its head, so far from being graceful, are positively awkward and ungainly. But how admirably the creature is fitted by this very neck for its habits and life. It browses upon the tender young twigs and leaves of the trees, just as other animals do upon the grass at their feet.

The elephant, too, seeks the same food, but we have only to compare the small head of the giraffe with the ponderous head of the elephant, to see why he was not also provided with a long neck for the purpose of reaching it. He tears off what he wants with his long trunk and conveys it to his mouth, while the giraffe simply nibbles it where it grows upon the tree.

The pig and the mole have short thick necks. The one roots in the ground with its snout; the other actually burrows in the earth. A long neck would be out of place in either animal.

The vertebrae of the back, or Dorsal vertebrae, as they are also called, are those that bear the ribs. In man and the four-handed animals there are twelve of these vertebrae, and consequently twelve pairs of ribs. Most mammals have more than twelve. The lion, for example,



has thirteen, the giraffe fourteen, the whale fifteen, and the elephant twenty. The four lowermost bones of the column in man form a sort of rudimentary tail, man being a tail-less animal. In this respect the apes are like him, and they, too, have only four of these vertebrae.

There is, however, considerable divergence here among the various orders of mammals. This tail part of the column contains, in the giraffe, eighteen vertebrae, in the elephant twenty-seven, in the lion twenty-six, and in the long-tailed monkey thirty-one.

Lesson 07

Conductors and Non-Conductors

"I want you to think about that poker in the fire, and what it taught us," said Mr. Wilson.

"The heat travelled from one end of the poker to the other, sir," said Will. "One particle became heated, and then passed on the heat to the next, and so on. This is the manner in which heat travels through all solid bodies. We call it conduction."

"Yes, sir," said Fred, "but heat does not travel equally well through all solids. Some are good conductors, some bad conductors, and some do not conduct or carry away heat at all. We call them non-conductors."

"I am glad you have not forgotten your lesson, boys," said Mr. Wilson. "We will now have another little experiment. I have here a basin of ice, and in it are some pieces of metal, marble, stone, brick, wood, cork, leather, and wool. You shall take them out and hold them in your hands, one by one. I want you to remember that, as they all come out of the ice, they must all be at the same temperature—the temperature of the ice. If we place the thermometer in the ice, and against each of them in succession, it will in every case register 32°F. Now, as you remove them from the basin, you shall tell me what you observe."

"The piece of metal feels intensely cold, sir; the marble and stone don't seem to be nearly so cold as the metal."

"Quite right," said Mr. Wilson. "Now try the other things."

"The brick and the wood are not so cold to handle as the stone was," said Fred, "and the leather and wool feel almost warm in comparison."

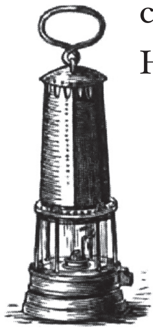
"Right again, boys," said Mr. Wilson. "Now let us see what all this means. In the first place we must remember that every one of these bodies is colder than the hand, and they all rob the hand of some of its heat. The metal, however, is the best conductor, and takes away the greatest amount of heat from the hand, the other substances taking less and less in proportion to their lower conducting power.

"The great thing to remember is that the hand feels the sensation of cold in proportion to the amount of heat abstracted from it.

"We will next place the same things in a basin of hot water from the kettle, and proceed in a similar way.

"The metal now feels hotter than the other substances; the leather, cork, and wool convey the least heat.

"The explanation in this case as in that above clearly depends upon the difference in the conducting powers of the different bodies. It was the knowledge of the superior



conducting power of metals that enabled Sir Humphry Davy to construct his safety lamp. You remember, of course, that, in our early lessons on the coal-mine, we first learned to know the use of the Davy lamp, and in our later lessons on coal-gas I took you further, and showed you something of the construction of the lamp itself in relation to the fire-damp in the mine. Our lesson on the conduction of heat will now help you to grasp fully the whole principle of the lamp.

"The flame is enclosed in a covering of gauze made of metal wire, and the lamp owes its usefulness entirely to the high conducting power of this metal wire. The explosive gases enter into the lamp through the gauze, and burn there, but the flame, instead of passing outside, is dissipated or conducted away by the wire.

"Stone, as we have seen, is a better conductor than brick or wood. Hence a stone house (unless the walls are very thick) is colder in winter and hotter in summer than one built of brick or wood.

"Ice-houses (or pits) for storing ice are built of brick and thatched with straw, because the low conducting power of brick and straw prevents the warmer air around from acting on the ice. In the hot summer weather, too, the ice is wrapped in blankets and covered with sawdust.

"Fire-bricks are much used for lining the backs of stoves, because they are very bad conductors, and they prevent the heat from escaping backwards into the chimney.

"Metal tea-pots, coffee-pots, kettles, and other vessels for cooking and boiling purposes usually have their handles made of bone, horn, wood, or some other non-conducting substance, and, if not, we are always careful to make a thick pad of flannel, cloth, or paper, to serve the purpose.

"In the same way, all tools which have to be made hot, such as soldering and branding irons, are provided with wooden handles.

"We keep our tea hot on the table without any fire, by merely covering the teapot with a cosey made of wool or down. Both of these substances have very low conducting powers—indeed they are classed as non-conductors.

"This will explain why in winter we clothe ourselves in fur cloaks, flannel, and other woollen garments. These things are not warm in themselves; they merely act as non-conductors, and prevent the heat from passing away out of our bodies.

"In the heat of summer, when we wish to be cool, we exchange our furs and flannels for light, thinner materials, of higher conducting power, and these allow some of the heat of the body to escape into the air."

Lesson 08

Tea—Its Cultivation and Preparation

The tea-plant is raised from seeds, which are sown in March, after having been stored, throughout the previous winter, in moist earth. They are planted out in their growing quarters (usually on the dry, sunny slope of a hill) when they are one year old. No leaves are plucked for the first three years, but the plants are carefully pruned back, so as to keep them down to a height of three or four feet. The first cropping takes place in the fourth year, and after this there are three crops of leaves every year, as long as the tree lives.

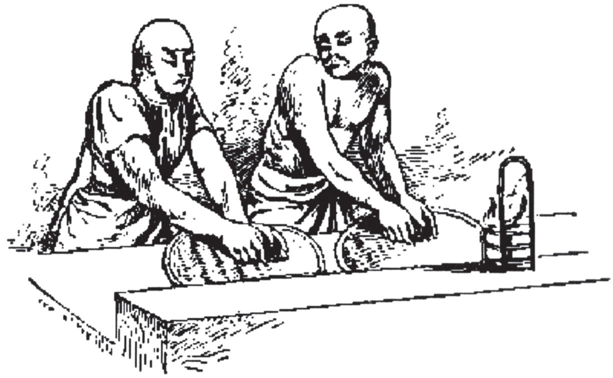
Two very interesting points in connection with the leaves must be noticed in passing. The first is that, when freshly picked, they have neither the odor nor the flavor with which we are familiar in the prepared article. These are developed by the after treatment. The second is that different qualities of tea are produced from precisely the same leaves, by varying the mode of preparation. The picking of the leaves requires much care. Each leaf has to be picked separately with the finger and thumb, and in such a way as neither to bruise the leaf itself, nor injure the tender young shoots of the plant.

The first picking takes place in April. This crop consists of the young, tender leaves of spring, with the first bloom on them. They produce the finest and most delicately flavored teas of the year. The second crop follows in about a month, the leaves being larger, less bright in color, and not so rich in flavor. The third crop is picked when the leaves have reached their full size. They are then more bitter and woody, and have very little of the delicate aroma and flavor of the earlier crops.

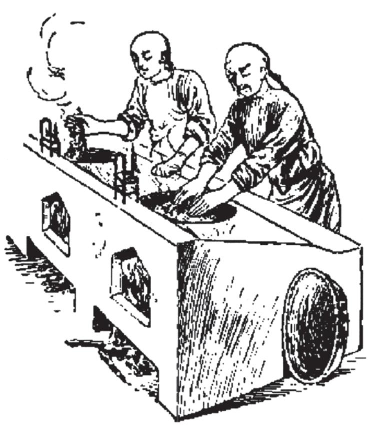
These last two crops furnish most of the tea sent out of China, for the Chinese rarely part with any of the first crop, preferring to keep it for themselves and their friends.

An acre of ground will grow on an average about 2000 plants, and the annual crop is from 250 to 300 lbs. of tea. Most of the picking of the first crop is done by women, but even children help in the later pickings.

The first step in the preparation of the leaves is to expose them to the action of the sun and air for two or

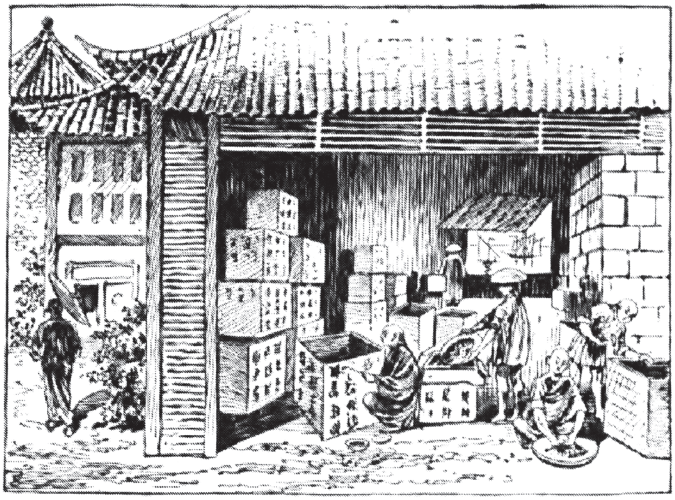


three hours. For this purpose they are laid either on mats, or in wide shallow baskets, and stirred every now and then. The object of this part of the process will be clearly seen by treating any ordinary leaf in a similar way. The leaf, which when freshly picked was crisp and brittle to the touch, becomes limp and flabby after this exposure. It could be easily rolled between the thumb and fingers without crushing out any of the natural juices. This is the very thing necessary in the treatment of the tea-leaves. When sufficiently dried, they are rolled loosely by the hands on a flat table, and then thrown, a small quantity at a time, into an iron pan, over a charcoal fire, to complete the work of drying. While in the pan they are kept constantly stirred to prevent scorching, and, when quite ready, are swept quickly on to the table, where men, called twisters, complete the work of rolling, by rubbing the leaves between the hands while they are still hot. In the finest and most delicate kinds of tea, every leaf is rolled or twisted separately.



The final process is to throw the twisted or rolled leaves again into the pan over the charcoal fire, and carefully roast them, so as to drive off every particle of moisture. The utmost care is necessary, as before, to prevent scorching.

Nothing now remains but to sift and sort the tea, and pack it in chests lined with lead-foil for the market.



It is important to remember here a point which has already been noticed; that is, that different treatment produces different kinds of tea from precisely the same leaves.

In the preparation of green tea the leaves are dried and rolled immediately they are gathered. The whole process of preparation, in fact, is rapid and simple.

For black tea the leaves are first thrown into a heap, and covered with matting for some time, until the atmosphere begins to act upon them, and a sort of fermentation sets in. The fermentation causes the green leaf to change color, and become dark—almost black, after which the work of rolling is begun. Among the varieties of black tea are Pekoe, Souchong, Congou, and Bohea. The first two are prepared from the earliest crop. A very costly variety of Pekoe, known in the language of the country as the Tea of the Wells of the Dragon, is grown exclusively for the use of royalty, and is never exported. The second or main gathering gives Congou, which forms the bulk of the better supply that reaches us. Bohea is the name given to the latest gathered crop. It comprises all the coarser, commoner, cheaper teas in the market.

Hyson, Gunpowder, and Imperial are the best known of the green teas. Of late years the tea-plant has been introduced into India and Ceylon with great success, and we now receive immense shipments every season from both these countries; while, as a natural consequence, the China tea-trade is rapidly decreasing.

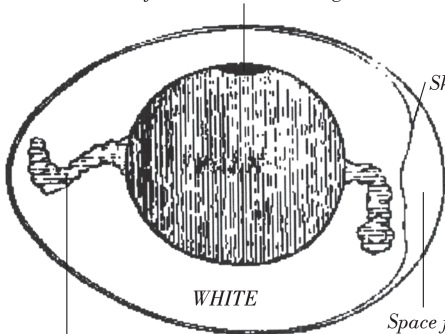
Lesson 09

Food—Why We Eat

"The subject which is to engage our attention this morning," said Mr. Wilson, "is an important one, because it comes home to our own every-day life. We are going to commence a series of lessons on food, and I shall endeavour, not merely to fill your memory with facts, but to lead you, step by step, to discover for yourselves such practical truths as will be of inestimable benefit to you in that important but much abused business of life, the duty of eating and drinking,

"I have here an ordinary hen's egg. I will break it in this cup, as your mother does when she is going to make a pudding or a custard. Look at the egg in the cup. There is a clear, viscid (sticky) liquid, in the midst of which floats a round yellow ball. I have no doubt you are already aware that we call the clear liquid the white of egg, and perhaps you may have heard its scientific name albumen. The yellow ball is the yolk.

"For the present I want you to confine your attention to the yolk—the yellow ball. Notice the little round spot in the yolk. This is the germ, or, as it is sometimes called, the embryo. If this egg had been hatched, by keeping it



warm for about three weeks, the little embryo would have become an actual chicken; it would have had strength enough to break the shell and set itself free, and would then have been able to run about and seek its own living.

"Now, how does it happen that a little speck like this can grow into a chicken? Let us find out.

"We will first remove the germ. This is the embryo, future chicken. What then is all the other matter? All that we see now in the cup is simply a store of food, laid up within the egg-shell, for the tiny germ to feed upon.

"Day by day the little thing absorbs more and more of this food-store into itself, and with it builds up its own body. Day by day, during those three weeks, the little body is growing bigger and bigger, and the store of food in the shell is getting smaller and smaller. At the end of the three weeks this

food supply becomes exhausted. What is to happen next? The little creature is now fully formed, and is, moreover, able to look after itself. It has not only built up a body, but it has also accumulated vital energy, or strength, sufficient to enable it to set itself free from its shell. This it does by pecking with its beak all round the inside of the shell until it breaks, and then out it comes.

"If we were to take it up immediately in our hands, and examine it, we should find the little body to consist of flesh and bones, with feathers already growing on the skin—eyes, bill, feet, everything perfectly formed. Its body, too, would feel warm, and it would show, by its struggles to get free, that it had a certain amount of strength.

"Now all these things—the flesh, bones, and blood of its body, with the clothing of feathers, as well as the warmth which you feel, and the strength which it shows—all come from the food which it has taken while in the eggshell.

"The little chick, moreover, has to grow into a large fowl. How is this brought about? This too is accomplished by the food which it eats, after it is able to run about and seek its own living.

"We might follow up the same development in the case of the mammal. The little kitten, the little rabbit, the little baby all grow and become strong by the food—milk—which the mother supplies, until they are able to eat other food. We see, therefore, that Nature, in each of these two foods—the egg of the bird and the milk of the mammal—has supplied everything that is necessary for the life and growth of the little creature. Let us try and find out what these different things are.

"The little chicken leaves its shell with every part of its body fully formed, and all these tissues—flesh, bones, blood, feathers—it makes from the food which it finds in the shell. We call these parts of its food proteins, or tissue-formers. The milk of the mammal must contain the same kinds of material, for it has also to do the work of building up the little body. When the tiny bird leaves the eggshell, and the young mammal is no longer dependent upon its mother for support, the food which each seeks must continue to do the same work, in order that the natural development of its body may go on.

"You remember, moreover, that we said the little chicken's body feels warm, and so does the body of the kitten. Not only so; their bodies must be kept warm.

"In the yolk of the egg was stored up a quantity of oily, fatty matter. It was this which gave the heat. Our early lessons, too, showed us that milk, in like manner, contains an oily, fatty matter, which we call cream, and you know that we use this cream to make butter.

"The fatty matter, then, of the yolk of the egg and the fatty cream of the milk are both for the same purpose—that of supplying the necessary heat to the little body. We call them heat-givers or fuel-food. But why is heat necessary? It is the heat produced by the food that supplies all the vital force, and power, and energy, of both body and mind.

"Think for a moment of a steam-engine ready for work, but powerless to move a wheel till force is put into it. Whence comes this force? It comes from the fuel which is burnt in its furnace.

"So it is in the body. This heat-giving food is the fuel, and without fuel to burn, the fire would go out, the body would become cold and powerless; it would die."

Lesson 10

General Properties of Matter

"You all can tell me what we mean by the properties of a body" said Mr. Wilson. "Our lessons, from the first, have been concerned in investigating the properties of all sorts of bodies. We have found one body to be tough, another brittle; one transparent, another opaque; one soluble, another insoluble; one rigid, another flexible. The toughness or the brittleness, the transparency or the opacity, the solubility or the insolubility, the rigidness or the flexibility is in each case a property of some particular body, but not of all bodies.

"We are now going to take this word property in a much wider sense, because it has been found, after very careful investigation, that there are some properties which do not belong to particular bodies only, but to every kind of matter.

"Such properties as those we have just named, we might call special properties, because they belong only to special bodies. Those which we have next to consider, we shall call general properties, because they are common to matter of every kind. There is no kind of matter to which they do not belong, in a greater or less degree.

"These general properties of matter are extension, divisibility, weight, porosity, compressibility, elasticity.

"Let us take first the property of extension.

"See: I will place my closed hand on the table—so. Now one of you shall come to the front, and, without moving my hand, shall put his own in exactly the same position—not on top of it, not at the side, but exactly in the same place. You cannot do it; of course not.

"Here are two large stones about the same size. Could you place one on the table, and, without taking that away, put the other exactly where it stood? No, you cannot do it.

"The hand and the stone must occupy a certain amount of space or room, and what is true of them is universally true. Every kind of matter—solid, liquid, or gas—must occupy a certain amount of space or room.

"This little word room will convey to you the simplest idea, then, of what we mean by extension.

"Sometimes we consider this property of extension in one direction only, as when we measure the length, the breadth, or the thickness of a body. Sometimes we have to consider the length and breadth of a body combined. This too is extension—extension of surface. Sometimes, in addition to the length and breadth, we have to consider the thickness. This again is extension—extension of space or volume.

"I fill this basin with water to the brim. Watch what happens when I thrust my fist into it. The water overflows.

As soon as I remove my hand, the water falls in the basin, and we can see how much was forced out. Let us fill the basin again, and instead of my hand, I will drop the stone in it. The result is the same; some of the water overflows as before.

"Why was the water driven out each time? No doubt you will say that it was to make room for the hand in the one case, and the stone in the other. So it was. The amount of water driven out would have occupied exactly the room, or space, which the hand and the stone required respectively. The water and the stone cannot occupy the same space, at the same time.

"When I drive a nail into a piece of wood, the nail gets in only by thrusting aside the particles of the wood. It would not be possible for the wood and the iron to occupy the same space at the same time.

"What is true of these things is universally true of every kind of matter. No two bodies can occupy the same space at the same time.

"Let us pass on now to the property of divisibility.

"Our lessons have shown us that matter of all kinds can be separated, or divided, into minute particles by various means—sometimes by mechanical grinding, sometimes by dissolving, sometimes by boiling and evaporating.

"I have here a test-tube filled with water, and I will drop into it a small piece of some powerful dye. Even a piece of common stone-blue will answer the purpose as well as anything. I stir it well, and soon the whole of the water is colored. More than this, the least drop I could remove from the tube would retain the color. Imagine the test-tube to contain ten thousand such drops, and it is evident that the piece of coloring matter must have been divided up into at least ten thousand particles. This is what we mean by divisibility. It enables man to reduce all bodies to any required size. On the other hand, it is this property that causes bodies to wear away; even the rocks wear away by reason of it, and become particles of loose dust.

"Weight is another property which every kind of matter possesses. I think you can tell me what it is that gives bodies weight."

"The force of gravity attracts all bodies towards the center of the earth, sir, in proportion to the amount of matter which they contain," said Fred. "A drop of water poured from a glass falls down, and not up, for the same reason. We know that bodies have weight, for we can feel the muscular exertion of holding them in the hand, while gravity is attracting them downwards."

"Quite right, Fred," replied Mr. Wilson. "But gases too have weight. Can you tell me how we learn this?"

"Yes, sir. You have only to take an air-tight, stoppered bottle, exhaust all the air from it by means of the air-pump, and weigh it. Then, if you remove the stopper, allow the air to enter the bottle, and weigh it again, the difference in weight will be the weight of the air. If your bottle held exactly 100 cubic inches, the air in it would weigh 31 grains."

"Right again, my lad. But if I had filled the bottle with hydrogen instead of air, the increase of weight would have been only 2 grains. That is, 100 cubic inches of hydrogen weigh just 2 grains. But this shows us that even hydrogen, the lightest of all bodies, has some weight."

Lesson 11

Locomotion in Mammals

Man possesses two pairs of limbs, and the vast majority of the vertebrate animals are like him in this respect. All mammals have both pairs, except the whale family, and in these the hinder pair are entirely wanting.

The human arm consists of three parts—the upper arm, the forearm, and the hand. The framework of the upper arm is a single long, hollow bone; in the forearm there are two bones.

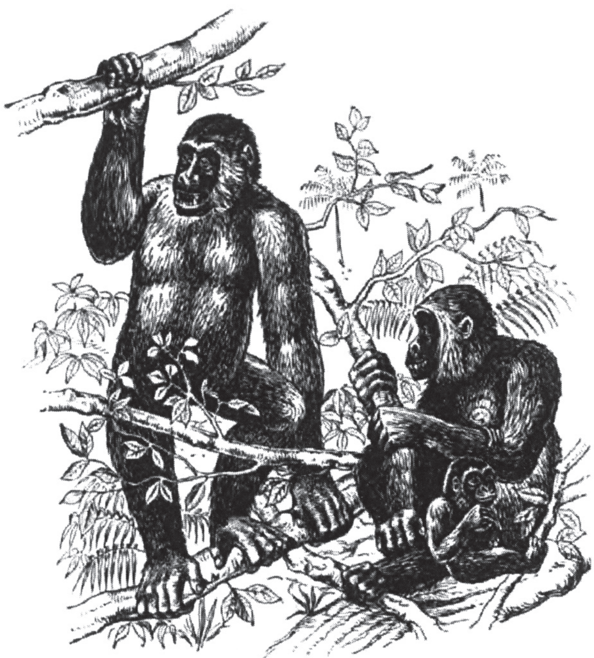
The leg, in like manner, consists of three parts—the thigh, the lower leg, and the foot ; the thigh containing one long, hollow bone, the lower leg two, as in the arm.

The first great purpose of limbs is to supply the means of locomotion, or moving about. In man the lower limbs only are adapted for support and locomotion, as may be plainly seen by a comparison of the hand with the foot. The hand, with its opposable thumb, is meant for prehension, or grasping purposes.

Most mammals run and walk on the ground, but there are others that climb trees, others that burrow in the earth, others that fly in the air, and others, again, that swim in the water.

Let us take these one by one, for their limbs must be specially adapted to their special mode of life.

First among the climbing mammals are the four-handed family, all of whom spend their lives in the trees. A glance at the skeleton of one of them will show the great similarity in its structure to that of man. There are



the same bones, arranged in the same way, except in the hand-feet. To such creatures a foot like ours would be a hindrance in their tree-climbing. In most of the family the thumbs of all four limbs are opposable like ours, and are thus admirably adapted for grasping, and clinging to the branches of the trees. In some, however, the thumb is placed side by side with the fingers, and not opposite

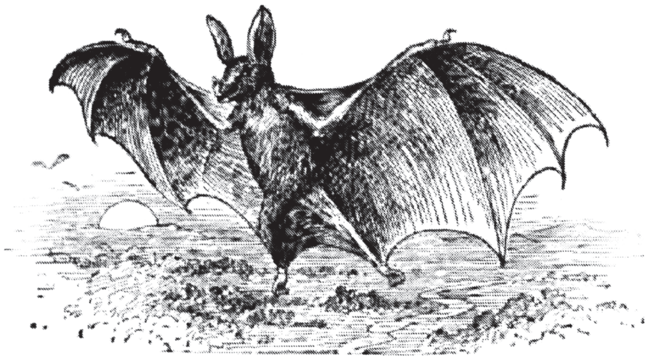
to them. These individuals cannot use their hands for climbing, but make their way by leaping from branch to branch. In all of them there is an unusual length of arm. The arms reach below the knee.

The squirrel lives in the trees, and is a good climber, but he depends upon his long, sharp talons in his climbing, and so also does the cat.

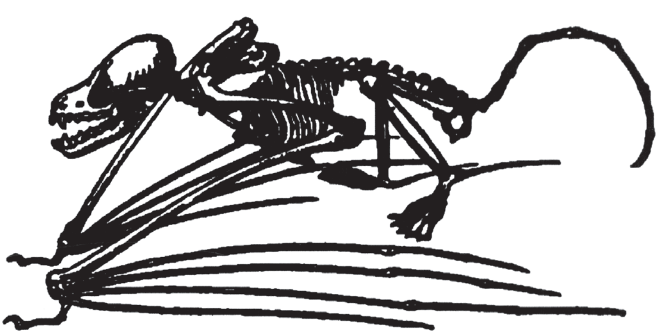
Chief among the burrowing animals is the mole, and we have already noticed the special modification of the neck bones to fit him for his life. Let us look now at his limbs. Those broad, shovel-like paws might seem to a careless observer out of all proportion to the size of the body. It is the paw only that is enlarged; the limbs themselves are

extremely short. There are the usual bones, but they are short and thick, and built for strength. The paws themselves are thus close to the body and turn outwards. They are his digging implements.

The next remarkable hands are those of the bats—the flying mammals. Suppose we examine the skeleton of one of these. The upper arm and the fore-arm are seen to consist of the usual bones, except that they are



considerably lengthened, as compared with the lower limbs. It is the hand itself, however, that shows the most wonderful development. The bones of the fingers are lengthened out, till they are longer than any other bones in the body—longer than the body itself. These bones form the framework of a sort of wing. Between the fingers themselves, up to the very finger-nails, a thin skin or web is stretched to form the wing. This is the creature's means of locomotion in the element in which it is meant to live and find its prey.



Lesson 12

Boiling

"You explained in one of our lessons, sir," said Fred, "the manner in which heat is carried through certain bodies by conduction, and you told us that this mode of conveying heat is confined to solids, liquids being very bad conductors of heat. But liquids get hot as well as solids. Will you explain to us how the heat travels in these bodies?"

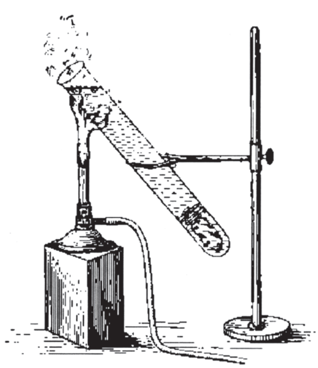
"Yes, boys," said Mr. Wilson, "I will try to make this quite clear to you. But in the first place I want you to think of the one great distinction between solid bodies and liquids."

"In solids the molecules or particles have a certain fixed position with respect to each other, sir, and that position never alters, but in liquids the molecules are free to move. Cohesion is strong in solids, but weak in liquids."

"Quite right," said Mr. Wilson, "and this will help you to remember that, when a solid body is heated by conduction, the heat affects it, molecule by molecule, each one transmitting to the next the heat which it has itself received, and so on. The great thing to keep in mind is that the molecules themselves do not move, or change their position in any way. After this little retrospect into our past work, we shall now be prepared to inquire into the mode by which liquids become heated.

"Suppose we begin with a little experiment. We will place a piece of ice in the bottom of this large test-tube, with something forced down upon it to keep it there. This coil of wire will do as well as anything. As soon as I fill the tube with water, you will see the necessity for the coil of wire. The ice is lighter than the water, and would rise to the surface if it were not held down.

"I am now going to fix the tube obliquely over the flame of the Bunsen burner, in such a position as to heat only the upper part of it. In a short time the water will

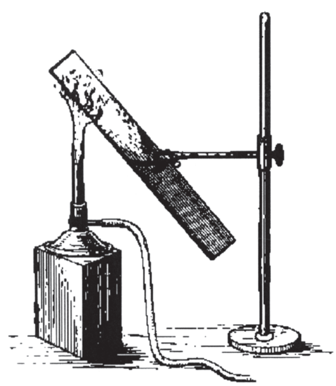


begin to rise in temperature. The thermometer will prove this, if we place it in the liquid. This rise in temperature continues until the water actually boils. We can see that the water in the upper part of the tube is in a state of ebullition, and steam-vapor is rising from it. If we test it now with the thermometer, that instrument will register 212°F.

"But what do we see in the bottom of the tube ? The ice remains in it unmelted. That part of the tube, and the water in it, are as cold as they were at first. It would, in fact, take hours before the heat could make any sensible difference in the water below the flame.

"The heat has readily passed upwards, but it cannot descend. Let us now remove the tube, and place over the flame, in the same oblique position, this strip of metal. As before, we will allow the flame to play only on the upper part of the metal. Your sense of touch will be sufficient to tell you that the lower end is gradually being heated, as well as the upper part, and in a short time even that end would be too hot for you to handle.

"How has the heat been carried downwards through the metal?"

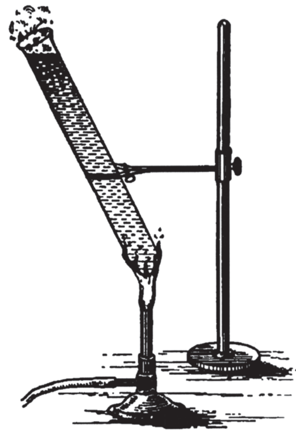


"The heat has been carried by conduction, sir," said Will, "and, now I remember, it does not matter whether the poker slants upwards, or downwards, or rests horizontally in the fire. The heat always travels to the other end."

"That's a very thoughtful answer, my lad," said Mr. Wilson. "Conduction acts downwards as well as upwards, horizontally or obliquely as well as vertically. It is quite unaffected by the position of the body through which it acts.

"This proves, therefore, that the heat did not travel through the water by conduction. Had the heat been conducted through the water, the lower part of the liquid would have become as hot as the upper—the ice would have quickly melted.

"We will now replace the tube in the stand, but direct the flame this time on the lower part of it.



"Now notice the result. The water is rapidly heated, the ice melts and disappears, and in a few minutes the whole of the liquid in the tube is seen to boil. The water has been uniformly heated, because the heat has travelled upwards from bottom to top. We have boiled the water.

"We will take an early opportunity of investigating more closely the mode by which heat travels in liquids. We have at present been merely leading up to this interesting subject."

Lesson 13

Coffee

Coffee stands next to tea as a favorite and refreshing hot drink. It has a pleasant aroma and flavor of its own, and, when taken in moderation, is a most wholesome beverage. Its refreshing powers are best felt when one is weary and drowsy with sleep. It then acts as a slight stimulant, rousing to fresh activity, and overcoming the desire to sleep, as if by magic.

Like tea, the beverage is an infusion. It is made by pouring boiling water on the reddish-brown powdered coffee supplied by the grocer. The powder itself is obtained by grinding coffee-berries in a mill. These coffee-berries are found, on examination, to resemble small, oval beans, or kernels. They are of a darkbrown color, hard and somewhat brittle, for they break easily, and they have the same peculiar aroma and flavor as the powder and the prepared beverage itself. They are the fruit of a pretty evergreen tree which grows in the tropics.

The tree very much resembles the laurel, and, like it, has oblong, pointed leaves, of a bright, deep, glossy green. Being an evergreen, it keeps this bright, glossy foliage all through the year. In its natural or wild state it grows from 15 to 20 feet high, but under cultivation it is kept well cut, and is rarely allowed to exceed 8 feet in height.

It bears pretty white and rose-tinted flowers, not unlike those of the jessamine, which cluster in profusion round the branches, especially between the joints of the young twigs. Most of the flowers burst out at one time, and so thick and close are they, that the tree appears as though covered with snow, while the air for a considerable distance around is laden with their delicious fragrance.

When the flower falls off, which it does as rapidly as it comes, it leaves the fruit—a small, dark-red berry, not unlike a cherry. It consists of a soft, pulpy, or fleshy part outside, with two hard, oval bodies or kernels in the centre. These kernels are the coffee-berries which we use.

If we examine some specimens of the berries, we find that one side is rounded or convex, the other flat. In the fruit itself the two flat sides lie together, and each kernel is enclosed separately in a tough membrane or skin.

The coffee tree is a native of Abyssinia, where it may still be seen growing wild. As far back as the year 1454 it was introduced into Arabia, and it is now cultivated in nearly all the tropical countries of the world. It is grown most extensively in Brazil and in the East and West Indies.

The culture of the coffee tree is very simple, and, as a rule, it will flourish in high lands, which are unsuited to most other crops. It is a curious fact that plants grown in low damp situations give a greater yield, but the berries are of inferior quality; while those grown in hilly districts produce less, but the quality is better.

The trees do not begin to yield till they are two years old, and, as a rule, the crop is only a moderate one for the next two or three years. After this, however, they continue to bear for about eighteen or twenty years. Two pounds of berries is a good average yield for one tree annually.

As the berries ripen, the outer skin begins to shrivel up, and it is then time to gather them. In Arabia the berries are not plucked, but shaken from the tree. Of course only the ripe ones fall, and as they fall they are caught on cloths spread on the ground below. They are then laid in the sun and dried, after which they are placed in a trough, and made to pass between large revolving rollers. The pressure of the rollers breaks the husk into small pieces, which are winnowed away, and the berries, after being once more exposed to the drying action of the sun, are packed for exportation.

There are several, almost distinct varieties of the coffee-berry. The Arabian product is smaller than the rest, and more round than oval in shape. Its color, too (a sort of dark yellow), is peculiarly its own. The East Indian variety is larger than these, and also of a light color. The Brazil berries are the largest of all, and their color is a sort of greenish-gray.

It will be well at this point to carry our minds back for a moment to our lesson on tea. In it we learned that the raw leaves of the tea-plant possess neither aroma nor flavor, and that these properties are brought out by the roasting process.

It is just so with the coffee-berries. The raw berries have none of the fragrant odor and peculiar flavor with which we are familiar in coffee. These are only acquired after roasting.

The roasting process is a very delicate one, as the flavor and fragrance of the coffee depend wholly upon the care with which it is done. The berries are placed in a close iron cylinder, something like a barrel, which is fixed over a slow gentle fire, in such a way as to enable it to revolve constantly on a sort of pivot, the continual turning of the cylinder bringing all the berries in succession under the influence of the heat.

Lesson 14

Constituents of the Body

"We are going to take another step this morning," began Mr. Wilson, "in our investigations into the subject of food. The little chick and the young mammal of our former lesson showed us clearly that, from the first, the living body requires to be continually built up with food, if it is to grow in size and strength. Now, as the food is the actual material with which this building-work is done, it necessarily follows that it must contain the very essentials which form the substance of the body itself. For example, just as bricks would be altogether out of place for enlarging or repairing a steam-engine built of iron and steel, and no other material but iron and steel would be suitable for the work, so it is in the living body. Its substance can be built up only with the same kind of material as that of which it is itself composed.

"Before, therefore, we can discuss the suitability of anything as an article of food, we must learn something of the material of which the body itself is made.

"Suppose we begin with the flesh. Think of a piece of lean flesh—a joint of beef in the butcher's shop. It looks very solid as it hangs there, but if we were to place it over a fire, we should see it begin to give off vapor, and it would continue to do so until it had lost 77 per cent of its weight. That is to say, a piece of beef weighing 100 lbs. would weigh only 23 lbs. when it had been perfectly dried. We know that the vapor which it gives off takes nothing with it. It is merely water in the gaseous form. Hence we learn that this solid lump of beef weighing 100 lbs. contained no less than 77 lbs. of water.

"The 23 lbs. of solid matter left behind are mainly a substance known in the scientific world as myosin. This myosin consists essentially of albumen, the very substance we found in the hen's egg, and it is the chief solid constituent of all flesh. It forms the muscular parts (i.e. the flesh) in our own bodies, as well as in the bodies of other animals.

"Let us next turn to the bones, and see what we can learn about their composition. I have here a bone that has been lying for the last day or two in this dish of dilute muriatic acid. You will perhaps know the acid better under its more common name—spirits of salt. We will remove the bone from the acid, dry it, and examine it. The first thing to notice is that, while it retains its form, it has lost the hard, firm, rigid nature usual in bone, and is now quite flexible. We may bend it or twist it as we please, and we can cut it easily with a knife. The acid has acted on the bone by dissolving out from it all the material that made it hard and rigid. That which remains is a substance known as ossein. If we boiled this in water, it would yield a sort of glue which we call gelatine. This substance is not only the chief constituent of bone, but also of skin, nails, hair, and feathers.

"These two substances, the myosin of the muscular flesh and the ossein of the bone, are the materials which we spoke of in our last lesson, under the name of proteins, or tissue-formers. They are the principal building materials of the body. Both of them were provided in the white of the egg (albumen), and in the milk of the nursing mammal. It is important to remember that the particular protein for building up bone substance will not make muscle or flesh, and vice versa.

"Now let us look at the structure of bone from another standpoint. Here is a bone, or rather all that is left of a bone, similar to the one I took out of the acid. This has been burnt in the middle of the fire. Take it in your hands and examine it. The first thing you notice is that although, like the other, it retains its original form, it has lost weight; it is very light indeed. Try to bend it, and it at once breaks up in your fingers, for it is very brittle.

"The fact is, all the glue-like ossein has been burned out of this bone in the fire, and that which remains is earthy, mineral matter. The gristle-like ossein, which forms certain parts of the body of the animal, is changed into actual bone by these earthy or mineral matters.

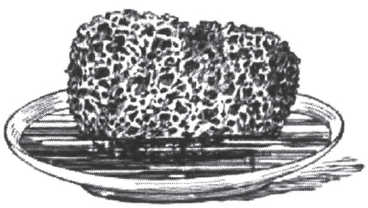
"Lastly, we will turn to the blood. A quantity of blood, dried over the fire in the same way as we dried the flesh, would show a loss of 76 parts of water out of every 100 parts, thus leaving about 24 parts of solid matter. This solid matter consists chiefly of the two substances of which the flesh and the bones are formed—myosin and ossein, together with a varying amount of the earthy or mineral matter.

"It must be borne in mind that the blood has to build up and nourish the bony as well as the fleshy structures of the body. This is why we find in the blood all the materials for the work."

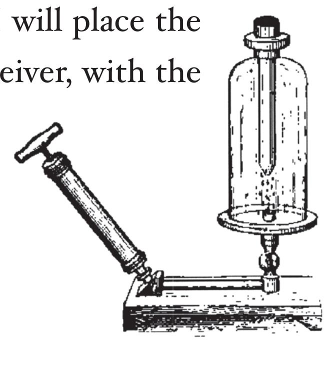
Lesson 15

General Properties of Matter

"One of our earliest lessons," said Mr. Wilson, "taught us the nature of porous bodies; we were soon able to distinguish these bodies, either by actually seeing the pores themselves, as in sponge, bread, charcoal, pumice-stone, and cane, or by watching their action in absorbing liquids, as in chalk, lump-sugar, and dry clay. Our experiment with the chamois-leather and mercury proved the porosity of the leather, for the little balls of mercury passed through its pores.



"Before we go any further I will show you a very pretty experiment with the air-pump. I have here a piece of thick malacca cane, pointed at one end, and hollowed out into a little cup at the other. I will place the cane in the open mouth of the receiver, with the pointed end downwards, taking care to see that it fits air-tight. I will next pour a little mercury into the cup at the top, and then exhaust the air from the receiver.



As the receiver is exhausted, the pressure of the outer air drives the mercury downwards through the pores of the cane, and a shower of tiny drops of the metal can be seen falling from the lower end.

"In the cane and many other bodies the pores can be readily seen; they are then called sensible pores. But in some bodies the pores are too small to be detected, even with the aid of the microscope. And now, I suppose, you are wondering how we know that such bodies have pores at all. I will explain it to you. A piece of metal, say copper or steel, does not look very porous. The most powerful microscope could not detect any pores in it. But by placing it in a freezing mixture of salt and snow, it can be made to shrink up or contract with the cold.

"What does this shrinking mean? It means that the molecules are driven closer together; therefore, there must, under ordinary circumstances, be spaces between them. These spaces between the molecules are the pores. Such pores are called physical pores. Every solid substance is more or less porous.

"Liquids are porous too, although, in this case again, it is impossible to detect the pores. Can you think of any of our old experiments which prove that liquids are porous?"

"Yes, sir," said Fred. "We filled a tumbler with water to the very brim, and then put in salt, a spoonful at a time, stirring it all the while. The salt disappeared, but none of the water overflowed. The salt found room by filling up the spaces or pores between the molecules of water."

"That's the very one I was thinking of, my lad," said Mr. Wilson, "and now I suppose you will not be surprised that porosity is one of the general properties of matter—in other words, that all matter is more or less porous.

"We are now in a position to investigate another of the general properties of matter—that of compressibility.

"From what we have said it will be easy to understand that the more porous a body is, the more compressible it must be. The most compressible bodies are gases, which are also the most porous, because their molecules are at a considerable distance from one another. It is quite possible to compress one hundred gallons of air into the hulk of a single gallon.

"Just as solids vary in porosity, so do they vary in compressibility. Some, such as wood, cork, and sponge, are very compressible; others, such as glass, have very slight compressibility; pressure will rather reduce them to powder than lessen their bulk.

"Look now at these coins. The impression on them proves the metal of which they are made to be compressible, because the impression was produced by pressing the molecules closer together.

"Liquids are the least compressible of all bodies. It has been proved that 20,000 cubic inches of water cannot be reduced, by the utmost pressure, to less bulk than 19,999 cubic inches. This slight reduction in bulk explains why in your earlier lessons you have been taught that water is incompressible, and to all practical purposes it is so.

"We will now turn our attention to the last of these general properties of matter—that of elasticity.

"It is the power which bodies have of springing back to their former shape after they have been interfered with. It is a common property of both solids, liquids, and gases.

"Some bodies, as we have seen, show their elasticity after being squeezed; among these are such common objects as sponge, cork, and wool. Others, such as india-rubber, flannel, and cloth, require to be pulled, to show their elasticity. Others, again, only show their elasticity when they are bent ; among these are cane, whalebone, and steel.

"Take this air-balloon and throw it on the table. It springs upwards. The balloon, in striking the table, became flattened, and the air in it was compressed. The air, however, is elastic, and immediately after being compressed it sprang back to regain its original bulk. It was the springing back of the air that caused the balloon to fly upwards.

"This elasticity of the air in the air-balloon is easy to understand, but I will now prove to you that even such hard bodies as glass are elastic.

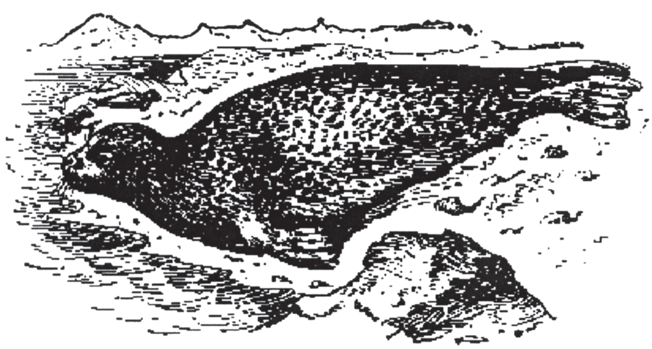
"I have smeared the smooth, polished surface of this slab of marble with ink. Watch what happens when I drop this glass ball on it. It strikes the slab and rebounds. The ball touches the slab of course at one spot only, but when we look at the ink on the slab, we find a large circular mark. The fact is, the ball on striking the slab became flattened, and in that condition the mark was made. Its own elasticity, however, caused it to spring back at once to its original shape, and the springing back gave it the upward rebound."

LESSON 16

Limbs and Locomotion

Our last investigation in this subject dealt only with the climbing, burrowing, and flying mammals. We will now proceed to examine the rest of the great family as to their special modes of locomotion, commencing with the swimmers.

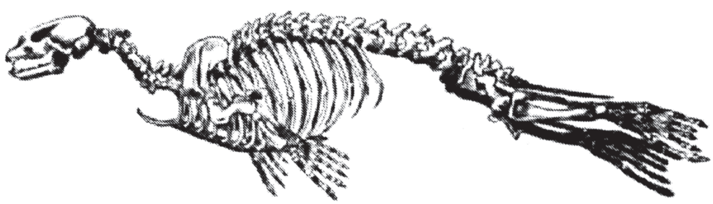
Among the swimming mammals some, such as the seal and walrus, are fitted to live out of the water as well as in



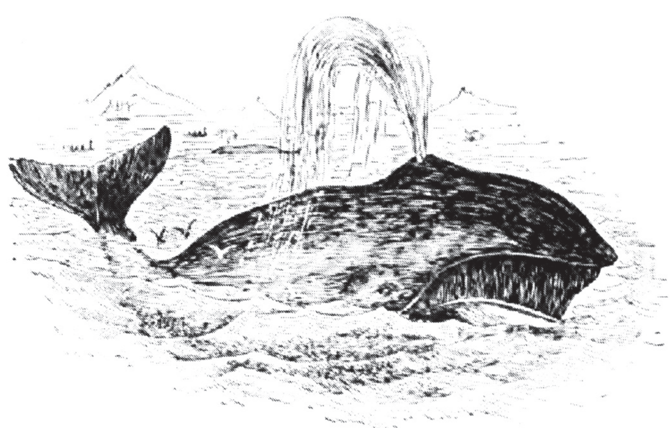
it. We have already spoken of them as fin-walkers. Their four short limbs are called fins, and must be regarded as swimming aids, rather than as a means of locomotion on land. Slow, awkward, and ungainly on land, these creatures have marvellous power as swimmers. The water is their natural home, and in the water they find their prey.

An examination of the skeleton will, in this case again, show that all the usual bones are present in the limbs. Those of the upper and forearm are short and thick, but the bones of the fingers are long. They form the framework of a large hand. The hand itself is webbed, and is the only part of the limb that passes out of the body.

The hind limbs are usually turned backwards in a line with the body. They, too, end in broad webbed flippers, which serve the purposes of a tail.

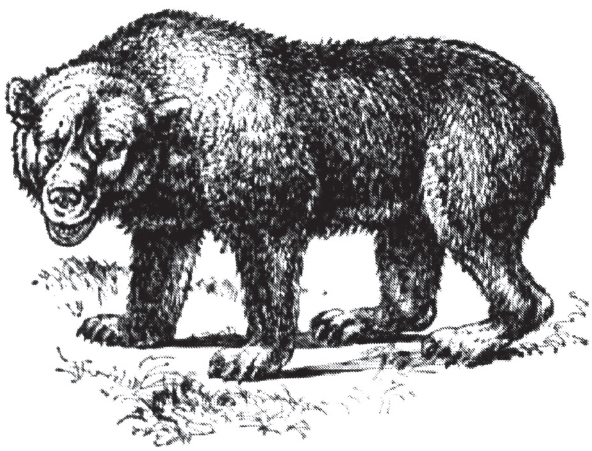


The whale family live entirely in the water; they are not adapted to live out of the water, for they have no means of locomotion on land. Their front limbs resemble in every respect the fins of the other swimming mammals, but

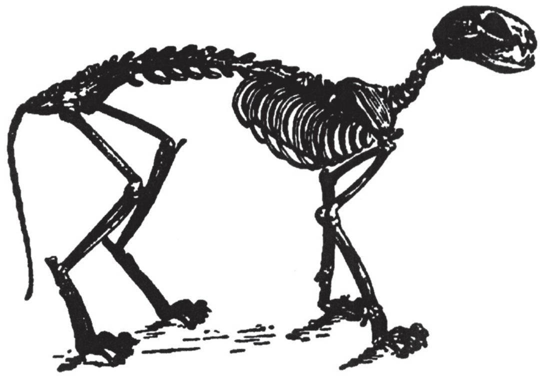


they have no hind limbs. The body ends in a large tail-fin, which is the actual propeller ; the fin-limbs merely act the part of balancers to steady the huge carcase in the water.

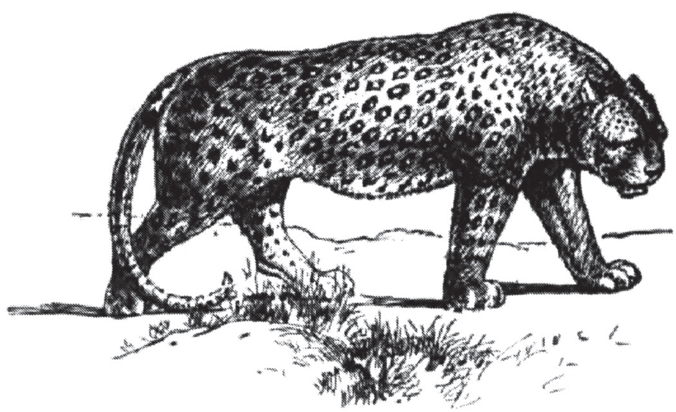
The running and walking mammals present remarkable divergences according to their several habits and modes of life. Most of the carnivorous mammals are toe-walkers; the bear and badger families alone plant the foot flat on the ground.



A careful examination of the skeleton of the cat will show that what appears at first sight to be the animal's foot is merely the extremity of it, formed by the toes. Behind the toes we may trace the limb to the next joint, but this joint is not a backward-turned knee, as it seems to be. It is the heel, the other end of the foot; and above it, in each case, is the lower leg, with its two bones, just as in other animals. These animals walk with a silent, springy tread on the tips of their toes only, the heels raised well above the ground. No other mode of locomotion could be so suitable to animals of their predatory nature.



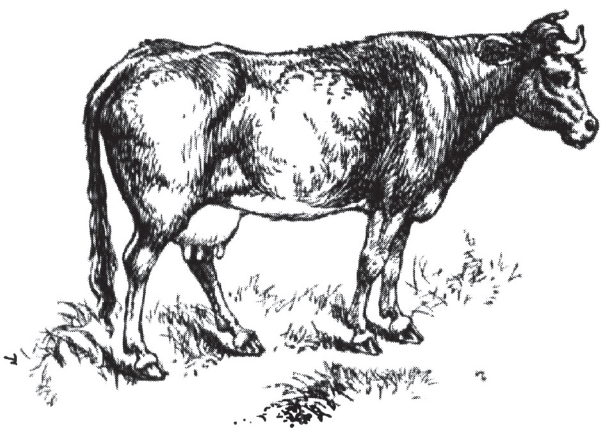
In the great majority of the rodents, or gnawing mammals, we find the hind limbs much longer and stronger than the front. In most of them the run becomes a series of leaps. One of the rodents, the beaver, is specially fitted, by means of his webbed feet, for water locomotion. He always lives in and near the water.



The whole of the hoofed animals, including not only the horse, donkey, ox, sheep, and pig, but also the rhinoceros, hippopotamus, zebra, camel, giraffe, and the entire deer and antelope family, are toe-walkers. But the

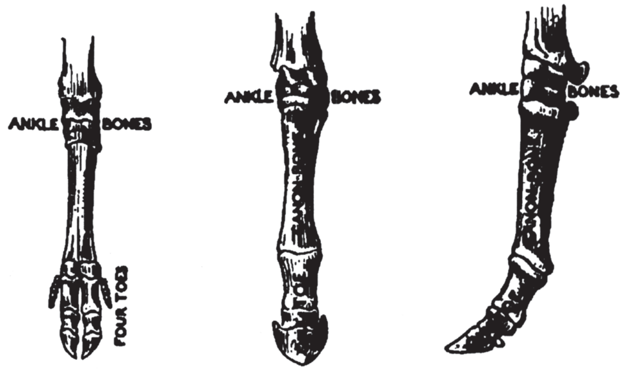
toes are encased in a hard horny hoof.

Taking the ruminants, or cud-chewers, first, we find the number of toes is reduced to four, and not only so, the hinder pair of toes never touch the ground in walking. The animals walk on two toes only, and each toe is encased in its own hoof, which is nothing more than a large nail, the whole giving the appearance of a cloven hoof.



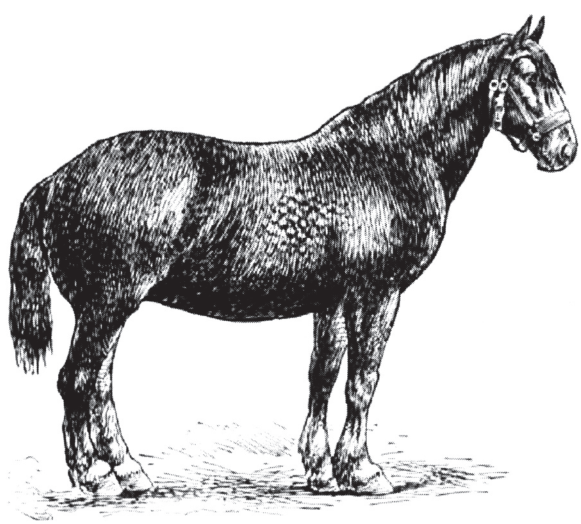
In the horse family we find the phalanges still further consolidated into a single toe, which is enclosed in its own hoof. That is to say, the horse's so-called foot is nothing but the extremity of its single toe.

This, however, is far from being the only modification in the limbs of these hoofed animals. The part immediately above the hoof is not the lower leg. It answers to the back



of the hand and the instep of the foot. Strange to say, however, instead of five bones, such as we and most other mammals have, we find here only a single bone, and that is changed beyond all recognition. It is commonly called the canon bone. In the foreleg the bones of the so-called knee are really the wrist bones, and in the hind leg those of the backward-turned knee are the ankle bones.

In the horse there is a small rudimentary bone behind the canon bone. This is commonly known as the splint bone.



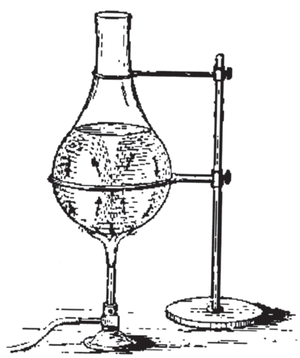
The bones of the upper and lower arms and legs are very similar to those of other mammals.

Thus the whole of this arrangement in the limbs of the hoofed animals, while depriving them of all grasping power, clearly increases the firmness, strength, and speed of the limbs.

Lesson 17

Convection

“The other day I promised to explain to you how heat travels through liquids,” said Mr. Wilson. “I will do so now by means of a very pretty experiment.



“I will fill this large glass flask with water nearly to the top, and drop into the water a few pieces of this blue substance: litmus. The flask shall be fixed upright over the flame of the Bunsen burner, and we will watch the water boil.

“As the flame plays upon the bottom of the flask, we see an upward central current of water, rendered distinctly visible by the blue coloring matter of the litmus. The current rises immediately above the spot where the flame acts on the bottom of the flask, till it reaches the surface of the water. Here it bends over in every direction, forming a great number of descending currents along the outer wall of the flask. These continue to travel downwards until they reach the heated lowermost portion of the flask, when they again ascend as before. Now let us see if we can discover what is actually taking place. First, what is the great difference between the molecules of a liquid and those of a solid?"

"The molecules of a liquid have little or no cohesion, sir," said Fred. "They are free to move about in any direction, while those of a solid are fixed and stationary."

"Just so, my lad," replied Mr. Wilson. "The molecules of the water in the flask were at first quiet, but the heat set them in motion in some way, so that the whole of the liquid was soon in rapid circulation. The particles of water themselves moved upwards, outwards, and downwards. We want to find out why this is the case.

"We have already learned something about the way in which water acts in cooling. The particles on the surface, of course, are the first to feel the effect of the cooling process. How do they act?"

"They contract in cooling, sir, and become denser and heavier than the particles below them."

"Exactly. But what happens then?"

"These heavier particles sink, and force the lighter ones upwards towards the surface."

"Quite right, but why are they lighter?"

"They are lighter because they are warmer, sir. It was only the cooling that made those on the surface contract, and so become dense and heavy."

"Good!" said Mr. Wilson. "Now let us go back to our flask. The flame heats some of the particles near the bottom of the flask. The heating makes them expand, and become lighter than those around and above them. There can be only one result: the heated, expanded particles must rise to the surface. It was the stream of these rising particles that formed the central current, which the coloring matter enabled us to see.

"But we have not done yet," he continued. "Think of this stream of heated particles rising through the cold ones all round them. What must happen as they rise?"

"I suppose," replied Fred, "they give out their heat to the colder ones, as they pass upwards, and if so, they themselves must be cold by the time they reach the surface."

"I am glad to see you reason so clearly, Fred," said Mr. Wilson. "That is exactly what takes place. But all this time more and more particles at the bottom of the flask have been heated by the flame, and these continue to rise and force the others onward. Hence it happens that those which were heated at the bottom, and have reached the surface, are now cooler and heavier than the others, and being heavier, as well as being forced onwards, they move in the only direction possible—that is, downwards along the sides of the vessel, there to meet again, at last, the heat of the flame, and rise once more.

"Thus we see that in water the heat is carried or conveyed by the particles of water themselves. The heated particles rise through the whole mass, and as they rise, give out their heat to the rest. This method of carrying or conveying heat is called convection. As the temperature of the whole of the liquid rises, the heat at the bottom converts the little particles of water into particles of steam. These are lighter still than the heated particles of actual water; they are extremely light. They rise in little balls or bubbles through the water.

"At first the water robs them continually of their heat, and they burst as they rise, but after a time, as the water itself becomes hotter, the bubbles reach the surface without bursting. It is this bursting of the steam-bubbles on the top which makes the commotion as water boils."

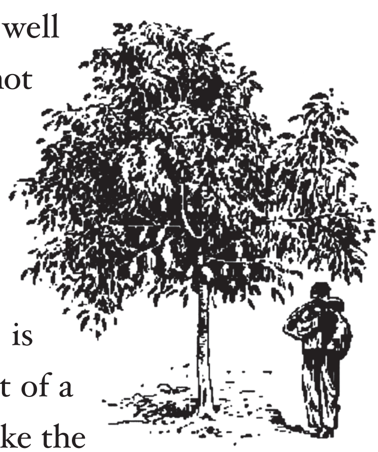
Lesson 18

Cocoa

A cup of hot cocoa forms a very pleasant beverage, and is esteemed by most people as a luxury. It differs from both tea and coffee in that it contains, in addition to its other properties, a considerable amount of flesh-forming matter. It is really food as well as drink, and is therefore a most valuable beverage.

If, again, we compare the three drinks—tea, coffee, and cocoa—we shall find that while the two former are simple infusions, the latter is rather a sort of soup or gruel than an infusion.

We are now going to inquire into the nature and source of this third beverage-making material. But before inquiring what it is, it will be well to say what it is not. Cocoa is not made from the coconuts which we see in the fruiterers' shops. It has no connection with them or with the palm-trees on which they grew. Its real name is cacao, and it is the produce, not of a palm, but of a tree very much like the



common cherry-tree. This tree is a native of America. It was found growing there by the first European discoverers of the continent, four hundred years ago. The Indians called it cacao, and they used it, as we do now, for the preparation of a refreshing beverage.

It is now grown extensively in the West Indies, and in Central and South America, and has lately been introduced into some of the tropical countries of Asia and Africa.

The cacao-tree, in its natural or wild state in the forests of Demerara, grows to the height of 30 feet, but under

cultivation the pruning-knife keeps it down to the size and shape of an ordinary cherry-tree. It is an evergreen, the leaves being very similar to those of the cherry, except that they are smooth and glossy, as is the general case with evergreens. The tree does not begin to bear till its sixth year, but after that it is very prolific. The flowers, which are small, grow in thick clusters on the trunk and main branches. The fruit is a kind of oblong pod, from 7 to 9 inches in length, and about 4 inches in breadth. It is covered with a thick, outer rind, which takes various colors—yellow, red, purple—as it ripens.

The tree presents an unusual and interesting appearance, as it bears at the same time its abundance of bright, glossy, green leaves; buds in all stages of growth; thick clusters of flowers; and above all, fruit-pods, some yellow, some red, and some purple.

The pod is a hard, tough, woody case, smooth on the outside, oblong in form, and somewhat pointed towards the end. It is divided lengthwise into five compartments or cells, which spring from a central core. Such a pod we call a capsule. In each cell or compartment a number of seeds or nuts are packed closely together round the central core, and embedded in a pinkish-white pulp. Each pod usually contains from twenty to forty of these nuts. They are known as cocoa-beans; it is from them that all preparations of cocoa are made.

The first process in preparing the newly-gathered nuts for the market is to induce them to ferment. This is usually done by burying a heap of them in the damp earth for two or three days, and then spreading them out in the sun. When this fermenting process has advanced far enough, the beans are roasted in revolving metal cylinders, just as coffee is roasted. The roasted beans are next crushed, and broken up into small pieces, commonly known as cocoa-nibs.

Some people prefer to use the cocoa-nibs themselves in the preparation of the beverage. They make excellent cocoa, but they require long and careful boiling. They give out, during the boiling, a very large amount of oil, which may be seen floating on the surface of the liquid when it is cooked. Cocoa is more frequently used in the form of thin, flaky slices, or as a powder. The former is known as flaked cocoa, the latter as soluble cocoa.

Flaked cocoa is prepared by grinding the nibs to a very fine powder, mixing the powder with water into a paste, and rolling the paste into thin sheets, which are then allowed to dry and harden.

In the preparation of soluble cocoa, which is the commonest form in which the article is used, the beans are first pressed, to extract all the oil, and then ground into a powder with a certain quantity of starch. This kind of cocoa thickens when boiling water is poured on it. It is really the starch and not the cocoa that thickens.

Chocolate is the highest form in which cocoa is prepared. The nuts for this purpose are treated as if for ordinary soluble cocoa, except that they are mixed with a certain quantity of sugar and starch, and the whole is then ground into a soft, smooth paste on hot metal tables. In this form, with, generally speaking, a little flavoring matter added, it is moulded into sticks, cakes, balls, etc., which are sold at the confectioners' shops, under the name of chocolate creams.

The name chocolate is our form of the Mexican word chocolatl, the name by which the prepared cacao-bean was known to the natives of Mexico before Europeans visited them.

Lesson 19

Kinds of Food

"Now that we are clear as to the constituents of which the body is formed, we can proceed to examine the different kinds of food necessary to support the body. Suppose we go back once more to the hen's egg," said Mr. Wilson. "I will break it, as before, in a cup. Notice the clear, sticky fluid in the cup, and notice too the change that takes place in this fluid when I pour it into boiling water. It changes to a white, opaque, solid substance. We call it white of egg. Its scientific name, albumen, is given to it because of this white appearance; the Latin word albus means white.

"Albumen is a proteid or tissue-former. It was with this as its food that the little chicken built up its tissues while in the egg-shell. Let us next turn our attention to milk, Nature's other food. I have some new milk in this glass. I will pour a little of this rennet into it, so that you may observe the change that takes place. It curdles at once into a white, opaque, solid substance—the curd. The scientific name for this curd is casein. It is the proteid or tissue-forming constituent of milk. It is with this substance that the young sucking mammal builds up its tissues.

"The food which every animal afterwards seeks for itself must contain proteid or tissue-forming matter of some kind, because its body has to grow, and its tissues can only be formed from these materials.

"Let us now go back once more to the little chick. Its body, you know, felt warm immediately it left the egg-shell; the bodies of all mammals and all birds are warm, and must be kept warm. Do you remember whence the chick obtained the heat which warmed its body?"

"Yes, sir," replied Fred. "You told us that in the yolk of the egg there is laid up a store of oily, fatty matter. It is this fatty matter which supplies the heat. In like manner, there is in milk an oily, fatty constituent. We can separate it from the milk, and when we have done so, we call it cream. The cream in the milk of mammals serves exactly the same purpose as the oily matter in the yolk of the egg. It supplies the little body with the necessary heat."

"Just so," said Mr. Wilson, "and I want you to understand clearly that, as soon as the little creatures begin to seek their own living, they must combine with their other food something which will serve the same purpose, in order that the bodily heat may be kept up. We ourselves, in like manner, require heat-giving as well as tissue-forming food, because it is this which supplies all our vital heat and energy."

"I remember, sir," said Fred, "you called both the oil of the yolk of egg and the cream of the milk Nature's fuel-foods and you spoke about these fuel-foods burning. You don't really mean that they burn in our bodies; do you, sir?"

"Yes, my lad," replied Mr. Wilson. "I mean that these fuel-foods burn in our bodies, as surely as the coal burns in the grate, although there is no flame, no smoke, such as we usually find when things burn. One of these days we will discuss this matter more fully. You must be content now to know, first, that these things and others of a similar nature are called fuel-foods, because, like ordinary fuel, they burn, and secondly, that they actually burn in our bodies, and supply heat and vital energy.

"Let us now enumerate some of these fuel-foods. First among them must stand all fat and oily matter of every kind. This, of course, does not surprise you, because these substances are so much like the fuel-food of the egg and milk. I have next some sugar in this spoon. I am going to hold the spoon over the flame of the spirit-lamp. You notice that the sugar soon becomes heated and burns. It is readily combustible and, in burning, gives out great heat.

"We take sugar as a food, because of this. It is a heat-giving or fuel-food. It burns in our bodies and, like fat, is a source of heat and vital energy.

"You remember, no doubt, our early lessons on starch, and you can tell me what kinds of food contain starch."

"Yes, sir," replied Fred. "Starch is found more or less in all vegetable foods. It is an important part of the substance of the corn-grains, peas, beans, rice, potatoes, arrowroot, sago, and tapioca. I remember how we used to separate the starch from flour by washing and kneading it in the muslin bag under water."

"Quite right, Fred. But I wonder whether you remember what happens to these starchy parts of our food when we take them into the mouth."

"Oh yes, sir," said Fred eagerly, for the whole thing flashed through his mind like lightning. "The saliva in the mouth changes these starches into sugar. Now I see it all. Starch is another of the fuel-foods. The saliva changes it into sugar, and this sugar burns in the body to provide the bodily heat.

"I remember, you mixed some starch into a paste with water, and made me hold some of it on my tongue for a few minutes, till it began to taste quite sweet. It was the saliva from my tongue that changed the starch into sugar."

"Excellent," replied Mr. Wilson, "and now just one thought more, Fred, and we will leave this subject for the present. I am going to take your mind back to that bone which I soaked in the acid. Part of the bone was left—the ossein—but all that had made it hard, firm, and rigid had been dissolved out by the acid. The bones of the little bird, as it was forming in the egg-shell, and those also of the young mammal for some time after its birth, consisted at first entirely of this one substance—ossein. There was, however, stored up in the egg and in the milk, in addition to the substances we have mentioned, a sufficient quantity of earthy matter in each case to change that ossein into actual bone. It could not have become bone without this earthy matter. From the time that the young animals begin to seek their own living, in their own way, Nature supplies the necessary amount of this earthy or mineral matter in the very food they choose.

"If we burn a carrot, a cabbage, or a potato, we find that, although the greater part of its substance is consumed in the burning, there is a residue which will not burn away. It forms an ash. This ash is earthy or mineral matter, which the vegetables took up while they were growing in the ground. Whenever, therefore, we and animals in general eat vegetable food, we take in more or less earthy matter, which those vegetables themselves have absorbed from the soil.

"The very water we drink contains dissolved minerals; salt is a mineral; all our fresh vegetables contain large supplies of mineral matter."

Lesson 20

Measurement of Matter

We have already learned the full meaning of the term extension, as applied to matter, and we know that it may be necessary to consider extension in one, two, or three directions—length, surface, volume.

From very early times man must have begun to find it necessary, in dealing with matter of any kind, to get a correct idea of its size. Primitive man no doubt made use of the hand, arm, and foot as natural measures, and perhaps these were then convenient enough, for they were always ready when they were wanted.

Boys nowadays in their games measure distances with the hand, or step them with the feet, and this often leads to quarrelling, because boys' feet and hands are not all the same size, and such measurements cannot be fair and exact.

As it is with boys, so has it always been with men. These rough-and-ready methods of measuring with hand, foot, and arm must have often caused dispute; hence arose the necessity for more fixed and definite standards of measurement. Among the commonest of these very early measures were the span, the cubit, the foot, the inch, and the fathom.

The span was the distance which can be stretched between the thumb and the little finger.

The cubit is stated in ancient manuscripts to be the length of a man's arm from the elbow to the extremity of the middle finger; it is usually called the natural or common cubit. It is worthy of note that the cubit is the earliest measure of length we meet with, and was in common use throughout the ancient world as the most convenient standard unit of length.

The foot was, of course, the length of a man's foot; the inch was the breadth of the thumb; and the fathom was the length of the outstretched arms from the tips of the fingers.

These and similar inexact measurements were the standards that prevailed in the ancient world. In course of time, and during the period of confusion between the ancient and modern world, the old standards were lost, but the people, retaining the old names, began to give to each a certain definite length, and to fix that length by law, in order to put an end to disputes.

For example, the average length of the span is 9 of our inches, and of the cubit 18¼ inches. When therefore we read in the Bible of the cubit and the span, we know that the Jews meant by each of these measurements an actual, recognized, and fixed length. In like manner, when the Greeks and Romans fixed upon the foot as their unit of measurement, they meant by it, not the length of any man's foot, but a certain fixed length settled by law.

The Romans divided their foot into twelve equal parts, which they called unciae (twelfths), and from this we derive our own word inch, the twelfth part of our foot.

The French afterwards adopted the foot as a unit. It is said that the measure was taken from the foot of the famous Emperor of the West, Charles the Great, and was subsequently adopted as a fixed definite unit of length.

The Saxons adopted the length of a man's gird or girdle as their unit measure of length, and called it a gird or yard. Men, however, differ very much in their measurement round the waist, and hence, to prevent mistakes and disputes, a certain length was fixed upon for this yard, and the true measure was kept at the royal capital, Winchester.

In the time of Henry I of England another unit was taken, from the length of that king's arm, and the old name, yard, was given to it. This yard has been the English standard of measure ever since 1135.

The measures in force in the United States were adapted from the English system determined in 1760. Our ancestors were colonists of England, and besides speaking the English language, they had English laws, English customs, and English weights and measures. In this old English system the yard was determined by the length of a pendulum swung under certain conditions in a vacuum at the level of the sea. From this that which is now called the imperial yard was made, and from this yard, the only authentic representative of the old standard, our measurements are derived. It is a long bronze bar, one inch in thickness, with a plug of gold let in near each end. Through the center of each gold plug a fine cross-line is cut; the distance between the two fine cross-lines is the true yard. The bar is always to be measured at one temperature, 62°F.

From the yard, as the standard unit, are formed the various multiples and sub-multiples, which give us our complete measure of length.

Lesson 21

The Skin

In all mammals, indeed, in all warm-blooded animals, the skin has practically the same structure and the same functions. It will be well, therefore, to consider now the structure of our own skin, as typical of the rest, especially as it will lead to some very practical results, so far as we ourselves are concerned. We can then proceed to examine the variety of coverings with which Nature clothes her creatures to suit the varying conditions of their lives and habits.

The skin, although merely a thin covering for the body, is in reality a very complex organ, both in its structure and functions. The anatomist can easily separate it into two distinct layers or skins, one underlying the other.

The outermost or top skin is called the cuticle. It is a thin, horny, almost transparent layer, having neither blood-vessels nor nerves. It has, therefore, no sensibility to pain, and does not bleed if cut. It forms a protection to the more sensitive layer below. You may run a needle through the skin on the palm of the hand without making it bleed, or causing pain, because, in doing so, you pierce this outer layer only, in which there are neither blood-vessels nor nerves.

The true skin lies below the cuticle, and is known as the cutis or dermis. As the cuticle lies on the dermis, it sometimes gets the name epidermis—epidermis meaning simply on the dermis.

The true skin is a closely interwoven mass of fibrous tissue, crossed and re-crossed with blood-vessels and nerves. If, instead of running the needle through the epidermis, we prick the skin with it, we draw blood, and at the same time cause a little sharp twinge of pain. This tells us, first, that the blood-vessels form so close a network everywhere through the true skin, that it is impossible to prick it without piercing some of them, and causing blood to flow; and secondly, that the nerve-fibers are as abundantly distributed as the blood-vessels, or we should not feel pain from the prick of the needle.

The two layers of the skin lie naturally close to each other, so that it is impossible to make a fold of the skin without taking up both. When, however, we scald or burn the skin, and a blister is formed, it is the cuticle or epidermis only that rises. The irritation of the burn causes a watery fluid to exude from the under surface of the cuticle. This fluid, not being able to escape, collects there, and forces asunder and separates the cuticle from the true skin below, and so a blister is formed.

We have thus far regarded the skin as merely a double protecting coat for the body. Now let us look at it from another point of view. What happens to our skin when we have been undergoing any violent exertion, or when we sit for some time in a very hot room? We find it covered with round drops of liquid. This liquid we call sweat or perspiration. It oozes out from the skin. Let us ascertain what it is, and how and why it is thrown off by the skin in this way.

If a piece of the skin from any part of the body were examined under a microscope, it would be found to be perforated with a great number of tiny holes. These holes are the pores of the skin. In the palm of the hand there are about 2500 on every square inch of the skin; and there are from three to six millions of them on the entire surface of the body.

The pores are the openings of little tubes which extend inwards from the surface. They are about a quarter of an inch long, and the inner extremity is coiled up into a sort of ball. We call them the perspiration or sweat glands.

By the term gland we mean an organ whose business it is to be constantly separating or taking away certain fluids from the blood, some to be thrown off from the system as injurious, others to be used in the work of the body.

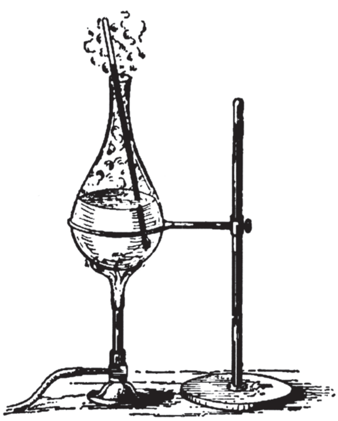
Our lessons on digestion showed you certain little glands in the mouth and under the tongue, whose duty it is to separate the fluid, called saliva, which is so necessary in the work of masticating the food.

The sweat, which these sweat-glands pour out over the surface of the skin, is a poisonous fluid, which must be thrown off from the system if the body is to be kept in health. We must take an early opportunity of learning how this is done.

Lesson 22

The Boiling Point of Liquids

"Let us try and learn something more about the heating of liquids this morning," said Mr. Wilson. "We



will begin, as before, with the simple experiment of boiling some water in this flask over the Bunsen burner. I will stand the thermometer in the flask, and we will watch it gradually rise, as the water increases in heat.

"You will notice that, when ebullition sets in, the thermometer registers 212°F.

"Instead of taking the flask away as soon as the water boils, we will let it remain in the flame; that is to say, we will continue to add more heat to the water. What does the thermometer say now, Fred?"

"It still registers 212°, sir," replied Fred. "The water is still boiling, but it does not seem to get any hotter."

"That is so, my boy," said Mr. Wilson. "The boiling water would remain at 212°; it would never rise higher than that.

"I will now hold another thermometer, not in the boiling water, but in the steam which rises from it. What do we see? The steam, too, registers 212°F.; and it cannot become hotter than this. The thermometer would not rise higher, however long it might be held in the steam.

"We will now try another liquid—alcohol or spirits of wine, in place of water. As before, we will put the thermometer in the flask to mark the gradual rise in temperature. The mercury rises in the tube till it reaches about 172°F., and at that point the liquid begins to boil, and pass away as vapor.

"No further rise in temperature will take place, and all the time the thermometer continues to register 172°, the alcohol will boil and pass off in invisible vapor.

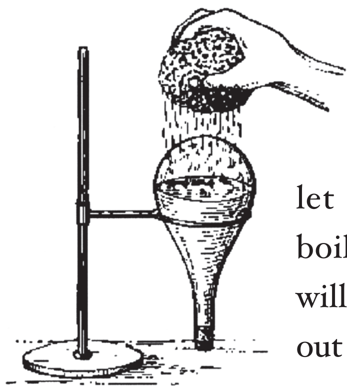
"Common ether will boil and pass away as vapor at about 98° Fahr.; in other words, the heat of the sun on an ordinary summer's day is sufficient to boil ether.

"I have here some strong brine; let us boil that in the flask now, with the thermometer, as before, to mark the rise in temperature. Watch carefully till you see the liquid boil. Why, what is the matter? The thermometer registers 212°, but the brine is not boiling. See, the mercury is still rising, and yet there is no ebullition. The brine will not boil till the thermometer registers 230°F.

"Spirits of turpentine must rise to nearly 270°F. before boiling sets in; mercury does not boil below 660°F.

"The point at which various liquids boil is called their boiling-point. Thus the boiling-point of water is 212°F.;

of alcohol 172°; of ether 98°; of brine 230°; of spirits of turpentine 270°; and of mercury 660°F.



"I think now it is time for us to have another experiment. I will place this flask, half-filled with water, over the flame, and let it boil, as before. As the water boils, the steam which rises from it will fill the rest of the flask, forcing out the air to take its place. You can see by the violent commotion that the water is boiling, and remember that now the rest of the flask above the water contains, not air, but steam. While things are in this condition I will remove the flame, cork the flask securely, and invert it. The agitation in the water will gradually cease; the boiling is over.

"Now watch carefully what happens next. I dip this sponge into cold water, and squeeze it over the upturned bottom of the flask. The boiling at once begins again, although this cooling must have lowered the temperature much below 212°. Let us see what this means. The steam at first took the place of the air which it had expelled from the flask. It exerted a certain pressure on the surface of the water. When the cold water from the sponge cooled the flask, some of that steam was condensed, and fell in drops of water. There was less steam then to press upon the surface and, in consequence, the boiling began a second time.

"At the ordinary pressure of the atmosphere water does not boil below 212°F., but when that pressure is diminished, water boils at a lower temperature."

"Then, sir, I suppose," said Fred, "water would boil at a lower temperature in a balloon, or on the side of a mountain, than it does here, for the pressure of the atmosphere always diminishes as we ascend."

"Yes, my lad," replied Mr. Wilson, "you are quite right. On the top of Mont Blanc (15,800 feet high) water boils at about 180°F.; at Quito (11,000feet) the boiling-point is about 194° , and at Madrid (3000 feet) about 207°.

"It must be clearly understood, moreover, that these various temperatures cannot be exceeded in any case. On Mont Blanc, for instance, it would be impossible to make the water hotter than 180°, because that is the boiling-point there, and this point is no sooner reached than the water ceases to exist as a liquid, and passes off as steam.

"Food is cooked with extreme difficulty in such places. Indeed, it cannot be said to be cooked at all, for these low boiling-points do not allow the water to reach a sufficient temperature to extract all the nourishment and flavor from the food. An egg boiled on Pike's Peak would not coagulate, a potato would remain hard.

"In deep mines, on the other hand, the atmospheric pressure is greater, and the boiling-point is higher than 212°F."

Lesson 23

Vegetable Oils

Oily matter of some kind is met with in most plants. It is found in various parts of the plant but, as a rule, is most abundant in the fruit and seeds. The reason is obvious if we think of the work which the seeds have to do. In every case the little embryo plant feeds upon the store of food laid up in the seed till the germinating period is over, and it is able to seek its own living from the soil. The oily matter found in certain seeds is simply a peculiar form of that plant-food. Cotton, rape, colza, castor, and poppy oils are among those obtained from the seeds of plants, and linseed and hemp-seed oils, as their names indicate, belong to the same class.

Palm oil, cocoa-nut oil, and olive oil are all obtained from the fruits of their respective trees.

If an ordinary almond is held in the flame of the spirit-lamp, it will afford a good illustration of these oily nuts and seeds. It takes fire readily, and burns with a flame. It contains 46 percent of its weight in oil, and it is the oil that burns.

Most oils are extracted by pressure, and are known as cold-drawn oils—that is to say, they are obtained without heating. Some can only be obtained with the help of heat as well as pressure, and some, again, have to be distilled from the substances which contain them.

There are two classes of these vegetable oils; they will be best understood after a little experiment. Take two pieces of clean white blotting-paper, and let fall on one a drop of some common oil, such as olive, colza, or castor; on the other a similar quantity of oil of peppermint. Wave the papers about in the air gently, and the oil of peppermint will gradually disappear from the one, leaving neither mark, nor stain, nor trace of any kind, while the other will bear a widely-spreading greasy stain, and the whole of the oil will remain on it.

In the one case we have an oil which disappears by flying off into the air; we call it a volatile oil. The word volatile comes from a Latin word meaning to fly. Among these volatile oils are oil of turpentine, lemon, cloves, lavender, bergamot, rosemary, and peppermint.

The other oil remained as a greasy stain on the paper, and made no attempt to fly off. This we call a fixed oil. Oil of linseed, hemp, cotton, rape, colza, castor, poppy, olive, palm, and coconut all belong to the class of fixed oils.

Each of these vegetable oils is useful in its own particular way, and because of its own distinctive properties.

Linseed oil is the product of the flax plant. It is a curious fact in connection with this plant that, although it grows equally well in warm as in temperate climates, there is a great difference in the respective products. In temperate climates it is cultivated specially for its linen-producing stalks, the seeds and their oil being a very secondary consideration. In warm climates the stalks never reach robust growth, and the main objects of culture are the oil-yielding seeds.

These seeds contain one-fourth their weight of oil, which is obtained by pressure between closely-fitting iron rollers. The crushed seeds themselves are pressed into oil-cake, and make a valuable food for cattle, usually finding ready sales.

Linseed oil is largely used in the preparation of paint and putty, because it has the property of drying very rapidly when exposed to the air in thin layers.

Hemp and poppy oils are obtained in the same way, possess the same drying properties, and are applied to the same uses as linseed oil.

Rape and colza oils are obtained from the seeds of the cole or rape plant, a member of the cabbage tribe, which is grown largely in India and Southern Europe. The seeds contain 40 per cent of their weight in oil, which is obtained by pressure.

All oils are very inflammable, but rape and colza are the best of all vegetable oils in this respect. They are used in lamps, and give a bright luminous flame, without charring the wick. Best colza oil is employed in the lamps of lighthouses.

These oils have none of the drying properties of linseed and other oils, and would be unsuitable for the purposes to which they are applied; neither would linseed oil be suitable for lamps.

Castor oil is obtained by pressure from the seeds of a plant, originally a native of India, but now grown in America and the south of Europe. In those parts of the world it attains the height of 20 feet. We may sometimes see it growing in the north, but it is a comparatively small plant there, not reaching more than 3 feet in height. The seeds are about the size and shape of a bean, and contain a large quantity of thick oil, of a very nauseous odor and taste. We use castor oil as a medicine, but in India it is abundant, and so cheap that it is used for burning in lamps.

The seeds of the cotton plant yield much oil, which is obtained by pressure. Cotton oil is plentiful and cheap, but it lacks the qualities of most of the other oils. It is often used, because it is cheap, as an inferior substitute both for the lighting and the drying oils. It is also largely used for making soap, and for lubricating machinery, and in cooking, as a substitute for olive oil.

Lesson 24

Animal Food

"We learnt from our last lesson on food that the little, growing animal requires three distinct kinds of food-materials—tissue-formers, heat-givers, and bone-makers—if its body is to increase in size and strength," said Mr. Wilson, at the next meeting of the class.

"But our lessons of last year's course showed us that food has other work besides that of building up the growing body of the young animal. All animals, whether young or old, are more or less active, and perform many varieties of work with their bodies. Man works not only with his body but also with his mind. How does this work affect the body? Can you tell me, Fred?"

"Yes, sir," replied Fred. "I think I can explain it. Every act of our daily life destroys some part of the substance of the body. The muscles, as the movers of the body, the brain, as the center of thought and intellect, the eyes, ears, nose, skin—every part of the body destroys some of its own substance in the very act of performing its work. This is why we feel faint and tired after exertion. We have a desire for food. We are hungry. If we were kept without food, our bodies would shrink in size, and we should become weaker and weaker."

"First-rate, my lad," said Mr. Wilson, and his eye sparkled with pride at Fred's intelligent answer. "The tissues of the body must be renewed, and built up again, as they are destroyed, or the body would lose in weight and strength. The blood does the work of repairing and making good all losses, as well as that of building up the growing body. It is the food which we take that supplies the blood with the materials for this work.

"Our daily diet should contain all three kinds of food-material in some form or other, but not in equal quantities. We require daily just sufficient tissue-forming and bone-making materials to renew the waste which is going on, and just enough fuel to create the necessary amount of heat. It is found that the body needs about four times as much heat-giving, as tissue-forming food, and not more than a quarter of that amount of bone-making or mineral food. If we take more, or less, than these proportions, the body will suffer in some way or other.

"These food-materials may be obtained, as we have seen, from both the animal and the vegetable world. The flesh itself of certain animals provides our main supply of animal food. The sheep gives mutton and lamb, the ox beef and veal, and the pig pork, bacon, and ham. Poultry (fowls, ducks, geese, turkeys, and pigeons) supply nourishing flesh-food of another kind. The flesh of the deer gives us venison, and certain other wild animals, such as hares, partridges, pheasants, grouse, and woodcock, are called game.

"Flesh-food is specially valuable because it is very similar in its nature to the fleshy parts of our own bodies. The muscular or lean, fleshy parts of the meat contain the proteid substance, myosin, the very identical material of which our own bodies are made. It is therefore specially well-fitted for building up our own tissues. Mixed with the lean of the meat, however, there is always more or less fat. The amount varies in different animals, and depends upon their manner of feeding. This fat is, as we have seen, an important heat-giving food. Taken into the body, it does not build up the tissues, but it burns, and in burning creates the heat which the body requires.

"The value of flesh-food varies in proportion to its digestibility. Mutton, venison, poultry, and game are easily digested; beef, though it contains much nourishment, requires a more robust digestion; pork and veal are less digestible than either.

"The quality of the meat, both for flavor and digestibility, may be readily detected by the juices in the lean, which ought to give a delicate color and softness to the flesh. This fact should never be forgotten, when one is choosing a joint of meat at the butcher's. The final value of the meat, both as regards economy, and also its excellence of flavor, depends largely upon the cook.

"We must not leave this part of our subject without a word or two as to the high value of the bones as food-material. This is a fact by far too little known or appreciated.

In the great majority of homes the bones are discarded, and thrown aside as useless and altogether unprofitable. This is a great mistake.

"All bone consists largely of ossein—the substance we saw in the bone that had been soaking in the acid. This ossein, when boiled, yields a glue-like substance called gelatine, which is a very valuable tissue-forming food. Leg-of-beef bones make excellent soup, 6 lbs. of the bones being sufficient to yield as much nutritious matter as 1 lb. of the actual flesh itself .What waste it is to throw such bones away!

"While considering the bodies of animals, we must not pass over fish, for this provides a very valuable article of food, and one which will compare very favorably with butcher's meat. Many kinds of fish are used as food—the commonest are the herring, cod, mackerel, whiting, haddock, plaice, sole, shad, and salmon.

"The fleshy part of the substance of all kinds of fish consists of essentially the same materials as those which make up the flesh of other animals, except that it contains more water in proportion, and consequently less nutritive matter. Fish, although not so satisfying as beef or mutton, is very rich in a certain class of mineral matters known as phosphates, and on this account makes an invaluable brain-food.

"The cheaper varieties of fish contain more nutritive matter than some of the more expensive kinds. Thus, herrings contain a very large amount of flesh-forming material; salmon contain much less in proportion.

"Some fish, such as the herring, pilchard, eel, sprat, mackerel, and salmon, contain a large quantity of oily fat just beneath the skin. These are usually known as fat fish. Some, such as the sole, whiting, haddock, plaice, turbot, brill, and cod, have very little fat. They are known as white fish."

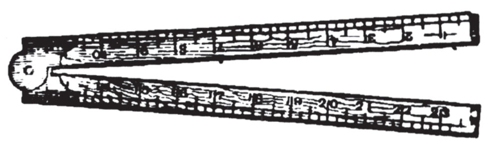
Lesson 25

Measurement as Practiced by the Mechanic

We have seen that in the measurement of matter we must consider extension in one, two, or three directions—length, surface, volume.

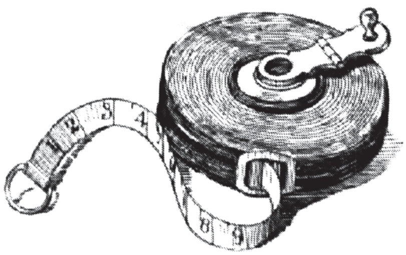
Measurement of length, however, must of course be the basis of all three.

For ordinary measurement the mechanic uses a two-foot rule. This is a perfectly straight and rigid stick of hard boxwood, fitted with a brass joint in the middle, so that it may be folded small enough to go into the workman's pocket. On



the face of the rule the inches are marked and numbered, and each inch is further subdivided into half-inches, quarters, eighths, and sixteenths. In measuring long lengths, where a two-foot rule would be tedious and inconvenient, the tape-measure is often used. This is a stout, linen tape attached to a reel, and having the necessary divisions and subdivisions plainly marked. It should have a thin, brass wire running through it, to prevent it from stretching, or contracting, or curling up. This instrument is especially useful in measuring the circumference of circular bodies, or indeed any objects with a rounded surface, where a rigid rule would be useless.

For setting off a certain fixed length on the material he is working, the mechanic mostly uses the compasses. On this account he sometimes calls them dividers.

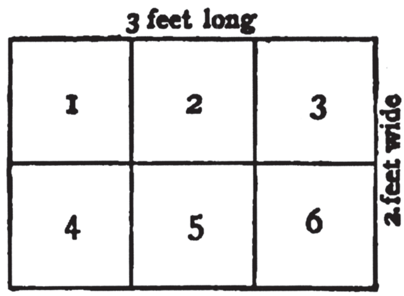


Among the most awkward measurements to take are the internal and external diameters of cylindrical and circular bodies, and of barrels and casks of all kinds. This measurement is accomplished by instruments called calipers. They are like a pair of compasses with curved legs.

The wire-gauge is a curious instrument used for measuring the thickness of wire. It is simply a steel plate, with a number of slits of different widths cut round its edge. The width of each slit is known and numbered, and the diameter of the wire is indicated by the number of the particular slit into which it fits. The wire-guage now most generally in

use measures the largest as well as the smallest wires; it has superseded all others.

Taking next the measurement of surfaces, let us commence by measuring the surface of this blackboard. If we take our rule, and measure along one edge, we shall find that it is 3 feet long. We will set off the 3 feet on this edge of the board. Let us next measure the adjacent side, which we find to be 2 feet. This we will mark off also on that edge.



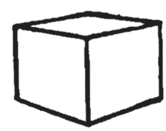
Notice that we call one measurement the length, the other the breadth, (or width,) but we ascertain both by means of the two-foot rule. We may now do the same on the opposite sides, and when we have set off the divisions, we will join the points by drawing straight lines across the board.

What have we done? We have divided the board into squares, and we know that the side of each of these squares measures a foot. A square whose side measures a foot is called a square foot.

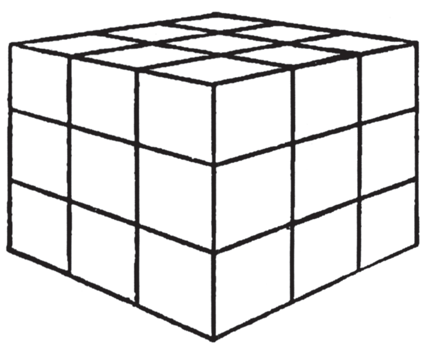
Now how many squares have we? Six. Then the whole surface contains 6 square feet. We might have told the area or surface of the board at once, without drawing the lines, merely by multiplying the length by the breadth; thus 3x2=6. This, of course, is the way the workman measures his surfaces. He ascertains first the length, then the breadth, and learns the surface, or superficial contents, by multiplying these two measurements together.

Volume means, as we have seen, length, breadth, and thickness. This can be best shown with the help of a number of inch cubes. If we measure one of these cubes, we shall find that it is 1 inch long, 1 inch broad, and 1 inch thick. Just as we called the surface inch a square inch, we shall call this one a solid or cubic inch.

It is important to remember that the square inch measures the mere surface, without the least reference to thickness. Hence it is clear that matter of all kinds must require all three dimensions, because it occupies space; it has not only length and breadth, but thickness as well.



We will now go back to our inch cubes. To make it clear I will build them up into a block, say three in length, three in breadth, and three in thickness.



There they are; now we will separate the cubes from the block one by one, counting them as we remove them. How many cubes did it take to form that block? Twenty-seven. That is to say, the block contained 27 cubic inches.

The workman would simply measure with his rule the length, breadth, and thickness of the block, and multiply these measurements together; thus, $3 \times 3 \times 3 = 27$.

Hence we learn that the solid or cubical contents of bodies are found by multiplying the length, breadth, and thickness together.

Lesson 26

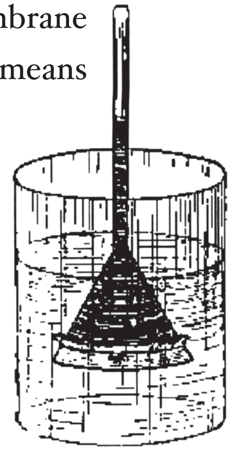
The Skin—Cleanliness

We have already learned that the skin, besides being a covering or protection for the body, is at the same time a special organ with special work to do. The fact that it contains, coiled up in itself, millions of individual glands for carrying on this work, is sufficient to show the importance of the organ.

If all the little tubes of the sweat-glands in your body could be placed in a line, end to end, they would extend from twenty-eight to thirty miles. Think of that. Every one of us has in his own body nearly thirty miles of sewerage or drain-pipes for carrying off these impurities from the blood.

But how does this watery sweat, with its impurities, find its way from the blood into the sweat-tubes, and so to the skin? Every little sweat-tube, which opens on the surface of the skin, is coiled up into a ball at its inner extremity. It is this ball or coil of tubing which we really mean when we speak of the sweat-gland. Each gland is closely enveloped with capillary blood-vessels, and the walls of these vessels, as well as those of the tubes themselves, are so exceedingly thin as to afford an easy passage for liquids through them.

This passage of liquids through a membrane is called osmosis. It is best explained by means of an experiment as follows: Take a glass funnel, with a long narrow tube, and bind a piece of thin bladder firmly over the mouth of it, so as to make it water-tight. Fill the funnel and part of its tube with a solution of blue-stone (sulphate of copper). Now place the funnel in a basin of water, so that the blue liquid in the tube and the water in the basin are at the same level.



Almost at once two things will happen. The liquid will begin to rise in the tube, and at the same time the water in the basin will be seen to gradually assume a blue tint. The explanation is that some of the water is entering the funnel, and some of the blue liquid is passing out into the water. This exchange goes on through the substance of the bladder itself; the two liquids have actually passed through the membrane. This is what we mean by osmosis, and this is the way in which the watery sweat, and all the impurities contained in it, are drained out of the blood in the capillaries. The coiled tubes of the little glands receive the sweat as it oozes through, and pass it outwards by means of the pores on the surface of the skin.

One very important purpose of the perspiration is to preserve the proper temperature of the body, so that it may not suffer from too great heat, whether from within or without. The natural temperature of the body is from 98° to 100°F., and it never rises above this while the body is in a healthy state.

Imagine a person very much over-heated, either by some violent exertion, or through being compelled to stay in a heated atmosphere. In either case the skin at once begins to act very vigorously, and the body is soon bathed in perspiration. This perspiration rapidly passes off from the surface of the skin in vapor, and in doing so carries away heat from the body, so that the natural temperature is still maintained.

You, no doubt, remember from some of our recent lessons that water can only assume the vapor form by using up a large amount of heat. The heat necessary in this case is derived from the body, and the withdrawal of that heat is Nature's way of cooling the body.

These miles of drain-pipes having such important work to perform, it is in the highest degree necessary that we should assist them as much as possible, if we wish to keep our bodies in a healthy state. One of the best ways of assisting them is by keeping the body clean.

People who neglect their bodies, by not frequently washing them all over, often become the prey of loathsome skin diseases and various disorders. They allow the mouths of the glands to become clogged or choked up with dirt; and the poisonous waste-matters having no proper outlet, remain there and create disease. Therefore wash well and often.

The skin should also be protected, as far as possible, from cold and damp. Perspiration is always going on, although we cannot always see the drops of liquid on the skin. This insensible perspiration, as it is sometimes called, must be allowed to go on without any interference. Therefore every care should be taken not to check the action of the glands by exposing the body to damp and cold for any length of time.

Remember, however, that this last piece of advice does not preclude the plentiful use of cold water on the skin. Never be afraid of cold water, provided that it is followed by a good rub down with a rough towel, to set the body in a glow again after the bath.

Lesson 27

Distillation

"Our investigations into the heating of liquids have led us to consider a very important subject this morning," said Mr. Wilson.

"Think of the water boiling in the flask. What would happen if I held this cold slate over the steam as it issues from the water?"

"The steam, or water-vapor, would be changed back again into drops of liquid water, sir," said Will. "Just so, and if I boil mercury in a test-tube, that liquid will also pass off in invisible vapor, which I can collect again on a cold surface in little round globules of liquid metal. It is so with all these boiling liquids.

"What do we call this process of re-converting the vapor into a liquid?"

"It is known as condensation, sir," said Will.

"What causes the condensation?"

"The vapor is condensed into liquid because the cold body, with which it comes into contact, robs it of the heat which it contained," said Fred. "It is the addition of heat that first evaporates the water, or changes it into vapor. As soon as that heat is taken away, the vapor changes back again into the liquid form. We say it is condensed. By this term we mean that the molecules of vapor, when they are robbed of their heat, contract and crowd closer and closer together, till they assume the liquid form again."

"Very good indeed, my boy," said Mr. Wilson. "Now we will illustrate this in another way. Here is some strong brine; I am going to boil it in this retort. As I don't wish the steam from it to escape, I will fit the neck of the retort into the mouth of this flask. I will stand the flask itself in this basin of ice-cold water, and place the Bunsen burner under the retort. Now let us watch the result.

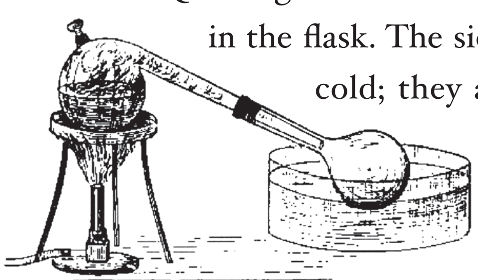
"What is the heat doing to the liquid in the retort?"

"It is heating and boiling it, sir," said Fred, "and when liquids boil they are converted into invisible vapor."

"What becomes of the vapor in this case?"

"It cannot escape, sir; it passes into the flask."

"Quite right. Now let us see what happens to it in the flask. The sides of the flask are very cold; they are surrounded by very cold water. How will this affect the water-vapor inside?"



"The vapor will be re-converted (or condensed) into liquid water again, sir."

"Here, you see, a double process is going on. The heat beneath the retort evaporates the water, and the vapor thus formed, after passing into the cold flask, is changed back again, or condensed, into liquid. We can see the liquid in the bottom of the flask. This double process is called distillation.

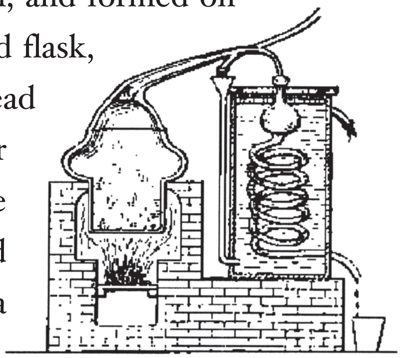
"Let us now remove the flask from the retort, and pour out the water. Taste it, Fred."

"Why, sir," said Fred, with surprise, "this is pure water; that in the retort is strong brine."

"Yes, Fred; the salt is all left behind in the retort. We call this distilled water. We might have done the same with solutions of sugar, alum, soda, or any other soluble substance. We should, in each case, get only pure distilled water in the flask at the end of the process.

"The variation in the boiling-points of different liquids is turned to useful account in the art of distilling.

"An apparatus, called a still, and formed on the principle of our retort and flask, is used for the purpose. Instead of the retort, a strong copper vessel is used, in which the liquid is boiled. The distilled vapors are passed through a long spiral tube, which is placed in a cistern kept constantly full of cold water.



"Brandy is obtained from wine by distillation. The wine itself consists of water, alcohol, and certain other matters. Alcohol boils and passes off as vapor at about 172°F., but water will not boil below 212°.

"When, therefore, the wine is heated in the boiler to 172°, and not allowed to exceed that temperature, the alcohol in it distils over, and passes, in vapor form, down the spiral tube to be condensed. The water, of course, remains behind, because the temperature is never allowed to reach its boiling-point, 212°.

"Whisky is distilled from malt liquors in the same way; rum from molasses; benzine from paraffin oil or coal-naphtha."

Lesson 28

Other Vegetable Oils

We have already examined a certain class of fixed oils, which are obtained by crushing the seeds of certain plants. Our next business will be to turn our attention to another class, obtained in each case, not from the seeds, but from the fruit of the plant, and requiring heat as well as pressure in the process of extraction.

First among these stands palm oil, which is obtained from the fruit of the oil-palm, a native of tropical Africa.

The tree grows to a height of 30 feet, and the fruit from which the oil is obtained hangs in bunches, often 2 or 3 feet across. Each individual fruit is oval in shape, and the finest of them grow to about the size of a hen's egg.

When ripe the fruit is quite smooth, and of a bright, golden yellow. It consists of a small hard nut, embedded in a soft, oily flesh. The oil is obtained by boiling the ripe fruit in earthenware pans, and then crushing the mass in wooden mortars.

Palm oil, as we see it in this country, is thick and solid like butter or dripping, but in the hot climates where it is produced it is liquid like other oils.

It is mostly used in the manufacture of soap and

composite candles, and for lubricating the axles of railway-carriage wheels. The natives of Africa use it as we do butter.

Coconut oil is another of the fats, or solid oils. It is obtained from the fruit of the coconut palm, which is cultivated in most tropical countries, especially in the East and West Indies, India, and Ceylon, and in the islands of the Pacific Archipelago. The tree has a long straight stem, which towers to a height of 100 feet, and is crowned with immense drooping leaves, each leaf measuring about 15 feet in length. The fruit hangs in clusters at the very summit of the tree. It is an immense nut, the kernel of which is enclosed in a hard woody shell, with a thick, tough, fibrous case outside. The oil, which at ordinary temperatures is a white solid fat, is obtained sometimes by pressure alone, but mostly by first boiling the kernels and then crushing them. It is largely used in the manufacture of soap and candles. It is the only fatty matter which will

make a soap capable of forming a lather with sea-water. We call it marine-soap.

To the natives of the countries where it grows, this tree is most invaluable. They use its wood to build and furnish their houses; the fibers of the husk and the long tough leaves serve as thatching material, and for making mats, baskets, ropes, brushes, and such things; the nuts themselves provide them with food; the milky liquid inside the kernel supplies their favorite drink; and they even make an intoxicating liquor called arrack from the juice of the flower.

Olive oil is the produce of the fruit of a tree which grows in the countries situated on both shores of the Mediterranean, and in California. It is an evergreen shrub, not more than 10 feet high, covered with long lance-shaped leaves, and bearing small, white, sweet-scented flowers, which are followed by fruit about the size of a small plum or damson. When the fruit is ripe, it assumes a dark purple color, and the flesh becomes oily, and rough, and bitter to the taste.

The oil is extracted by pressure in a screw-press. That which flows first, and with only a slight pressure, is considered the best. It is known as Virgin oil. The common kinds of olive oil are obtained by first heating the fruit, and then subjecting it to very strong pressure. This is the common sweet-oil, which is used for various household purposes. It is a pale yellow, inodorous liquid, and is very inflammable.

The best kinds of olive oil are used in the preparation of food, although to a much more limited extent with us than in the countries of Southern Europe, where it may be said to take the place of butter and cream, and is used at every meal.

Lesson 29

Animal Food—Milk, Butter, Cheese, Eggs

"We have already been taught to regard milk and eggs as perfect foods," said Mr. Wilson. "They are the distinctive foods which Nature supplies for the sustenance of the young, helpless, growing progeny of her creatures. One of the earliest conquests of civilized man was accomplished when he domesticated the useful cow, and compelled her to contribute to his daily needs by supplying him with the milk, intended originally for the support of her own offspring.

"In all civilized countries today milk, in one form or other, is a very important article of the daily diet. We drink it as a beverage; we add it to our tea, coffee, cocoa, and other drinks; we use it with various other things to make nutritious puddings, cakes, and custards. In whatever way we take it, it becomes a highly useful article of diet.

"In the dairy the milk, or rather one of its constituent parts, the cream, is converted into butter with the help of the churn. The milk is left to stand quietly for a time in shallow pans, until the cream, which consists of tiny globules or bladders of fatty or oily matter, rises to the surface. These tiny globules rise in this way, because they are lighter than the rest of the liquid.

"The object of the churning process is to burst the delicate skin which encloses the little globules, thus setting free the oily, fatty matter within, which forms into lumps of butter. It is clear then that butter, which consists entirely of fat, is a fuel food.

"It is no part of our business now to follow up the process of butter-making. We are only concerned in learning the use of the butter itself as an article of our daily food.

"When the cream has been removed from the surface, the skim milk left behind in the pan may be still further separated into two distinct parts. In the dairy this is done by pouring in rennet, but vinegar or any acid will separate them. In fact, they separate themselves when the milk turns sour.

"One of these parts, as we saw in our lesson on the different kinds of food, is a white, opaque, solid substance—the curd. Its scientific name is casein. This is the tissue-forming principle of milk. In the dairy it is collected and made into cheese, by squeezing out the water, and drying and pressing it into moulds.

"Cheese may be made either of new or skim milk. When made from skim milk it contains as much of the tissue-forming casein as that made from new milk, but it is less palatable, because it contains no cream. It is sometimes called skim-milk cheese. Suffolk and Dutch cheeses are made from skim milk.

"If made of new milk the cheese contains a large amount of the fatty element, as well as the essential principle, casein. This adds to its flavor, and thus to its market price, but it does not make it more valuable as a tissue-forming food. Gloucester, Cheshire, and most of the fine cheeses of commerce are all made of new milk.

"Cream cheeses are made from new milk too, but, besides the cream which that milk contains, an additional quantity of cream is added.

"Cheese taken in large quantities is neither a good nor an economical article of food. Few persons are able to digest a large piece of cheese at one time, although cheese is said to be a good aid to the digestion of other food if taken in small quantity, certainly not exceeding an ounce at a meal.

"We may, in passing, notice the thin watery fluid which is left behind when these more essential parts of the milk have been removed. It is called whey. Dissolved in the liquid are certain mineral salts, as well as from 3 to 5 per cent of milk-sugar. Our lessons have, of course, made clear to you the purpose of these constituents.

"Let us now glance at the last of these animal foods—eggs. We have already examined the egg as to its structure, and the purpose for which it was designed.

"What becomes of the clear, sticky, colorless portion when it is boiled?"

"It changes into a white, opaque, solid substance, sir, which we call albumen, from the Latin word albus, which means white."

"Quite right. Just one word more about this albumen, and then we have done. Albumen is an important constituent of the yolk, as well as of the rest of the egg; 20 per cent of the yolk itself consists of albumen. What else did we find in the egg? We have already noticed a yellow fatty oil. This oil forms 30 per cent of the yolk of the egg.

"The albumen is the tissue-forming constituent, the fatty oil the heat-giving part of the egg.

"As an article of food, eggs should be but lightly cooked.

"Albumen in its raw state is easily digestible, but when boiled it becomes hard and more or less indigestible."

Lesson 30

Steam

"I want you to think once more about the water boiling in the flask over the Bunsen burner, and some of the things it taught us," said Mr. Wilson.

"Water, at the ordinary pressure of the atmosphere, boils at 212°F. What do we mean by saying that the water boils?"

"Water is said to boil, sir, when it is being converted from the liquid into the gaseous state—when it passes off as steam," said Fred.

"Right," said Mr. Wilson. "We know that the water itself at this point—the boiling-point—stands at 212°, but what is the temperature of the steam as it flies off?"

"The steam too is 212°, sir. Neither the steam nor the water ever exceeds that temperature, although I can't yet understand what becomes of all the heat which the water continues to receive after it has begun to boil."

"Ah, my lad," said Mr. Wilson, "I am glad to find you puzzled on this point. It is the most remarkable fact about the process of boiling, and I can see you have been thinking about it. This additional heat is not lost—it is not wasted. It is used up in the work of changing the water into steam. It is in the steam, although we cannot register its presence by the thermometer. It is hidden away, so to speak, in the steam.

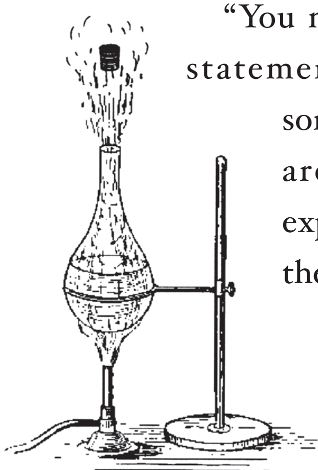
"We speak of it as latent heat; the word latent means hidden away. It is this latent heat which has overcome the natural force of cohesion in the water, and driven the molecules or particles so far apart that they form now, not a liquid, but a gas.

"If the steam were passed into a cold chamber, it would be robbed of this latent heat, and the molecules, with nothing to keep them asunder, would rush together by the force of cohesion, and form little round globules of liquid again. The steam would be condensed.

"You have seen the steam rushing from the spout of the kettle, or from the funnel of a locomotive. Why should it rush in this way? I will tell you. At the moment of the change, so great is the force of this latent heat that the water expands suddenly to 1700 times its original bulk. That is to say, a cubic foot of water raised to the boiling-point would make 1700 cubic feet of steam, nearly enough to fill a room 12 feet long, 12 wide, and 12 high.

"It is this great expansive force of steam—or, as we sometimes call it, the elastic force of steam—which makes it so useful as a mode of motion.

"Suppose we have a little experiment now. I will half fill this test-tube with water, cork it with a cork that fits it rather loosely, and place it over the flame of the Bunsen burner to boil. Presently, as the water boils, the cork flies out with a sudden pop, and steam may be seen issuing from the tube. Either the cork must be forced out, or the sudden expansion will shatter the tube. The steam will, by its expansive power, force its way out in some direction. There is practically no limit to its expansive force, except the strength of the vessel which holds it.

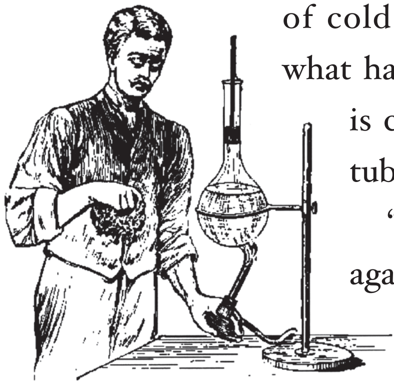


"You may form some idea of what this statement means when I tell you that sometimes the strongest iron boilers are shattered into pieces by the expansive force of the steam within them.

"I think," continued Mr. Wilson, "you will now be able to grasp the meaning of another very interesting experiment.

"I have here a flask with a long neck, the same size throughout; I will pot some water in it. This piston fits the tube, so as to be capable of moving freely up and down in it, but at the same time it is air-tight. We will fix the flask over the flame of the Bunsen burner, and leave the water to boil. Now watch the result. As the water boils, the expansive power of the steam will force the piston up the tube.

"The very moment this happens I shall remove the lamp with one hand, and with the other squeeze a sponge



of cold water over the flask. Note what happens. Immediately the flask is cooled, the piston falls in the tube.

"If we repeat this again and again, the result will be the same. The piston will rise as the water boils, and fall when the flask is cooled. Why is this?"

"The piston rises because the expansive force of the steam is sufficient to overcome the pressure of the atmosphere on its upper surface.

"But let us see what effect the cooling process has on the steam in the flask. The cooling condenses the steam into drops of water. The water does not occupy so great a space as the steam, and consequently a vacuum is formed.

"The pressure of the air from the outside then reasserts itself to restore the balance and so forces the piston down once more."

Lesson 31

Coverings of Mammals

Man is the only mammal, with the exception of those belonging to the whale family, whose skin is naked—that is, unprovided with a natural covering. This does not show that other animals require a warm covering more than man. It shows man has used superior intelligence. He is able to clothe himself, and to vary his clothing to suit the variations of climate.

In the lower animals Nature does it all. Every creature is provided with a covering of some sort, to suit the conditions under which it is intended to live. Nature, too, provides for her creatures a change of clothing to suit the returning seasons. You must have noticed the difference in the thickness of the cat's coat in summer and winter. In the hot weather much of the coat becomes loose and is shed, leaving the rest thinner in consequence, but before the winter returns there is a new growth from below as thick as ever.

You cannot take the cat or a rabbit in your arms in the summer time without finding your clothes covered with loose hairs. This is not so in the winter.

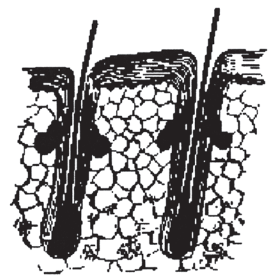
The whale family have already been alluded to as exceptions to other mammals in this respect. These creatures have a naked skin, but beneath the skin is an undercoat, so to speak, of solid blubber or fat. This fat wraps the animal at all points like a thick blanket, and he does not feel the icy cold of the polar seas in which he lives.

We have only to think of the great bulky body that has to be propelled through the water, and the wonderful adaptation of such a covering will be at once seen. The smooth, slippery skin glides easily along, and, in fact, assists locomotion, where a thick outer woolly coat would be an impediment. While providing in this way, however, for its easy movement in the element in which it lives. Nature has not been unmindful of its needs in other directions. A thick woolly overcoat was out of the question; therefore the under-jacket of fat was provided, so that the creature might not be left unprotected against the cold in those icy seas.

Land mammals have various coverings of hair, fur, or wool, but all these are in reality the same substance, for fur and wool are only hair somewhat modified.

Let us examine the structure of a hair. Each hair consists of a root, a shaft, and a point. The root is bulbous in form, and is embedded in the dermis, or true skin, where it is nourished with blood from numerous tiny blood-vessels. The little pit or hollow which holds the root of the hair is provided with a delicate lining called the root-sheath. This sheath closely envelops the bulb, and when a hair is pulled out by the root it tears away the sheath with it.

The shaft or stem of the hair consists of a long conical fibre, and, if examined by means of the microscope, is seen to be made up of an outer layer of scales, which appear to overlap each other like the scales of a fish or a snake. Deeply embedded in the dermis, and opening by the side of each hair, is a little gland, which has the power of separating from the blood a fatty or oily fluid to serve the purpose of a natural hair-oil, in keeping the hair moist and supple. These are known as the sebaceous or fat glands. If we place the hand on the woolly coat of a sheep, we find that it is greasy or oily to the touch. This is due to the oil sent out over the wool from the sebaceous glands, which are thickly spread in the skin of the animal.



Let us now look at the hairy coverings of animals from an economic point of view—that is, having regard to their usefulness to man.

The hair of animals does not enter largely into the manufacture of clothing fabrics. We import, however, for this purpose, goat's hair from Turkey and South Africa, and the hair-wool from the alpaca and llama of South America.

The hair of all our domestic animals, too, is turned to account in many ways; but perhaps none is so useful as the long hair of the tail and mane of the horse.

The best of this hair is spun into a coarse thread, and woven into a rough kind of cloth much used in the arts and manufactures.

Another kind of hair-cloth, used for seating chairs and sofas, is made of the same material, but for this the hairs are not twisted, and they run in one direction only of the fabric, the cross threads being strong flax or hempen yarn.

Some of the best tail-hairs are used in making violin bows and fishing lines, and also for sieves.

The short hair, which is not available for any of these purposes, is used for stuffing chairs, sofas, and mattresses.

The springy, elastic properties of the hair admirably adapt it for making a comfortable seat. In preparing it for this purpose, the hair is first spun into a thick rope, and these ropes are then plaited and twisted very tightly, one in the other. In that state they are put into a slow oven and gently heated. This treatment has the same effect as the heated curling-tongs of the hairdresser. It enables the hair to keep the curl that the twisting has given it. The curly character of the hair adds to its elasticity, and therefore to its suitability for stuffing purposes.

Even the short hair which is removed from the skin of the horse and ox in the process of leather-making is turned to good account. The builder mixes it with his mortar for ceilings and all sorts of plaster work. The hair holds the mortar together, and helps to bind it to the laths which support it.

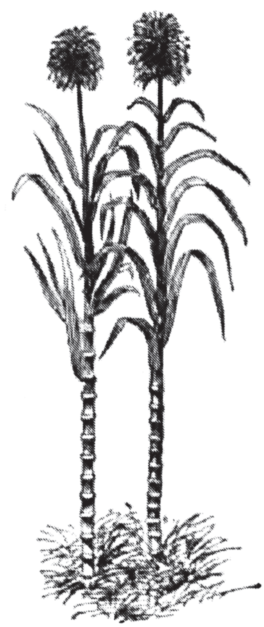
Lesson 32

Vegetable Secretions—Sugar

It will be readily understood, from the rapid growth they make, that plants are, as a rule, gross feeders. Yet each plant takes up from the soil only that which is required for its own special needs—nothing more. From this earth-food it elaborates, by means of its leaves, its own special secretion. Hence it is that the sap of the one plant becomes a sweet, sugary juice; while that of another yields camphor; a third gives resin and turpentine; others india-rubber and gutta-percha. One of our recent lessons introduced a number of plants whose sap is elaborated into oily matter, and stored away in their fruit or seeds. We shall now proceed to study these vegetable secretions briefly, commencing with sugar, as perhaps the most important of all.

All the varieties of sugar known in commerce are called by one common name—cane-sugars. They do not all come from the sugar-cane, although that plant is still one of the chief sources of our sugar supply. Besides that obtained from the sugar-cane, there are other preparations known as beetroot sugar, and maple sugar, maize, and palm sugar. The common name, cane-sugar, is given to all of them, because in their properties they all resemble the sugar of the sugar-cane.

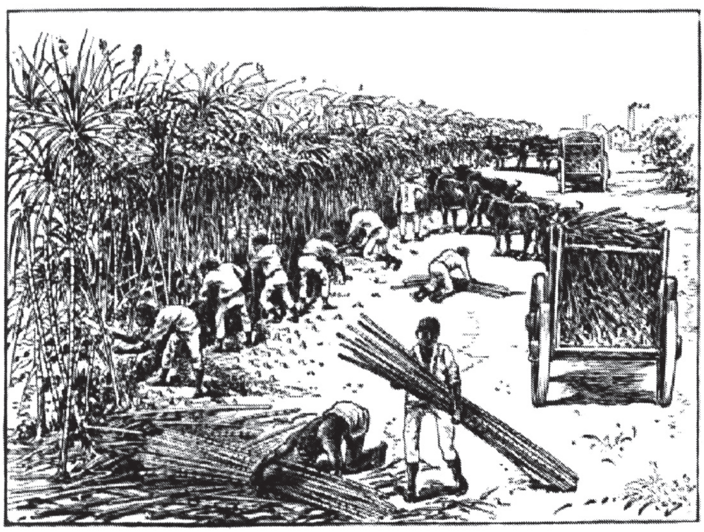
There are many varieties of the sugar-cane under cultivation in different parts of the world, each being peculiarly adapted to its own locality, climate, and soil. Originally a native of the Old World, it was introduced into America by the Spaniards in 1520. It is now extensively grown in the United States, Brazil, and the West Indies, as well as in India, and Mauritius, and the East Indies.



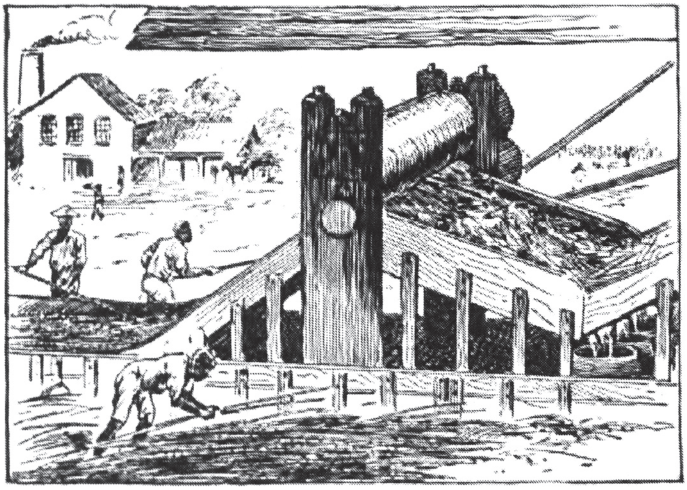
The plant itself is one of the grass family, and its cultivation is simple. The young plants are raised from cuttings, and not from seed, as the sugar-cane is rarely allowed to mature its flower, and so ripen its seeds. The plants take from twelve to fifteen months to reach their full growth. The stem is then a thick, stout, jointed cane, from 8 to 12 (and even in some varieties, 20) feet in height. The stems of most grasses are hollow; the sugar-cane is a solid stem. The juice, which contains about 15 or 20 percent sugar, resides in the central pith of the stem.

As the canes ripen, the flowers begin to appear, and it is then time to cut them down, A sugar plantation, towards harvest time, with its yellow, striped, or purple-tinted stems, surmounted by immense bunches of feathery lilac and rose-colored flowers, presents a very beautiful and attractive sight, especially to one who looks on it for the first time.

The canes usually ripen about March or April, and the sugar harvest then begins. Men pass along between the rows and cut them down with large knives. Each cane is then divided into short lengths, the natural joints of the stem being preserved as cuttings for future planting. The



divided canes are next carted to the sugar-mill, where the juice is extracted by pressing them between heavy iron rollers. It is estimated that the average yield of the trimmed canes is from one to three tons per acre, and it takes the juice of twelve or fourteen tons of canes to produce a hogshead of sugar. The sugar harvest is the great season of the year for the people of those countries



where the canes grow. To them, and especially during harvest time, the sugar-cane becomes a staple article of food. Men, women, and children suck and chew the ripe stalk; many Black people practically live on it, and get fat, during this time.

The raw juice contains not only sugar, but a considerable amount of gluten. Hence it is in all respects a true food, capable of supporting life and animal vigor.

This gluten has to be removed from the juice, or it would act as a natural ferment, and turn the sugar into an acid. This is done by adding a certain quantity of quicklime to the juice; the lime combines with the gluten, and carries it to the bottom of the vessel. The juice, thus clarified with the aid of the lime, is first filtered, and then boiled rapidly down in large copper boilers. The impurities rise as a thick scum to the top during the boiling, and must be carefully skimmed off from time to time. Indeed, the whole process of boiling is an important one, and requires great care to prevent the juice from burning or blackening. The crushed canes themselves provide the fuel for this part of the work.

The water is gradually evaporated, while at the same time the juice thickens into a syrup. When it is sufficiently thick, this syrup is run off into wooden vessels to cool. As it cools it separates into crystals, and in this state it is put into casks, perforated with holes, to drain. The liquid portion of it, that refuses to crystallize, drains off into vessels placed below, and is known as molasses or treacle.

Beetroot sugar is obtained from a variety of the beet plant known as the sugar-beet, which contains as much as one-eighth part of its weight of sugar. The sweet juice is easily extracted from the beetroot, and when boiled and refined it has all the properties of cane-sugar.

Beetroot is extensively grown for its sugar in France, Belgium, Russia, Germany, and other countries of Europe. In fact, beetroot sugar is commonly known as European sugar. In each of these countries the manufacture of beet-sugar forms a most important industry.

Maple sugar, or, as it is sometimes called, North American sugar, is obtained from the sap of the sugar-maple, a large, handsome tree, which often attains the height of 60 or 80 feet. The tree is a native of Canada and some parts of the United States, especially of those regions where extensive natural forests of maples flourish.

The sap of the tree is very sweet; it contains the same kind of sugar as the sugar-cane. The sap begins to flow in February, and, when March comes, parties of sugar-makers start for the forest. They make incisions into the trunks of the trees, and place small buckets below to catch the sap as it flows. To assist the flow of the sap into the buckets, they usually fit into the holes little pipes made of elder shoots. The sap is collected twice a day, and boiled on the spot in large boilers. Two or three men can usually make, in the season (March and April), as much as 4000 or 5000 lbs. of sugar.

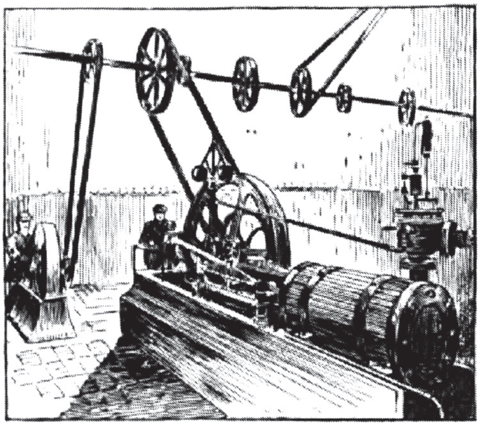
The people of Central America make another variety of sugar from the green stalks of corn.

These, if boiled, yield a sugar having all the characteristics of cane-sugar. It is known as maize sugar, or Mexican sugar.

Lesson 33

The Steam-Engine

"Our lesson this morning," said Mr. Wilson, "is to teach us the principle of the steam-engine, but before proceeding to examine the steam-engine itself, I must



direct your thoughts back to the piston and the long-necked flask of our last experiment.

"Why did the piston rise in the neck of the flask?"

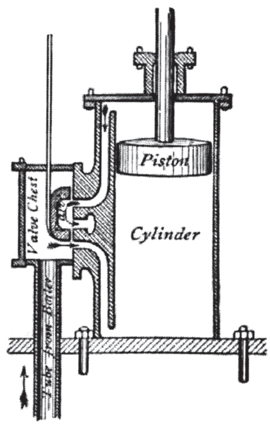
"As the water boiled in the flask, some of it was converted into steam, sir," said Fred. "It was the expansive force of the steam, at the moment of the change, that sent the piston up."

"Why did the piston not fly out of the neck altogether?"

"It would have done so, sir, but you cooled the flask."

"What was the result of this cooling?"

"It condensed the steam into water, and, as the water did not occupy so much apace as the steam from which it was formed, a vacuum was left in the flask, and the piston moved downwards again owing to the pressure of the air outside."



"You have followed the experiment well, my lad," said Mr. Wilson. "We shall have no difficulty now in proceeding to examine the working of the steam-engine, for we shall find that there is a remarkable resemblance in principle between it and our flask and piston.

"The steam-engine consists essentially of a cylinder, fitted with an air-tight piston, which works by the elastic force of the steam, up and down, or backwards and forwards, as the case may be. Here we have the principle of the flask and piston, except that in the steam-engine both the up movement and the down are brought about directly by the steam. The piston, you remember, moves downwards in the neck of the flask, not by the action of the steam at all, but by the pressure of the outer air after that steam has been condensed.

"Now let us find out how, in the steam-engine, both movements are brought about by the steam itself.

"The water is boiled in a great boiler, and the steam is led, by means of a pipe, from the boiler into the cylinder. But before it can reach the cylinder, it is first admitted into a small box-like chamber, called the valve-chest.

"In one side of this valve-chest are three holes, two of them communicating respectively with the upper and lower parts of the cylinder. The third, which is exactly midway between the two others, is in communication with a chamber called the condenser.

"In front of the three apertures is a smooth, flat plate of steel, capable of moving up and down. It is known as the slide-valve, and is just long enough to cover the center hole and one of the others. When, therefore, one of these is closed the other is always open.

"If you look at this diagram of the engine, you will see that, as there are two apertures leading to the cylinder—one above, the other below, the piston—it would not do to have both open at once. If that were the case, the steam would force its way through both; there would be equal pressure on either side of the piston, and of course no movement could take place.

"Still keeping the diagram before us, let us imagine the slide-valve to be in position to cover, and so close, the lower of the two apertures leading to the cylinder. The upper one is open, and allows the steam to enter the cylinder above the piston. The elastic force of this steam presses upon the piston and moves it downwards.

"In the meantime the slide-valve has moved up, and is now closing the upper aperture, leaving the lower one free for the steam to enter.

"When, therefore, the steam enters by the lower aperture, and by its elastic force presses upon the piston, it tends to force it upward.

"But there is already steam in the upper part of the cylinder above the piston. How can the piston move upwards in opposition to this? The fact is this steam in the upper part of the cylinder has already done its work in forcing the piston down; it is no longer wanted. It escapes through the centre of the three apertures, from the cylinder, into the condenser, at the very moment when that which enters through the lower aperture is exerting upward pressure on the piston. The piston, finding no opposition from above, rises by the elastic force of the steam in the lower part of the cylinder.

"The rising of the piston brings the slide-valve down again; the same movements are repeated, and so on perpetually. This is a description of a very simple and somewhat primitive steam-engine, but whatever work an engine is meant to do, it is all accomplished by the two simple backward and forward movements of the piston in the cylinder, and they are both brought about by the elastic force of steam."

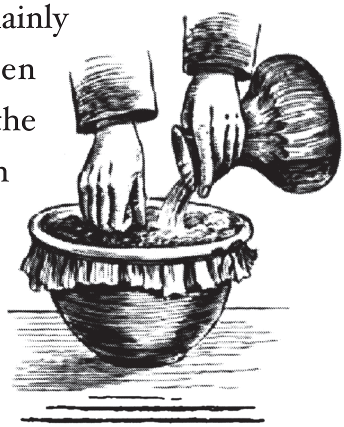
Lesson 34

Vegetable Foods

We use many varieties of vegetable substances as food. The principal are the grains—wheats, oats, barley, rice, and corn; the preparations known as sago, arrowroot, and tapioca; the seeds of beans and peas; fresh vegetables, such as are sold by the green-grocer; fruits, and sugar in various forms.

First among the vegetable foods stand those which yield flour or meal. We call them farinaceous foods, from farina, the Latin name for flour. These foods shall form the subject of our first inquiries.

"Now, Fred," said Mr. Wilson, "you pleased me the other day very much by showing me that you had not forgotten the way to separate the starch grains from flour. You shall now come to the front and do it for me, as you have seen me do it in our earlier lessons. That will do; the water in the basin is white and milky with the starch. Now open the bag, and let us see what we have left behind in it. There is a white, sticky substance something like bird-lime left in the bag. We call it gluten. This gluten is very much the same kind of substance as the albumen, myosin, gelatine, and casein of animal food. It is a tissue-forming substance.



"The flour, you see, consists mainly of these two constituents, gluten and starch. The starch is now in the water; the gluten in the muslin bag.

"Here are some grains of wheat. Let us cut them open and examine them. The middle of the grain, you observe, is white, and this white part is enclosed within an outer covering or skin. The white inner substance is starch; it is the outer covering of the grain which contains the tissue-forming gluten. The gluten is always found in this outer part of the grain, just beneath the skin.

"The miller, after grinding the grain, passes the meal through a series of sieves. The first sieve separates the larger particles from the rest. These are really portions of this very outside skin, and are sold as bran. The second sifting separates some finer portions of the same skin, which are known as middling. The brown meal, which remains after this sifting, is really the best and most nourishing of all, for it contains all the gluten. It makes good, wholesome, brown bread.

"Many people, however, prefer white bread; hence the meal is sifted again and again, the result being that much of the gluten is separated from it, and the flour is white only because it consists very largely of starch.

"You will now understand that although the miller may call this best wheaten flour and best whites, it is far from being equal in nutritive value to the browner, unsifted, whole-meal flour.

"This pure, unsifted whole-meal of wheat contains about 12 per cent of gluten, 60 per cent of starch, and 14 per cent of water. The remainder is made up of fat, sugar, and mineral matter. The proportion of gluten in the flour is lower after each sifting, so that fine wheaten flour does not contain usually more than 10 per cent.

"The different qualities of wheaten flour in the market are known under various names. I have already told you that that called the best makes the whitest bread; but is it really the best?

"Wheaten flour is almost universally used in England, but in Scotland it gives place to oatmeal—that is, the meal or flour of ground oats. Oatmeal is even richer that wheaten flour in gluten, for it contains no less than 18 per cent of this tissue-forming substance.

"Oatmeal will not make up into light spongy bread, such as we make with wheaten flour. Hence the Scotch people eat it in the form of porridge and oat cake, which form their principal food, and a very valuable and wholesome food too. In our land almost the only use we make of oatmeal is in a breakfast porridge. The grain itself is largely used for feeding cattle and horses.

"Nearly all the barley grown with us is used in the preparation of sugar for malt. Barley-meal, although much used for feeding cattle and pigs, is not made into bread. In a few places in the north of England, however, it is mixed with equal quantities of wheaten flour, and made into cakes called bannocks.

"We usually see it as pearl barley and Scotch barley, and in this form it is used for making soups and broths. The reason why barley-flour is not used for bread is that the meal is coarse in flavor and color, and bread made from it, instead of being light and spongy, is heavy and close. Otherwise it contains about the same proportion of tissue-forming gluten as wheaten flour. The same remarks apply equally to rye-flour, which is used as a bread-stuff in this country, in making the rye-loaf and Boston brown bread.

Lesson 35

Vegetable Secretions—India-rubber and Gutta-Percha

Both these useful substances are vegetable secretions; they are in each case the solidified sap of the plant.

India-rubber is obtained from a variety of trees, which grow in Central and South America and the East Indies. The best rubber and the largest quantities of the article come from Brazil, and are furnished by the great forests which cover the basin of the Amazons. The East Indian rubber is obtained from a kind of fig-tree, which grows to an enormous size.

The mode of collecting the juice is almost identical everywhere. The trees are tapped by cutting a number of slanting holes in the bark with an axe, and tin cups are fixed, by means of clay, below the incisions, to catch the juice as it flows. From time to time, daring the day, the collector goes round from tree to tree, and empties the contents of the little cups into a pail. As he usually works about a hundred trees at one collection, he is kept pretty busy. The juice as it comes from the tree is a yellowish-white liquid, having something of the consistency of cream. It dries when it is spread out in thin layers and exposed to the sun.

The East Indian rubber is always sun-dried, and in drying turns nearly pure white.

The milky juice is dried in a very peculiar way. A number of variously-shaped molds made of clay are dipped into the vessel containing it, and, of course, when they are taken out, some of the juice adheres to the mold. This is laid in the sun, and as it dries it forms a thin coat or layer over the mold. The process is repeated again and again. Each dipping and drying adds to the thickness of the deposit, until the coat is thick enough, when the mold is broken up, and the solid rubber is left.

The South American rubber is not sun-dried. The collector, in this case, dips his clay mold into the juice, and then holds it over the smoke of a wood fire for about half a minute. This quickly changes the milky juice into a thin layer of india-rubber, and he continues the dipping and smoking process until his deposit is thick enough on the mold. Then the mold is broken up, and the rubber removed, and set in the sun to further dry and harden. This smoker-drying changes the color from a creamy white to almost black.

India-rubber is now put to an immense variety of uses, but before it is available for any of these purposes it has to undergo a process of mastication to remove dirt, and all solid impurities. It is first softened in boiling water, and in that state cut up into small pieces with sharp knives. These pieces are rolled by wooden rollers, to crush out all foreign substances, which are then washed away, and the purified rubber is kneaded, or masticated, into a lump while it is still warm and soft.

Gutta-percha is prepared from the milky juice of a tree which grows in the forests of the Malay Peninsula and the islands near it. We have retained the native name, which is derived from gutta, meaning gum, and percha, the name of the tree. Gutta-percha simply means the gum of the percha-tree. The tree is very large; its trunk often measures 3 feet in diameter, but the wood is of a loose, spongy, fibrous nature and, of course, valueless as timber.

The sap begins to flow immediately after the rainy season; this is the time to commence operations. The Malays have different modes of collecting the juice. Sometimes they merely bore a hole in the bark, and catch the sap in gourds as it exudes. More frequently, however, they cut the trees down, strip off the bark, piece by piece, and collect the sap as it flows. It dries and hardens rapidly into a solid lump on exposure to the air. Collected in this way, the gutta-percha is discolored with dirt and impurities, which have to be removed before it can be of use. This is done by first heating the substance in boiling water, till it is quite soft, and then tearing it to shreds by machinery. In this way all the impurities sink to the bottom of the water, and are washed away, leaving the shreds of soft gutta pure. All that remains is to knead them up, while they are still soft and pliable, into a solid lump.

Lesson 36

Radiation of Heat

When next the boys assembled for their lesson, Mr. Wilson began by calling upon them to describe the mode in which heat passes through solids and liquids respectively.

"I want you to think once more," said he, "of the poker in the fire, and tell me exactly by what means the handle becomes heated, although it is some distance from the fire."

"The heat travels through the poker, and through all solid bodies, by conduction, sir," said Fred. "One molecule of matter receives the heat, and passes it on to the next."

"Right. Now tell me what takes place when a liquid is heated?"

"In liquids the heat is carried, or conveyed, by the upward flow of the heated molecules themselves, which are not fixed and stationary as they are in solids. We call this convection."

"Exactly," replied Mr. Wilson, "and now that we are sure of our ground as to solids and liquids, we will turn our attention to the passage of heat through the air, which, you know, is a gas.

"One of you shall come to the front, and stand before the fire. You at once feel a sensation of warmth. The heat, of course, comes from the fire. We must find out how it travels through the air to your body.

"First, does it travel through the air by conduction? We will see. While you stand in the same position, I will hold this drawing-board between you and the fire. What do you observe?"

"I no longer feel any heat from the fire, sir."

"No, you get no heat now. But if the fire sent out its heat through the air by conduction, all the particles of the air would be heated in succession, and you would still feel the heat, in spite of the board.

"If we stood in the open air exposed to the most brilliant summer sun, we should experience exactly the same thing. Immediately the screen was put between us and the sun, the sensation of heat would disappear.

"Hence we learn that, although heat does pass through the air from one body to another, it does not travel by conduction, nor does it heat, to any extent, the air through which it passes. Air is a non-conductor of heat.

"Heat, as you know, passes from the sun to the earth, but balloonists experience severe cold in the higher regions of the atmosphere, although they are then so much nearer the sun. The sun's heat travels through the atmosphere without raising its temperature to any extent.

"Lower down, at the surface of the earth, the air is more or less warmed by the heat which is given out from the warm earth. We shall inquire further into this presently; we are now concerned only with the passage of heat through the air.

"Suppose we have an experiment. I have got something in the fire; it is a large iron ball. I daresay it is red-hot by this time. I want a dozen of you to come to the front, and stand in a circle in the body of the room. Now I will

take the ball out of the fire, and hang it by its chain in the middle of the circle. Of course, each of you will tell me that he feels the glow of heat from the red-hot ball. Now sit on the floor below the ball, and you will still feel the heat, and so you would if I could place you above it.

"You may take your places again; I have something else to show you now. Here is a large ball of wool, and you can see that I have stuck it full of pins, all pointing towards its center.

"I want you to imagine that, from every part of the surface of the red-hot ball, straight lines of heat are sent out through the air, much in the same way as the pins appear in the surface of the ball of wool. This is the universal way in which heat travels through the air from one body to another. We call these straight lines rays of heat. The drawing- board screen proved that the rays travel only in straight lines, for when it was placed in front of the heated body, it intercepted the rays, and no heat was felt. Heat, then, passes through the air in straight lines, which we call rays of heat, and we say that it travels by radiation. The body itself which sends out the heat we call a radiator.

"Just one more thought before we leave the subject. You stood in front of the fire just now and became warm; we naturally stand before the fire to warm ourselves. We are warmed by taking in the heat which is radiated from the fire. We might stand there too long, or get too close to the fire, and we should be glad to move away. We should be getting too hot; we should burn ourselves if we remained there.

"Other bodies placed in front of the fire would be warmed too by taking in this radiated heat. We say they absorb the heat, and we call the bodies themselves absorbers of heat.

"So then we see that one body radiates heat, and another absorbs it, and the double process would go on till both bodies were at the same temperature.

"I have a pretty experiment to prove this, but as it would take up too much time during the lesson, I will show it to you after school. I shall simply hang up our red-hot ball again, and place half a dozen thermometers in a circle round it. You will have nothing to do but watch what happens. You will see that, as the ball cools by radiating its heat, the mercury in each of the thermometers will rise by absorbing it, and after a time the ball and the thermometers will show the same temperature."

Lesson 37

More about the Farinaceous Foods

"You all know what this is," began Mr. Wilson, as he held the object before the boys at the opening of the next lesson.

"Yes, sir; it is a cob, or ear, of corn."

"Right; so it is," he replied. "Now I am going to start this morning with corn, as another of the farinaceous foods. But first of all, tell me why the name farinaceous is given to these foods."

"Farinaceous comes from the Latin word farina, sir, which means flour," said Will. "All these foods are used in the form of fine meal or flour."

"Quite right," replied Mr. Wilson. "Now let us pass on to consider this one—corn.

"Corn is not grown in England—their summers are not long enough to ripen the grain. It is, however, grown largely in many parts of the world, and is an important article of food. Corn, like the other grains, consists mostly of starch. It contains only about 9 percent gluten, while wheat contains from 10 to 12, and oatmeal 16 percent. On the other hand, corn-meal is richer in fatty or oily matter than any of the other grains. This renders it easily digestible.

"In this country we not only grind the ripened corn into flour, and use it as we do other flours, but we cut the green cob before it is ripe and boil it for the table. In this state the corn upon the cob makes a most delicious and nutritive vegetable.

"Because of its deficiency in gluten, it is customary to mix this corn-meal with an equal quantity of wheaten flour for making bread.

"We also use corn-meal for porridge, eating it with milk and sugar. It is commonly known as stirabout, mush, hasty pudding.

"Nearly all the corn that finds its way to shipment abroad is in the form of corn-starch. It consists entirely of the starchy portion of the grain, and is used for making milk-puddings, blanc-manges, etc.

"To prepare this corn-starch, the kernels are first well soaked in water till they swell up and become rather soft. They are then crushed between rollers in a tank of water. As the crushing process goes on, the water becomes white and milky-looking. Don't forget the flour in the muslin bag, and you will know at once what goes on in that tank.

"When the whole of the grain is crushed fine, the milky-looking liquid in the tank is made to pass through sieves, which hold back the pieces of husk and skin.

"You remember, of course, that in all the grains the gluten is invariably found adhering closely to the outer skin. When therefore these pieces of the skin are held back in the sieve, all the gluten is held back at the same time. The milky-looking liquid which passes through contains only the starch of the grain. It is made to flow into tanks, and there left to stand for a time, till all the starch has sunk to the bottom. The clear water is then drained off, and the starch is removed and dried over a gentle heat. This starch is the corn-starch, which we use with milk and eggs to make our puddings and custards.

"Rice is another important farinaceous food. It forms the staple food of the people of the East. Rice is to them what bread is to us. It contains, however, a very small amount of tissue-forming matter—in fact, the least of all the corn-grains—not more than 6 or 7 per cent; while 75 per cent of the grain is starch.

"It is not, therefore, of much nutritive value unless used with some other food rich in flesh-forming and fatty matter. We use rice both whole and in the form of meal, but we always use it with such things as eggs and milk, or in soups.

"Next among the farinaceous foods come sago, arrowroot, and tapioca, which are pure starches, and contain no gluten. These foods differ from the others of the class in that they are obtained not from the grain, but from the substance of the stems of the plants. It is no part of our present business to dwell upon the mode of preparation in either case. That was done in one of our earlier lessons. We have now only to arrange them in our list of starch-foods. Considered as food, they have little value, unless used with some tissue-forming and fatty substances; they are quite incapable of supporting life alone."

Lesson 38

Vegetable Secretions—Camphor and Gums

Among the useful vegetable secretions, camphor undoubtedly holds an important position. Originally the juice of the plant which produces it, this substance, like others we have already met with, assumes the solid form during its preparation for use.

Camphor, as we see it, is a white, hard, tough, crystalline substance, with a very powerful aromatic odor, and a bitter, unpleasant taste. It is so volatile that a piece left exposed to the air would in time disappear altogether by evaporation. Very slight heat is required to change it from the solid form, but it can then scarcely be said to become a liquid, because it passes off at once as vapor.

It dissolves very slowly in water, so slowly that we might almost describe it as insoluble, were it not that it imparts some of its odor and taste to the water. It dissolves rapidly in alcohol, forming camphorated spirits or spirits of camphor.

Insects of all kinds dislike the strong, pungent smell of camphor. Little saucers of this substance are always kept, therefore, in cabinets of natural history specimens, to keep away insects. It is a good protection against moths, to put some camphor in the drawers where furs, blankets, and woollen clothes of all kinds are kept.

Camphor is used as a medicine, but it is a fallacy to think that it has the power of warding off infection. It is even a bad thing to wear camphor about the person, as it is weakening and lowering, both to the muscular and the nervous system.

A few drops of camphorated spirits taken on a lump of sugar, as soon as a chill is felt, will often save a person from catching cold. Camphor-ball, or camphor-ice, as it is sometimes called, is invaluable for chapped hands and faces, and also for burns and chilblains.

Camphor is obtained from a plant belonging to the laurel family. The camphor laurel grows chiefly in China and Japan, and there it is as large as an English oak. It has lately been introduced into several of the warmer countries of the world.

It is obtained in a curious way. The valuable secretion is stored in every part of the tree—root, stem, branches, and leaves. When, therefore, the tree is fully matured, it is uprooted, and every part of it is chopped up into small pieces.

These pieces are then put into iron retorts, with wooden lids or coverings perforated with holes, and above the lids are placed large dome-shaped hoods made of earthenware. The hood is filled with loose twigs, hay, or straw, and after all the crevices have been stopped, the retort is placed over a slow fire.

The heat causes the volatile camphor to rise in vapor, and as soon as the vapor touches the cool, rough surface of the hay and twigs, it condenses on them in flaky crystals, and is afterwards scraped off.

It is now a dirty brown color, and is known as crude camphor. It is purified by a second distilling process, somewhat similar to the first, and when it is again collected, it is the hard, white, crystalline substance which is familiar to us all.

Gums are another class of vegetable secretions, possessing their own special characteristics distinct from all others. Gum-like exudations may frequently be seen oozing through the cracks in the bark of trees, especially of many of our fruit trees. The juice hardens on exposure to the air, and then has the appearance of little, rounded, semi-transparent, glistening, solid drops. It is perfectly odorless, and has an insipid taste, but it dissolves in the mouth, and becomes very glutinous and sticky. This is the nature of all gums.

The most valuable of these secretions is Gum Arabic, which is obtained from a tree of the acacia tribe, that grows chiefly in Arabia, hence the name. It also grows in the East Indies, Abyssinia, and Egypt. It is an exudation from the stem, and hardens on exposure to the air.

It is very soluble in water, forming, when fully dissolved, a thick, glutinous solution, with strongly adhesive properties. It is on account of its adhesive and stiffening properties that this gum is so extensively used in the arts and manufactures. It makes a valuable cement for attaching labels to glass and other objects. It is largely used also in calico-printing, and in the manufacture of crape and other fabrics.

Gum Senegal is a similar though inferior secretion, and is much used in calico-printing.

The so-called gum, used for postage stamps, envelopes, and labels, as you already know, is not actually a gum, but is made from baked starch. Its proper name is dextrine or starch gum.

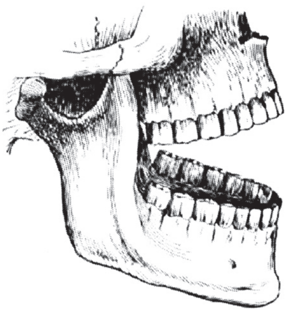
Lesson 39

Teeth

Our very earliest lessons led us to pay special attention to the teeth of each animal that passed under our notice, because we were taught to regard the teeth as a sure indication of the food, life, and habits of the individual. The lessons on digestion made the reason for this clearer to us, by showing the important work which falls to the lot of the teeth in the proper mastication of the food.

We are now in a position to study the teeth a little more closely, and as we shall best understand those of the various classes of mammals by referring to our own, we will confine ourselves today to an examination of the teeth of man.

You all know that your own teeth are of different shapes and sizes. This is not an accident, for each kind of tooth was designed for a special purpose.



Let us commence with the long, broad, flat teeth in front of both the upper and the lower jaw. There are four of them in each jaw, and they have sharp, cutting edges. We use these teeth for biting through our food. It is with these teeth that a boy takes a bite out of an apple or a slice of bread and butter.

In our earlier lessons we were content to call these the chisel-teeth, because their sharp, cutting edges bear some kind of resemblance to a carpenter's chisel. We must now learn to recognise them by their scientific name—incisors—a word which means simply cutting-teeth.

Next to the incisors, on either side, and in both jaws, is a long, rounded, conical tooth. There are thus four of them altogether. Some of you may keep a dog at home. If so, look in his mouth, and you will find that he has four teeth like these, but they are very large, sharp, and prominent. We speak of these four conical teeth of ours as canines, or dog-teeth, because they are like those of the dog. Canis is the Latin name for dog.

Behind the canines, in each jaw, and on either side, are a number of large, square, broad-crowned teeth, which differ from both the incisors and the canines. The working surfaces of their crowns are rough and uneven, resembling in this respect the roughened millstones of a mill. Indeed, they form the mill for grinding the food; we often speak of them as the grinders. Even their scientific name—molars—points to the same thing, for the word molar comes from a Latin word signifying a mill.

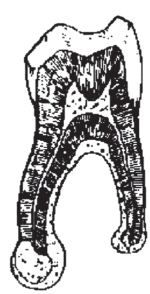
The full number of molars for an adult is twenty—that is, there are five on each side of both jaws. But boys and girls have not so many. Indeed, there was a time when we had no teeth at all; we required none, for our food consisted entirely of milk, although we ourselves cannot recollect that time.

Teeth begin to make their appearance when the infant is about six months old, and the cutting of this first set is usually completed by the end of the second year. By this time the child's digestive organs have grown strong enough to enable it to give up its milk diet for more solid food, which the teeth are now ready to masticate.

It is easy from this to see why these are called the milk-teeth. There are twenty in the complete set, viz. four incisors, two canines, and four molars in each jaw—that is to say, two incisors, one canine, and two molars in either half of the jaw.

These milk-teeth fall out when the child is about seven years of age, to make room for the new teeth. There are more than twenty teeth in the permanent set, as they are called.

The complete permanent set contains thirty-two; but the last of the molars do not make their appearance till adult age.



It will assist us in the proper understanding of what is to follow, if we now examine briefly the structure of a tooth. The bulk of the substance of all teeth is a hard, bony matter, called dentine, but the whole of that part of the tooth which appears above the gum is coated with an exceedingly hard substance, known as enamel.

The tooth is lodged in the gum by one or more roots or fangs, and the blood-vessels for nourishing it, as well as certain nerves, enter the tooth at the extremity of the fang. There are no nerves or blood-vessels in the hard enamel coating on the outside.

Good teeth are such an important factor, not only as regards our personal appearance, but also in our general health and well-being, that it behoves us to take every care in preserving them. It should not be forgotten that, hard as this enamel is, it is extremely brittle. It will not stand too much rough usage, and when once it is cracked or broken, it lays bare the softer dentine underneath, which soon begins to decay, and all the pleasure of life is destroyed by the racking pains of toothache. Very hot, as well as very cold liquids should be avoided, as both of them have a tendency to crack the enamel. Regular use of the tooth-brush night and morning, careful avoidance of nut-cracking, too many sweets, and also of that silly practice of picking the teeth with pins and needles, will do much towards keeping them sound and healthy.

Lesson 40

Radiators and Absorbers

"I think," said Mr. Wilson, "you clearly understand what is meant by a radiator."

"Yes, sir," replied Will. "A radiator is a heated body, which cools by giving off its heat in rays."

"That's right, my lad. I have a great deal more to say on this subject, and our best course will be to commence the new lesson with a simple experiment. I have here a couple of meat tins; one, you see, is bright inside and out, the other I have coated with lamp-black on the outside. Some few minutes back I filled both tins with boiling water from the kettle. We are now going to examine them. I will plunge a thermometer into each. Now, in the first place, I filled both vessels, as I told you, with boiling water from the same kettle, and therefore the water in both was then at the same temperature. Let us see what the thermometers tell us now.

"The water in the black-coated vessel is much cooler than that in the bright one. It has, in fact, cooled nearly twice as fast."

"How have these vessels cooled?"

"They have both cooled by radiation, sir," answered

Fred. “The heat has passed through the air in rays, and I suppose the radiation has been going on more rapidly in the blackened vessel than in the bright one.”

“Yes, Fred, you are right,” replied Mr. Wilson, “and the same thing would have happened if, instead of coating the vessel with lamp-black, I had covered it with dark-colored linen, or brown paper. Dark-colored bodies, and those with rough surfaces, are the best radiators; white and polished surfaces are bad radiators.

“Before the lesson began I stood two other tins, similar to these, in front of the fire. Of course all this time the fire has been radiating heat, and the two vessels have been absorbing it. We will now take them up and examine them. We find that the black one is hotter than the bright one ; find so it would have been if, instead of the black coating, it had been covered with brown paper, or some dark-colored substance, such as the linen we just mentioned. Hence we learn that dark-colored bodies and those with rough surfaces absorb heat more quickly than white and polished surfaces, like that of the tin.

“So, then, the best radiators are the best absorbers of heat, and bad radiators are bad absorbers.

“But we have still to learn,” continued Mr. Wilson. “what has become of the heat in the one case, for they both received the same amount of heat from the fire, and yet the bright tin is not so hot now as the black one.

“The black vessel absorbed the rays of heat; the polished one would not absorb them, but sent them back. We say the rays were reflected. That is to say, bad absorbers send back, or reflect, the rays of heat, instead of taking them in.

"The knowledge of scientific facts is of little use, unless it is turned to account in some way. You will readily see now why all metal utensils, such as kettles, urns, tea and coffee pots, as well as metal dish-covers for the table, should be kept bright; and also why the engineer is careful to keep the steam-pipes of his engines well polished."

"Yes, sir," said Fred, "the bright polished surfaces are bad radiators; they will not allow the heat to pass away."

"Have you ever noticed," asked Mr. Wilson again, "that the polished fire-irons in front of the fire are often scarcely warm when the black fender is very hot? Water will boil much sooner in a kettle covered with soot than in a brightly polished one. All cooking vessels should, therefore, be black and rough on the outside in order that they may absorb heat rapidly.

"Light-colored clothing is most suitable for summer wear. In tropical countries people almost universally dress in white garments. These, being bad absorbers, throw back, or reflect, the sun's rays, which dark clothing would rapidly absorb.

"On the same principle the slated roofs of buildings may be white-washed in summer to keep the place cool.

"The gardener trains his best grape-vines and gets his earliest ripe grapes on rough dark walls. Can you think out the reason for this, Fred?"

"I suppose, sir," replied Fred, "the wall, being a good absorber, and also a good radiator of heat, takes in the sun's rays rapidly, and as rapidly radiates them back on the fruit, and so ripens it quickly."

"That's a very thoughtful answer," said Mr. Wilson.

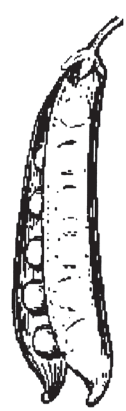
"Now let us, lastly, think of the snow and winter-time. Snow neither absorbs nor radiates heat. It protects the plants in the ground by preventing the heat from passing away by radiation, while it melts very slowly in a thaw owing to its low absorbing power."

Lesson 41

Leguminous Foods

"I have here some peas, and a few different sorts of beans," said Mr. Wilson. "We sometimes speak of these things under the common name of pulse. The Latin name for them is legumen, and this is why they are always described as leguminous foods.

"You have no doubt seen these things growing, and you know that they are the seeds of the plants which produce them. The fruit of the plant is, in every case, a pod, and these seeds are arranged in regular order in the pod. Our business now is not with the plants, but with these seeds. We want to learn something of their value as food material.



"Have you ever eaten some fresh, young, green peas? If you have, you can tell me how they tasted."

"Yes, sir," said Fred, "I have, and they always taste very sweet."

"That's quite true, Fred," replied Mr. Wilson. "Now, I have here some pea-meal. I will mix some of it into a paste with warm water, and you shall hold a little of the paste on your tongue."

Fred did as he was requested, and in a short time he was in possession of the whole secret.

"I know what you wish me to find out, sir," he said. "The paste soon began to taste sweet. That proves that there is starch in the pea-meal. The saliva from my tongue turned the starch into sugar, and it is the sweetness of the sugar that I can taste."

"Capital," said Mr. Wilson, "and now you know why the young green peas always taste sweet. Peas and beans of all kinds, like every other vegetable food, contain starch. They are less valuable, however, for the starch which they contain than for another constituent, of which we shall speak next. Indeed they contain less starch in proportion than any of the farinaceous foods of our recent lessons.

"They all contain nearly a quarter of their weight (from 23 to 25 percent) of a valuable tissue-forming substance. That is, they contain much more tissue-forming matter than either wheaten flour, oatmeal, or butcher's meat.

"You remember I told you that the Latin name for pulse of all kinds is legumen. This name is now used by scientific men to describe, not the pulse itself, but the tissue-forming matter which it contains.

"The legumin, when separated out from the starch and other matters of the seeds, is found to be very similar in character to the casein of cheese. In fact, the Chinese actually make a kind of cheese from the legumin of peas.

"Beans and peas, in the dried state, are not eaten very largely, in spite of their valuable tissue-forming legumin, for they are somewhat difficult to digest. Both, however, in their growing state as green vegetables, are favorites with most people, and are regarded generally as luxuries of the table.

"The variety of beans, known as broad or great beans, are often used in their dried state for feeding horses. They are then commonly called horse-beans.

"We use the green pods as well as the seeds of the scarlet-runner and French bean, but the seeds only of the broad bean and pea are cooked.

"When used in the dried state, the only things necessary to make peas and beans of all sorts excellent food are good soaking in cold water and careful cooking. A good plan is to soak them in cold water for one day, and then let them stand for a couple of days in their wet state. Under these conditions, the seeds will commence to grow, and as soon as this happens, the softened starch will be converted into sugar. They then require careful boiling for two or three hours. This treatment will render them perfectly digestible for all except the most delicate persons.

"It is in the highest degree important to remember that, provided they can be rendered easy of digestion, peas and beans are a most economical food, because they contain such a large proportion of the tissue-forming legumin.

"One of the most valuable of these leguminous foods in the dried state is the haricot bean. This is in reality the dried seed of a small white variety of the French bean."

Lesson 42

How Heat Affects the Absorption of Vapor by the Air

"Our early lessons made us familiar with the fact that the air always contains moisture or vapor," said Mr. Wilson, "although the quantity varies from time to time. We are now in a position to inquire into the reason of this.

"Any of you may perform this little experiment for himself. Take a towel, weigh it, or get somebody to weigh it for you, dip it in water to wet it thoroughly, then wring it out, and have it weighed again. It will weigh heavier than at first, because of the water it holds. If you hang it up in this condition in the open air it will, after a time, become quite dry, and if you then weigh it, you will find it to be exactly the same weight as at first.

"The water which it held will have disappeared. If I were then to ask you what had become of the water, you would tell me at once that it had been evaporated, and that the air had sucked up or absorbed the vapor, as a sponge absorbs liquids.

"Boiling, as we saw in one of our recent lessons, is essentially evaporation on a rapid and violent scale. The vapor (steam) is formed in masses at a high temperature, and it rises and spreads, by reason of its own tremendous expansive force. The vapor of ordinary evaporation is formed at much lower temperatures, and rises silently and invisibly, forcing its way, molecule by molecule, into the pores between the molecules of the air itself.

"So much, then, for the presence of vapor in the air: now as to the variation in quantity.

"Imagine a glass jar fitted with an air-tight lid and filled with perfectly dry air, at an ordinary average temperature, 60°F. Inside the jar is a small shallow saucer of water, suspended from a delicate spring balance.

"Now let us see what we have. We have a vessel containing perfectly dry air, and in it there is a small saucer of water. Note what takes place. Evaporation commences immediately, and it is very rapid at first. The air is thirsty, and drinks up moisture eagerly. Our delicate scales would soon tell us that the saucer is getting lighter, because it is being robbed of its water by evaporation.

"In a short time, however, the scales would show that less and less water is leaving the saucer. Evaporation is becoming slower and slower, and at last it ceases altogether. The air has finished its drink; it is quite full; it can hold no more. The molecules of vapor have filled up all its pores. We say that the air is saturated—that is, full of moisture.

"Now, what is the general effect of heating bodies—

solids, liquids, or gases? The heat drives their molecules farther apart, by overcoming the force of cohesion. If, therefore, air be heated, and its molecules driven farther apart, it must make the spaces or pores between the molecules larger.

"Let us then suppose that we could suddenly increase the temperature of the jar and its air to 90°F. We should see, by the balance again, that there would be a second rapid evaporation from the saucer, which would, after a time, become slower and slower, and at last cease entirely. What is the meaning of all this? The air at the higher temperature is more porous—it has greater capacity for absorbing moisture. Evaporation commences the second time, and goes on until all the pores are filled with moisture. It then ceases entirely, because the air has again become saturated at the higher temperature.

"Our balance would show us another fact. The amount of water removed by evaporation this time from the saucer would be twice as heavy as at first. That is to say, the increase of 30°F. in the temperature has enabled the air to take up just twice as much moisture as it could hold at the lower temperature.

"Suppose we imagine now the opposite process to be at work. As long as the air in the glass vessel remained at 90° Fahr. it would be able to hold all the moisture it had absorbed. We, however, will suppose that it is suddenly cooled again from 90°F. to 60°F. We should see the sides of the vessel become misty, and the interior would be filled with a dense fog.

"Let us see what all this means. The air is unable, at the lower temperature, to hold all the moisture, and consequently gives up part of it, which is at once condensed into liquid water again.

"If we could collect all this water, we should find it to be exactly the quantity which was taken up the second time, when the temperature was raised from 60°F to 90°F. If we reduced the temperature of the air still lower, it would give off more and more of its moisture, condensed in tiny globules of liquid water.

"You will now be able to reason out for yourselves why wet clothes on a line dry much more rapidly, as a rule, in warm than in cold weather, and in a dry atmosphere much more quickly than in a damp, humid one."

Lesson 43

Resin and Turpentine

If we examine a piece of common resin, we shall be struck with its resemblance, in many respects, to the gums, which we have already described. It has a semi-transparent, glassy appearance, and is somewhat sticky to the touch. On the other hand, further examination would show that it differs from them in being highly inflammable, and insoluble in water, while it is soluble in spirits of wine, and the essential or volatile oils. Resin is employed chiefly in the manufacture of soap, and also in the preparation of a common kind of wax, which is used for sealing the corks of bottles.

Oil of turpentine, or spirits of turpentine, is a clear, transparent, very limpid liquid. It has a peculiar and powerful odor, and is highly inflammable, burning with flame and smoke. If we let fall a drop on a sheet of paper, it will gradually pass away, leaving no stain. It is this last-named property which places it among the volatile oils.

Indeed, oil of turpentine is unquestionably the most valuable of all the volatile oils. Large quantities of it are used in making oil-colors for painting. Its thin, limpid nature helps the paint to flow freely from the brush, and when it is laid on, the oil of turpentine, owing to its volatility, flies off rapidly in vapor, leaving behind the substance of the color, with the thin coating of linseed-oil.

It is also largely used in the manufacture of varnish, and in making the common lacquer for covering iron goods.

It is a powerful solvent of fat and oily matter of all kinds. Hence we use it to take grease-stains out of our clothes, etc.

Now that we know something of the nature and properties of both these substances—the solid resin and the liquid oil of turpentine—we may go a step further, and say that the two come from the same source.

They are the product of certain trees belonging to the pine family. Several species of these trees elaborate a peculiar secretion—a thick, very sticky liquid, of a yellowish color, not unlike honey in appearance. It is obtained by making a number of cross-cut incisions in the trunk almost to the pith, hollowing out each one so as to form a sort of bowl or basin, into which the turpentine—a honey-like liquid—drains, and is collected in vessels placed round.

This liquid is known as crude, or common turpentine. The great pine-forests of North America supply immense quantities of this crude turpentine—in fact, they supply the world. No less than 30,000 tons are exported annually to England alone.

In the preparation of the secretion for use, it is heated with a certain quantity of water in a copper retort or still. When the water boils, the steam passes away into the condenser to be re-converted into water, and the vapor from the heated liquid distils over with it.

This vapor condenses too, and forms a clear, limpid fluid which, being lighter than water, floats on the surface. The new liquid, when collected, is the volatile oil or spirits of turpentine. In the retort itself a yellowish, solid substance is left behind. This is the resin.

The crude or common turpentine, therefore, consists of resin dissolved in the oil of turpentine.

One more thought about the volatile oils before we leave the subject. The list of these oils includes, amongst others, the oils of lemon, cloves, nutmeg, lavender, bergamot, rosemary, and peppermint, in addition to the oil or spirit of turpentine. They are clear, limpid liquids, much lighter than water; they leave no greasy stain on paper; they are obtained (like the oil of turpentine) by distillation; and they are characterised by their powerful odor and taste.

They were at one time thought to contain the subtle essence of the plant from which they were derived; this explains why they were called essential oils.

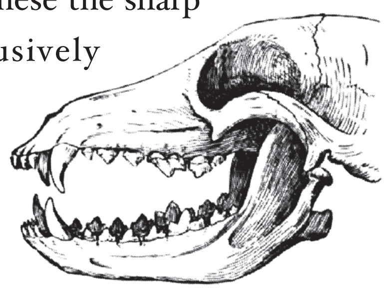
Lesson 44

Teeth of Mammals

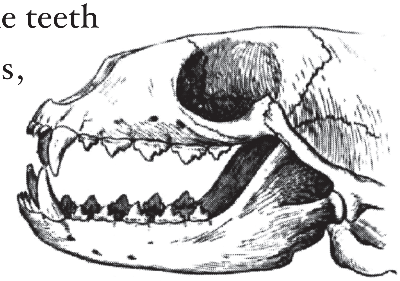
Speaking generally, the teeth of most mammals are arranged on similar lines to those of man; that is to say, we find, as a rule, the same kinds of teeth—incisors, canines, and molars. Every order of the class, however, is distinguished by the special development of one or other of these, to suit the habits of the individuals. Let us examine them one by one.

In the Carnivora, or flesh-eating mammals, the special development is in the direction of the four canine teeth, which are always remarkable for their size, sharpness, and prominence. The main object of these teeth is to seize and hold the prey and to tear their flesh. There is very little work for the incisors, hence they are always small, like those of the cat. The molars are well developed, but their surfaces are specially furnished with sharp, jagged ridges, which work against each other at every movement of the jaw, like the sharp edges of a pair of scissors. The peculiar development of the teeth in these animals is accompanied by a corresponding modification in the movement of the lower jaw. The flesh-food, on which they live, cannot be ground up as other food can. The molars, instead of doing the grinding work of a mill, become mere cutting or chopping instruments; in consequence, the jaw requires only a simple up-and-down movement.

A remarkable divergence may be seen in the case of some of the so-called Carnivora, such as the bears and the domestic dog, which vary their flesh diet with more or less vegetable food. In all these the sharp cutting ridges of the exclusively flesh-eating animals begin to disappear, and give place to the ordinary, roughened surface of the grinders, while, more remarkable than this, the jaw begins to take the double movement—sideways as well as up and down—which is wanting in the true flesh-eaters.



The greater the mixture of food, the greater the modification, both in the teeth themselves and in the movement of the jaw. In the dogs, for instance, only the two back molars are changed; in most of the bears three or four are affected, the bears being further advanced as vegetarians than the dogs. The teeth of the aquatic flesh-eaters, such as seals and otters, are deserving of notice. Their prey consists of the slimy, slippery inhabitants of the



water, and not only are their canine teeth well developed, but all the teeth are furnished with sharp, saw-like edges, to serve the double purpose of holding the victim, and cutting through its flesh.

In the walrus, one of the family, the canines of the upper jaw are very largely developed, and form great tusks, often measuring 2 feet in length, and serving as weapons of attack and defence. It has neither canines nor incisors in the lower jaw.

The Insectivora include the shrews, hedgehogs, and moles, in addition to the bat family. The former find their prey on and in the earth, the latter feed mainly on the insects that people the air, and this explains why they are flying mammals.

In this order the special feature about the teeth is that the molars bristle with sharp points, specially fitted to crush the hard coverings of the insects on which they feed. Only one movement—an up-and-down one—is required for this work. Another remarkable modification is seen here. Certain of the bats live on fruits in preference to insects. In these the molars are true grinders, with the ordinary, flat, roughened surfaces, and no sharp points, while the jaw has the double movement for mill-work.

In the order of Rodents we find the incisors specially developed. There are never more than two in each jaw, but they are long and broad, and have sharp, chisel-shaped, cutting edges, specially fitted for gnawing purposes. These animals live on vegetable food, which they gnaw or nibble with their chisel-shaped incisors. The remarkable provision about these teeth is that they never lose their sharpness—the very work of gnawing tends to sharpen them.

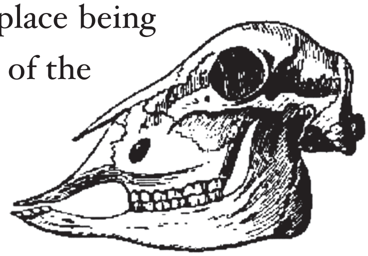
Like all other teeth, they are composed of the two substances, dentine and enamel. The front of the teeth is hard enamel, the rest is the softer material dentine. The gnawing work of the animal wears away both substances, of course; but as the dentine wears faster than the enamel, the edge is always left sharp.

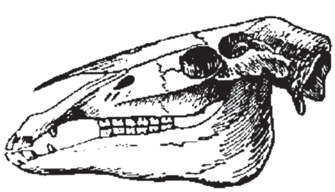
There is one other remarkable fact in connection with these teeth. From the nature of their work they wear away faster than the teeth of any other animal; indeed, they would soon wear away completely unless some provision were made to prevent it. Look at Nature's provision in this case. The incisors of all these gnawing animals are entirely without roots, such as other teeth have, and they grow from below as quickly as they are worn away at their edges.

Just one thought more before leaving this order. There are no canine teeth, but there is a considerable space between the incisors and the molars, where the canine

teeth should be. The molars themselves, too, are deserving of notice. Instead of irregular projections, these teeth have a number of parallel ridges running crosswise. The movements of the jaw, moreover, are most remarkable. In addition to the up-and-down and the sideway movements, it has a peculiar movement of its own: backwards and forwards. This helps the molars to do their work by a sort of rasping process.

The Ruminants, or cud-chewers, are distinguished, as regards their teeth, by one characteristic—the want of incisors in the upper jaw, their place being supplied by a pad. One member of the order, however, the camel, is a departure from the rule, as he has incisors in both jaws. The whole order, being exclusively vegetarians, either have very small canine teeth, or are entirely devoid of them. The molars are always large and well developed.

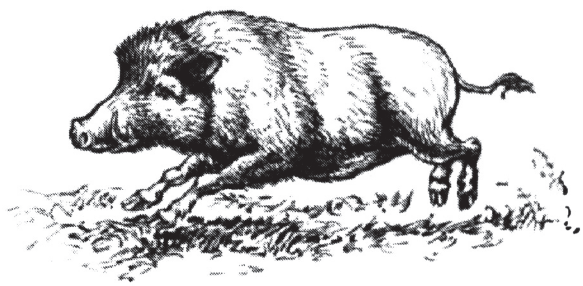




The teeth of the horse present the remarkable peculiarity of a space between the canines and molars. This is known as the bar.

The bit of the bridle fits into it. The canines, as might be expected, are very small ; the molars are largely developed, and are twenty-four in number, and there are six incisors in each jaw.

In the elephant and wild boar the canine teeth aredeveloped to an enormous size and form tusks, which serve as weapons of attack and defence.



Lesson 45

The Formation of Dew and Hoar-Frost

"I want you to think over our lesson on evaporation," said Mr. Wilson, "and the part that heat plays in regulating the quantity of vapor the air absorbs. It taught us that the air, at every temperature, absorbs vapor up to a certain point, but beyond that it will take no more. We say that the air is saturated and that, for each degree of temperature, it has its point of saturation. Air, at the ordinary temperature of about 60°F., may contain a certain amount of moisture, and yet not be saturated. But suppose that air becomes cooled, what will happen then?"

"The cooler air cannot hold so much vapor as it did at 60°F., sir," said Fred.

"Quite right, Fred, and the same quantity of moisture would be sufficient to quite saturate it at the lower temperature.

"Now, let us suppose the air to be cooled still further. It was already saturated; its capacity for holding moisture is still less under the new conditions; some of the moisture must go. It does go. It is condensed, and falls in little round drops of water which we call dew. The temperature at which the air begins to deposit dew is known as the dew-point.

"Before our lesson began I stood a tumbler of cold water on the table. Come and look at the tumbler, Fred, and tell me whether you see anything unusual about it."

"The outside of the tumbler is covered with little drops of water, sir," said Fred, "and some of them are running together and trickling down the sides of the glass."

"It is so," replied Mr. Wilson. "Now, the first point to settle is where these drops of water came from. They did not come from the glass, either by oozing through its sides or by overflowing from the top. They came from the moisture or vapor in the air of the room. Let me explain.

"The air of the room is warm, and is able, at its present temperature, to hold a certain amount of water-vapor. The glass is cold, and it reduces the temperature of the air all round it, first to its point of saturation, and afterwards to its dew-point, and then it is that the drops of dew begin to form on the cold glass. Dew is always formed in this way—not in the air, like fog and cloud, but on the cold surface of solid bodies. There is always some solid body colder than the dew-point of the air around. The air comes into contact with this colder body, and is robbed of some of its heat. The loss of heat compels it to give up some of its vapor, and this is deposited as drops of dew on the surface of the cold body itself.

"All day long the earth and all the objects on its surface are absorbing more heat from the sun than they can give out by radiation. When night comes on, the absorbing process is over, and the radiation only is going on. Consequently, the surface of the earth (and of most solid bodies at night) is continually losing heat, and is, as a rule, colder than the air near it. Hence the formation of dew when this warm air comes into contact with it.

"When the temperature of the earth and the solid bodies on its surface sinks below 32°F., the moisture is deposited in the form of tiny particles of ice. We call it then hoar-frost.

"Dew is usually formed on a fine, clear, still night, succeeding a warm day. Very little dew is formed on a cloudy night. The clouds act like a curtain, and prevent the radiation of heat from the earth.

"Dew is formed abundantly on grass and foliage generally, on trees, and on wooden palings, but very little is formed on the gravel paths or the stone pavements. Gravel and stone are bad absorbers, and bad radiators of heat."

Lesson 46

Fresh Vegetables and Fruit

Under the name of fresh vegetables we include tubers, such as the potato; fleshy roots, such as the turnip, carrot, parsnip, and radish; as well as green vegetables, such as the cabbage family, lettuce, spinach, cauliflower, water-cress, onion, etc.

These, like all vegetable food, contain both flesh-forming and heat-giving matter in various proportions. The potato, although it contains little or no nutriment for tissue-forming, is a very valuable heat-giving food. Nearly all its solid matter consists of starch.

Carrots, turnips, parsnips, cabbages, cauliflowers, and onions are very nutritious, both as tissue-formers and heat-givers. If one of these fresh vegetables—say a potato, a turnip, a cabbage, or a cauliflower—were placed over a fire, or in an oven, it would at once begin to give off vapor, and after a time it would gradually dry and shrivel up.

If we weighed it before and afterwards, we should find a great difference in its weight. The potato, for instance, would lose about 75 percent of its weight by this drying process; the turnip no less than 90 percent. It is clear then that all these fresh vegetables contain a large amount of water. Whence did they get this water?

It was absorbed from the soil by the roots of the growing plant. Now water, as we know, acts as a solvent, and dissolves the mineral matters out of the soil. The roots of the plant, in taking up the water from the soil, take up also the mineral matters, which that water holds in solution, and these mineral matters are absorbed into the structures of the growing plant with the water.

Let us now take our potato, dried as it is, and burn it. Of course most of its substance will be consumed with the burning, but in the end we shall have a residue, which will not burn, which no amount of heat can consume. It remains as an ash after the burning. This ash represents the mineral matter which was taken up from the soil by the roots of the plant.

It is more perhaps for their value as storehouses of mineral matter, than for their other properties, that fresh vegetables are so important to our health and well-being.

It is a common occurrence that people who have been deprived for any length of time of fresh vegetables, develop scurvy and other skin diseases.

One important mineral, potash, is always found in some form or other in carrots, turnips, parsnips, radishes, asparagus, watercress, lettuce, and endive. Potash is chiefly valuable as a preventive of scurvy and other eruptions of the skin, or, as scientific men would say, for its anti-scorbutic properties.

Soda, lime, common salt, and the salts known as phosphates are all equally necessary to our general health and well-being. They find their way into our system by the same means, and from the same source.

Fruit, of all kinds, although it possesses a very small amount of nutritive matter, is nevertheless of great value as food, because, in addition to the sugar which it contains, it is a storehouse for certain mineral matters and acid juices. As we saw in the case of the vegetables, the mineral matters are valuable as anti-scorbutics; the acid juices are equally valuable in medicinal properties.

No fruit can be safely eaten, however, in an unripe state, for then the acid juices are very powerful, and would quickly be the cause of indigestion and other derangements of the system. Unripe fruit should never be eaten unless cooked; unsound fruit should never be eaten cooked or raw. On the other hand, fruit, when it is ripe and sound, forms a pleasant and agreeable change of diet, and ought to occupy an important place in the meals of the day.

Lesson 47

Tar and Pitch

Our lessons on coal introduced us to tar as one of the off-products formed from that mineral in the manufacture of coal-gas. There is another kind of tar—not black like coal-tar—but of a dark brown color. This is made from wood.

If we examine it we shall find it to be a dense, heavy, sluggish liquid, having something of the consistency of molasses. It has a powerful smell, and a bitter, unpleasant taste. It is highly inflammable, and burns with a bright flame, giving off volumes of dense smoke. If we let fall a small quantity in a vessel of water, it sinks to the bottom, because it is heavier than the water. It will not mix with the water, and it is insoluble in water; but it is soluble in spirits of turpentine, and in all fats and oils.

We always employ either oil of turpentine or grease of some sort to remove tar stains from the hands. Water will not do it.

In its properties, therefore, this wood-tar resembles the coal-tar of our early lessons.

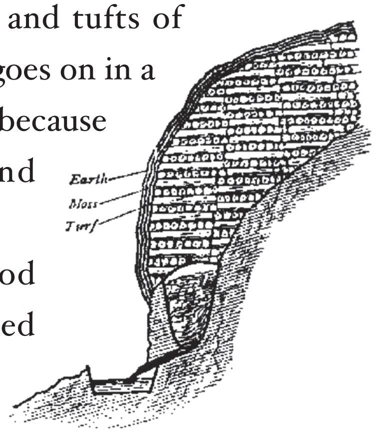
It is the property of not mixing with water that has caused tar to be so extensively used in preserving wood-work and other materials.

We tar wooden sheds, fences, and the outside of ships. We steep the ship's cordage in tar; we tar sheets of canvas to make water-proof tarpaulings, and we steep in tar great beams of timber, which are required to resist the action of water. When a wooden post is to be fixed in the earth, the lower end of it is first steeped in tar. The reason is simple. The moisture in the earth cannot enter the wood to rot its substance, because it cannot mix with, or pass through the outside coating of tar. A well-tarred shed will last for many years in spite of rain, because the rain simply runs off the tarred surface, and cannot penetrate.

Pitch is a black, solid substance. It is very brittle, and when broken has a bright shining surface. It becomes liquid and boils with a slight heat. Like tar, it is impervious to water. Tar and pitch, like resin and turpentine, come from the same source. Indeed, tar and pitch are the products of some of the same family of the cone-bearing trees from which we get resin and turpentine.

The particular kind of pine which yields tar and pitch is known as the Scotch fir, and is grown chiefly in Norway, Sweden, and Russia. In our country the swamp pine of North and South Carolina, Georgia, and Alabama yields tar. Tar, although a secretion, does not flow naturally from trees like turpentine. It is stored up in the roots, and the supply can only be obtained by the destruction of the tree. When the tree is fit for the purpose it is felled, and the roots are cut up into small logs. A circular pit, tapering towards the bottom, is next dug on a sloping bank or hillside, the sides of the pit being beaten hard and smooth. The bottom of the pit is made to communicate, by means of a pipe, with a tank placed below.

The little logs of pine roots are then carefully packed in the pit, and when it is full a fire is lighted on the top. As soon as the whole mass is fairly lighted, the mouth of the pit is covered with earth and tufts of grass. In this way the burning goes on in a slow, smouldering sort of way, because it is partially smothered and confined.

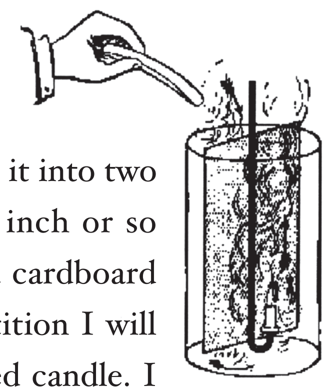


The result is that the wood becomes charred and converted into charcoal, and a dense, molasses-like liquid runs downwards through the mass, and passes into the tank below. This is the tar of commerce.

The tar, when heated in a retort, distils over a volatile spirit—oil of tar—and leaves the black, solid substance—pitch.

Lesson 48

Heat, the Cause of Motion in the Air



"We are going to begin this morning with an experiment, boys," said Mr. Wilson. "I have here a large glass jar. I have divided it into two parts, from the top to within an inch or so of the bottom, by fitting into it a cardboard partition. On one side of this partition I will lower into the jar a piece of lighted candle. I want one of you to come to the front and hold over the other side a piece of smouldering brown paper. Watch what takes place. The smoke from the smouldering paper passes down one side of the glass, then under the partition, and up the other side in which the candle is burning.

"What is the meaning of this?"

"I suppose the heat of the candle flame has made the air on that side of the partition hot, sir," said Fred. "Yes, Fred, you are right; the heat of the burning candle has raised the temperature of the air all round it. But what follows from that?"

"Air expands when it is heated, sir," replied Fred. "The heated, expanded air is of course lighter than it was, because the same quantity has to fill a greater space than it did at first."

"That's very good, Fred," said Mr. Wilson. "The expanded air is lighter than it was—lighter than the rest of the air near it; lighter than the air below it. It is therefore forced upwards by the buoyancy of that heavier air around and below it, or, as we often say roughly, it ascends.

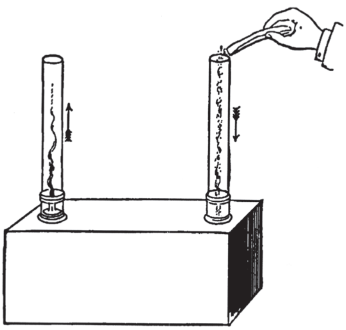
"But as the warm light air rises and passes out at the top of one side, the colder, denser, heavier air from the other side rushes under the partition to take its place, and so prevent a vacuum. We should not have been able to see the moving current of air in the usual way, so we held the smoking paper over the mouth of the jar, and that showed the direction of the movement."

"I remember, sir, you showed us this movement of the heated air by another contrivance in one of our lessons on the coal-mine," said Fred.

"So I did, my lad. Suppose you tell us all about it now."

"You had a small wooden box with two round holes cut in the bottom. The lid of the box was taken off, and the box was stood upside down on the table. You fitted two lamp-glasses into the round holes, and stood a lighted candle under one of them. I remember holding the piece of smouldering brown paper over the top of the other one for you. Our experiment just now brought it all back to my mind. The smoke passed down that glass and up the other, under which the candle was burning. It was the heat of the burning candle that caused the current of moving air."

"Thank you, Fred," said Mr. Wilson. "I am very pleased to know that you try to remember what you are taught. Now let us see where all this leads us.



"Think of the gas or the lamp burning in a room. Here the action is exactly the same. The heat of the flame raises the temperature of the air around, and this heated, expanded, lighter air rises towards the ceiling, the colder, denser air constantly moving in from all sides to take its place and force it upwards. The hottest air in the room is always near the ceiling, the coldest near the floor.

"The light hot air in the upper part of the room will do its best to escape, and float away higher and higher outside, if it can find a crack or an opening anywhere. When a room is very warm, pull the window-sash down about half an inch from the top, and hold a lighted candle near the opening. The flame will pass outwards through the crack, showing that there is a rush of air in that direction.

"If next you open the door a little way, or hold the candle-flame near the crack at the bottom, the flame will be seen to blow into the room, owing to the inward rush of air there.

"The fire in the grate acts in the same way, although the heated air passes up the chimney with the smoke and not into the room. There is, however, a constant movement of cooler air through the room towards the fire to take the place of that which has floated away up the chimney."

Lesson 49

Ventilation

"In one of our recent lessons we learned why hot air rises, and why the hottest air in the room is always near the ceiling," said Mr. Wilson. "But the burning of the candle, the gas, or the oil in the lamp affects the air of the room in another way besides heating it, and thus causing it to expand and become lighter than it was. Who can tell what I mean?"

"The burning, in each case, produces the poisonous carbonic acid gas, sir," said Will, "and this gas floats away into the air of the room."

"That is exactly what I meant, my lad," said Mr. Wilson. "But I think you can tell of another way by which the air becomes charged with carbonic acid gas, in addition to this."

"Yes, sir; we and all other animals are constantly sending out carbonic acid gas into the air by our breathing."

"Quite right, Will. Now think again. You called this carbonic acid a poisonous gas just now. Why?"

"We could not breathe this gas, sir, even in a small quantity, without making ourselves ill; and in a larger quantity it would quickly kill us."

"Right again," said Mr. Wilson. "Let me make this quite clear. Imagine a man shut up for twenty-four hours in a room 7 feet square and 8 feet high. At the end of that time every particle of air in the room would have passed through his lungs; he would have robbed the air of about one-twentieth of its oxygen, and breathed out into it an equal amount of carbonic acid gas.

"Such air would be quite unfit to breathe. But as long as the man lives he must continue to breathe, and thus at every breath he would be inhaling large quantities of this poisonous gas. We have only to picture two or three people in that room instead of one, and think of what the result would be.

"The very thought of it calls up in one's mind the hideous story of the Black Hole of Calcutta. On 20th June 1756, Surajah Dowlah, Nabob of Bengal, made a sudden and unexpected attack on the defenceless traders at Calcutta, or Fort William, as it was then more commonly called. After entering the town, he took 146 persons of our race and drove them at the point of the sword into a small room 18 feet long and 14 broad, where they were shut up for the night, the place being surrounded and strongly guarded by the Nabob's troops. There, through the sultry night of that hot climate, these poor sufferers endured unspeakable agonies of thirst and suffocation, trampling one another down in vain attempts to reach the one little window in the dungeon, filling the air with their wild ravings of delirium and despair. The dusky guards outside, meanwhile, replied to their appeals with jeers and curses. In the morning, 23 out of the 146, one of them a woman, were dragged from this den of torment alive, but pale, emaciated, exhausted, and quite unable to stand. The remainder were a heap of corpses.

"In our school-rooms, public halls, and all buildings where many people meet, as well as in our living and sleeping rooms at home, every care should be taken to see that there is a way of escape for the heated, vitiated air, and a free communication with the fresh air on the outside.

"This is what we mean by ventilation. There are many artificial contrivances for admitting the fresh air and driving out the bad. Most of them are constructed somewhat on the principle of the fan; they set the air in motion just as a fan does when we move it to and fro.

"The word ventilation itself comes from a Latin word, which actually describes the waving movement of a fan through the air.

"We cannot all have costly contrivances for ventilating our rooms, but we can all make use of a few simple practical hints.

"We spend a good share of each twenty-four hours in our bedrooms, and it is important to remember that, although we are sleeping, the work of respiration is still going on—it never ceases. It is as essential for us to breathe good fresh air then as when we are awake. The top sash of the bedroom window should be kept down an inch or so day and night, for the escape of the foul air. Or a row of holes may be bored in the upper part of the frame with a gimlet, and this will answer equally as well.

"But how about letting in fresh air to take the place of the bad air which escapes in this way? We need not trouble about this. The bad, heated air will be sure to rush away if we leave a means of escape for it in the upper part of the room. The pure air will force itself in through every crack and crevice, through the keyhole, under the door, to take its place as quickly as it passes off.

"As the air which enters the room in this way has to pass through the house, it is important to keep the house and all things round it clean and free from bad smells, or we shall begin by admitting bad air into the room.

"This applies to all workrooms and classrooms, as well as to sleeping-rooms, especially when gas is burned. The only thing to be avoided is the causing of draughts. Draughts create mischief. The best ventilator for a room is a fire; we have seen how the heat of the fire causes inward currents of air to flow from all parts of the room. If a number of persons sit in a room without a fire, the air soon becomes stuffy and foul; but if a fire is burning in the grate, it will help very much to keep the room ventilated.

"A simple way to rapidly purify a close, foul room is to open both the top and bottom sashes of the window at once; the reason for this requires no telling."

Lesson 50

Winds

"Our lessons have shown us that the heat of the fire, the gas, or the lamp causes currents of air through the room or, in other words, sets the air of the room in motion," began Mr. Wilson, at the next meeting of the class.

"I want now to get outside the room. Let us imagine ourselves, some calm, still evening, in a field, where an immense bonfire is burning. Immediately the flames began to ascend, we should feel, as we stood round, currents of cold air rushing in from every quarter towards the fire. These currents would at once become apparent if we held over our heads some long, thin, paper streamers.

"The reason is clear. The immense heat from the fire expands the air round and above it, thus making it lighter, bulk for bulk, than the air in its vicinity. This thinner, lighter air is not able to resist the pressure of the denser, heavier air around. There is a momentary struggle between the two, but it has to give way to the greater pressure. The dense, heavy air rushes in from all quarters towards the fire, and by its pressure forces the lighter air upward.

“This movement of the air as the result of heat from the bonfire will illustrate to you the manner in which winds are caused. These currents of air setting in on all sides towards the fire are actually winds on a small scale.

“Wherever winds occur, something similar to this must have been going on. The air in some spot has been greatly heated, and of course expanded, and made lighter. It consequently ascends, while colder, heavier air rushes in from all sides to prevent a vacuum. This rushing air forms the wind.

“Land and sea breezes are the simplest illustration of the formation of winds. We will see how they are caused.

“Carry your minds back, in the first place, to our lesson on the radiation and absorption of heat. You remember, of course, the meaning of the two terms, and that good absorbers are always good radiators, bad absorbers bad radiators.

“The land is a better absorber and therefore a better radiator of heat than the sea. The sun shines all day with equal power on the land and on the adjoining sea, but the land takes in more heat than the water. Being a good radiator, however, it radiates this heat into the air as readily as it receives it; thus the air above the land becomes hotter than that over the sea. This heated air from the land expands, and becomes lighter, bulk for bulk, than the colder, denser air over the sea. It is unable to resist the pressure of this colder, heavier air; it gives way to that pressure, and ascends, owing to its lightness, the air from the sea rushing in to fill its place. Thus all day long we have a breeze blowing from the sea to the land.

"Now when the sun has set, the source of heat is gone. The land is no longer absorbing heat. Through-out the night, however, the land continues to give up by radiation the heat it has taken in during the day. It soon becomes cold—colder than the sea, which, although it has absorbed slowly, has also radiated slowly. Hence the air above the water is warmer, in comparison, than that over the land; warmer means also, as we have seen, lighter, bulk for bulk.

"Heat has, in this case again, caused unequal pressure. The rarefied, lighter air over the sea cannot resist the denser, heavier air from the land, which is pressing upon it. As before it gives way, and rises into the higher regions, forced to do so by the onrush of the air from the land. This gives a land breeze, which lasts till the sun next morning begins to assert its power, and then the breeze from the sea sets in once more.

"Think now of the tropical regions of the globe, and of the immense power of the sun in those parts. The heated air acts in exactly the same way and, in consequence, movements of colder air from the temperate and polar regions, north and south, set in towards the equator. The directions of these winds are modified from various causes, but their origin is always the same."

Lesson 51

Sources of Clothing

Now that we know something of the laws which must guide us in the selection of our clothing, it will be well for us to look into the sources from which we derive our supply of clothing materials. We obtain these materials from both the animal and the vegetable world. From the former we get wool, fur, leather, and silk ; from the latter, linen and cotton.

All the animal substances are bad conductors of heat. Amongst them wool undoubtedly stands first as regards its general utility. It is. as you know, the natural covering of the sheep. The wool is shorn from the animal, during its lifetime, every spring.

Wool differs in quality and characteristics. Much of our common wool has long, coarse fibers, and is usually known as long wool. From it are made flannels, blankets, worsted goods, and stuffs, such as moreens, merinos, etc.

The wool imported from Australia and Saxony is of a different kind. Its fibers are comparatively short, but fine, soft, and silky. This class of wool is used in the manufacture of broadcloth and other fabrics, mostly for men's wear, and commonly known as woollen goods.

Fur is Nature's wise and beneficent covering for a large class of her creatures, which live mostly in the cold regions of the earth. It consists really of very fine, soft hair, set extremely thick on the skin, so as to form a smooth, close coat. Hair itself is a bad conductor of heat; hence this thick, close-fitting coat of fine hair is the very best provision that could be made to protect these creatures from the rigor of the climate.

In the short summer of those regions, when the thick coat is no longer required, much of the hair falls out and is shed, leaving the rest loose and open, but before winter returns a new supply grows, and the coat again becomes thick and close.

Among the fur animals whose skins supply us with clothing material are the rabbit, hare, squirrel, cat, ermine, sable, marten, racoon, badger, black and silver foxes, otter, beaver, seal, bear, etc.

Unlike the wool of the sheep, the fur coat of these animals becomes serviceable to us only after the animal is dead. The skin itself, with its fur covering, is taken from the animal, and dressed without removing the fur. The man who dresses the skin is called a furrier.

Siberia and British North America are the two great fur-producing regions of the world. They form immense hunting-grounds for almost every variety of fur-bearing animals. They give constant employment to large numbers of bold, adventurous men, who in their trapping and hunting are exposed to great risks and dangers.

Leather is made from the skins of many animals. These skins in their raw state would, like all other animal matter, decay and rot. The treatment which they are made to undergo is to prevent this. After the removal of the hair, they are soaked in a liquid called ooze, made by steeping oak-bark in water. This is the process of tanning; the result of it is to permanently arrest all tendency to decay, and at the same time to render the skin waterproof. It changes the perishable skin into durable and comparatively imperishable leather. Being a bad conductor of heat, and at the same time waterproof, it is the best of all materials as a covering for the feet.

Silk, the softest and most costly of all materials, is the product of the caterpillar of the silk-worm moth. During the change from the caterpillar to the moth, the chrysalis spins its cocoon of soft, glossy fibres. These fibers are spun and manufactured into the silks and satins and velvets of commerce.

Linen holds the first place among the vegetable materials used for clothing, both for its strength and durability as well as for its beauty of texture. Our earlier lessons have made us familiar with its history, properties, and uses. We are not concerned with those things now. Our business here is to regard it as being the best conductor of heat, among the textile fabrics, and therefore having its own special usefulness.

As an article of clothing it keeps the body cool, by allowing the superfluous heat easily to pass away. Because of the beauty of its glossy surface, it is used for shirt-fronts, collars, and cuffs. It is too costly to be used for the whole garment, except by wealthy people.

Cotton is a sort of vegetable wool. It is obtained from the seed-pods of a plant which grows in most of the warm countries of the world. It is a conductor of heat, but is not of such high conducting power as linen. It forms an admirable material for clothing in hot climates, and, being cheaper than linen, is much in request. It is by far the most abundant and important of all materials used for textile fabrics, and supplies man in all parts of the world with clothing material.

Lesson 52

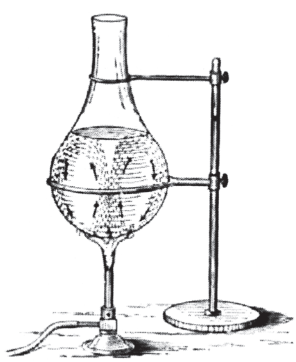
Currents

"I think you have seen this before," said Mr. Wilson, as he proceeded with an experiment at the opening of the next lesson. The boys watched carefully, and were soon eager and anxious to tell him all about it.

"Well, Fred," he continued, "suppose you tell us what it is."

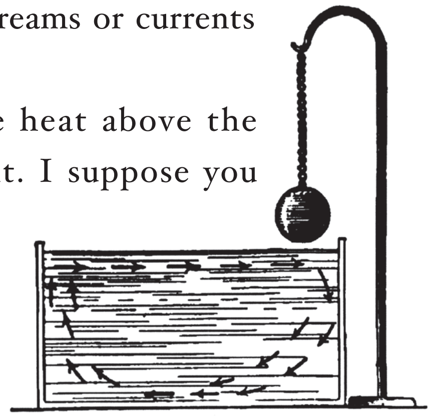
"This is the experiment by which you showed us the heating of liquids by convection, sir," said Fred.

"Exactly," replied Mr. Wilson, "But I am now using it for another purpose. Why did I put the little pieces of coloring matter into the water?"



"The little blue particles show us the direction in which the water moves, sir."

"Right, my lad. I am now going to talk to you about this moving water. The coloring matter shows us, as you say, streams flowing through the body of the water in the flask. These streams we call currents. You see it is the heat from the flame below which sets the water in motion, and causes it to flow in streams or currents through the flask.



"Let us now place the heat above the water, instead of below it. I suppose you wonder how I am going to do that. Look; I have here a large open glass trough filled with water, and into the water, as before, I will drop some little pieces of coloring matter. I have also in the fire, red-hot, the iron ball which we have already used for another purpose. Here it is; I will hold it by its chain just over one end of the trough.

"The water immediately under the red-hot ball is heated, and of course expanded, thereby becoming lighter, bulk for bulk, than the body of the water around and below it, while some of it actually passes away by evaporation. This lighter water is forced along by the upward pressure of the denser liquid below it, and thus a stream or current is set up through the trough, the warm water flowing along the surface, the colder, denser stream along the bottom of the vessel.

"Now I want this red-hot ball to represent the sun, and this trough of water the ocean. I shall be able to make you understand readily enough how similar currents are set up in the ocean by the heat of the sun.

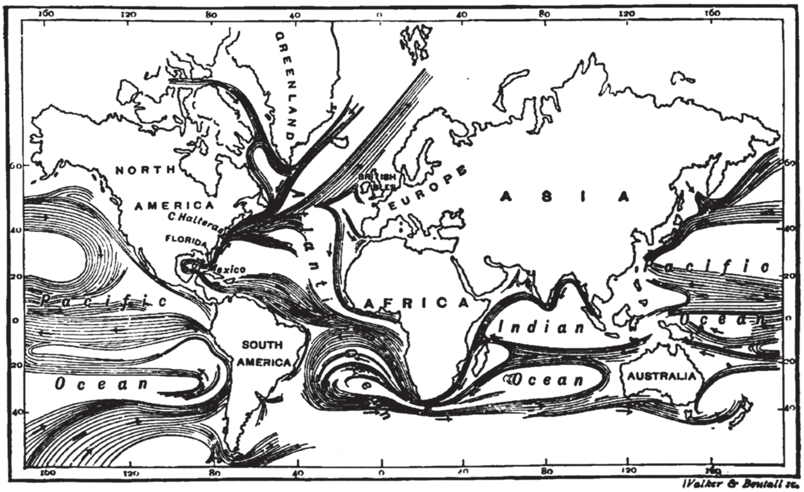
"We have frequently, in our lessons on evaporation, spoken of the effect of the sun in heating the water of the ocean. In what part of the world should we expect to find this going on to the greatest extent? Your thoughts immediately travel, of course, to the great oceans in the tropics, and you are quite right. The immense power of the sun in these regions heats the water of the ocean in very much the same way as our red-hot ball heated the water just now. Some of it, we know, rises in masses of vapor to form clouds; that which is not evaporated is expanded with the heat, and becomes lighter, bulk for bulk, than the body of the ocean water. The denser water from below exerts a greater pressure upwards than this expanded, lighter water can exert downwards. The balance has been upset between them; the stronger force gets the mastery; the light, expanded, surface water gives way, forced onwards by the pressure of that from below. In this manner, surface streams or currents of warm water are set up from the equatorial or tropical seas towards the poles.

"But let us go a step further. The dense, cold water, which by its upward pressure forces these currents onward, itself comes from the lower depths of the ocean. Such immense masses of water drawn from below tend to destroy the equilibrium—to create a vacuum. To prevent this, other streams or currents set in from the poles towards the equatorial seas. The water of these polar currents is, of course, cold, dense, and heavy. They flow, as we should expect to find them, along the bed or bottom of the sea.

"I have, thus far, spoken of these currents as flowing either from the equator to the poles, or from the poles to the equator. A chart of the ocean, however, would show us that they do not flow direct north and south. They would, if the earth were stationary, and if there were no great masses of land to intercept them. As it is, these currents are turned out of their course by the rotation of the earth on its axis, as well as by the irregular configuration of the land.

"The most important of these ocean currents is the great Equatorial Current, which commences off the west coast of Africa, crosses the Atlantic to the shores of South America, and after passing through the Caribbean Sea and the Gulf of Mexico, emerges once more into the Atlantic under the name of the Gulf Stream. It is veritably a warm river rushing through the Atlantic at the rate of about 50 miles a day. It skirts the eastern shores of North America, and at length disperses, some say in mid-ocean, others (and this is more generally believed) off the western shores of Europe.

"I called it a warm ocean-river just now. When it leaves the Gulf of Mexico its average temperature is 81°F., and even at New York its temperature is about 75°F. You will perhaps form some idea of the immense volume of this ocean stream when I tell you that its depth off New



York is not less than 100 fathoms, while at Florida it is probably twice that depth. It leaves the Gulf with a width of 32 miles, which has increased off Cape Hatteras to 75 miles.

"This immense volume of water then flows through the Atlantic, parting with its heat on its way, and it is generally believed to have a very marked and beneficial effect on the climate of Western Europe.

"I have sketched a brief outline of this very important current, merely to give you some idea of its course, its immensity, its usefulness. We are chiefly concerned here, however, with the producing cause of the currents—not with the currents themselves.

"I shall be satisfied if you remember that, as heat is the cause by which winds are produced in the ocean of air, so heat is again the cause by which currents are produced in the ocean of water."

Lesson 53

Cotton

Cotton supplies materials for clothing man in all parts of the world—indeed, it clothes more individuals by far than any other material, and may thus justly take its place among the most abundant and most important of all materials used for textile goods. It provides not only calico and print, muslin, lace, hosiery, and similar materials of light texture, but also heavy stout materials fit for men's wear, such as corduroy, moleskin, fustian, velveteen.

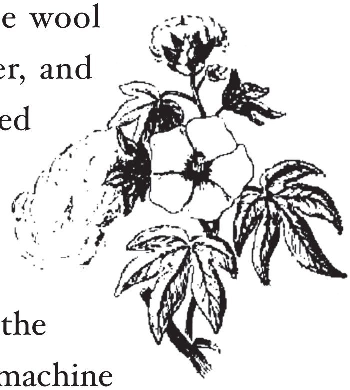
We dealt with some of its properties as a clothing material in our lessons on heat. Among its other properties it is soft and easily worked; it is warm to the touch, although very light, and when dirty it can be easily washed.

This valuable product is obtained from the seed-pod of the cotton plant. In the pod the seeds are packed in a soft, white, downy wool. This is the raw cotton of commerce—the material from which all our cotton fabrics are made.

There are several varieties of the cotton plant. One kind, which is cultivated chiefly in India and China, is a tree, and grows to the height of nearly 20 feet; another is a small woody shrub, about the size of an ordinary currant-bush. The plant which supplies almost all the cotton of commerce is an annual or herbaceous plant, which grows from seed sown every spring, comes to perfection and ripens, and dies down in the autumn.

This plant is cultivated largely in the United States, West Indies, Natal, Egypt, Queensland, and in almost all the warmer parts of the world. Provided only that the climate be dry and warm, it will succeed in soils too poor for the production of almost any other crops.

Its leaves are of a rich dark-green, and it bears large, bright-yellow flowers, with a purple spot in the center, not unlike our hollyhock. When the flower dies it leaves behind a triangular-shaped pod about the size of a walnut. The seeds which it contains are embedded in the mass of cotton wool. They are about the size of the seeds of a grape. When pressed they yield oil and oil-cake. When the plant is fully ripe the pods burst, owing to the swelling of the woolly matter which they contain. It is then time to gather in the crop. The cotton is 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.



As the pods are plucked, the wool and seeds are removed together, and carried away in baskets to be dried in the sun. When they are quite dry, the first part of the work of preparation begins by the separation of the seeds from the woolly down. This is done by a machine called a gin.

There are several varieties of gins. That used in America is the best. It consists of a sort of box, the bottom of which is formed of strong parallel wires, about one-eighth of an inch apart. Between these wires a number of circular saws project upwards into the box, which is loosely filled with the newly-picked cotton. The saws are made to revolve by machinery and, as they turn, their teeth drag the cotton through the bars, leaving the seeds behind. Some of the seeds are saved for next spring's sowing; the greater part are crushed for the oil which they contain.

The cotton, thus freed from its seeds, is pressed by powerful machinery into great bales, each bale weighing

about 350 lbs., and is then ready to be shipped to the manufacturer. The raw cotton is not all of the same quality. One kind, which is more highly prized than all others for the length and strength of its fiber, is known as long staple. Its fibers are usually about an inch and a half long. The best variety of the long staple is that known as Sea Island Cotton. It takes its name from the fact that it was first grown, and is still grown to greatest perfection, on the islands lying off the shores of Georgia, the soil of which is rich alluvium. In the commoner sorts, known as short staple, the fibers do not exceed three-quarters of an inch in length.

Lesson 54

Coverings of Mammals—Furs

In the coats of some mammals the hairs are very fine, soft, and smooth, and grow thick and close on the skin. Such a covering is called fur. The fur animals belong mostly to the colder regions of the earth—some of them to the extreme frozen north. Nature has thus provided the very coat that is best suited to such a climate.

Our lessons on heat showed us that fur is a non-conductor; it protects these animals from the rigor of the climate by preventing their bodily heat from passing away. All these creatures, like the rabbit and our domestic cat, partly shed their fur in the summer, so that during the hot weather their coat is loose and open. With the return of winter the fur coat is renewed as thick and close as ever.

Another very remarkable fact should be noticed in connection with these fur animals. Some of them, such as the foxes of the Arctic regions, some hares, and the ermine or stoat of our cold countries, actually change the color of their fur at the approach of winter. After a few days' exposure to the snow the fur becomes white, not because new white hairs have grown, but because every existing hair has changed color.

Let us once again carry our minds back to our lessons on heat. In one of those lessons we learned that white and light-colored substances generally are bad radiators of heat. These white fur coats do not radiate the bodily heat so quickly as darker-colored fur would.

This, again, is only one part of Nature's beneficent provision. The whiteness of the fur is so like the snowy surroundings as to afford these creatures a sort of protection against their numerous prowling enemies. They cannot be easily seen against the white snow all round them.

If the coat of a fur animal be carefully examined, it will be seen that the fur is not all alike. There is a thick, short, close, silky fur near the skin, and other long, stiff, straight hairs overlying it. The former is the real fur; the latter is known as the over-hair. This over-hair performs an important duty in helping to keep the fur somewhat loose, and so preventing it from matting together.

The furs of animals furnish us with one of the richest, warmest, and most beautiful materials for our own clothing. Many millions of animals are killed every year for the sake of their fur-skins, or pelts, as they are called.

It is clear, from what has already been said, that the best time for taking these animals is the winter, for then their coats are at their thickest and best.

A considerable number of the skins are dried and dressed for use with the fur on them. It is estimated that for this purpose alone no fewer than thirty million pelts are collected every year.

Among the furs used are those of the squirrel, sable, hare, rabbit, ermine (the white winter dress of the stoat), pole-cat, black-fox, silver-fox, red-fox, blue-fox, beaver, seal, sea-otter, minx, bear, skunk, marten, and racoon.

Many of these owe their elegance and value chiefly to the length and fineness of the over-hair; but in the preparation of the seal-skin the over-hair is all cut away.

This is done in a curious way. The skin is 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, the deeply-embedded

roots of the over-hairs are cut through, and it is an easy matter then to pull out the hairs.

Immense numbers, amounting to many millions, of hare and rabbit skins are used every year in the manufacture of felt for felt hats. For this purpose the fur only is used. It is first separated from the skin, and then by means of hot water and pressure the hairs are made to interlace and mat themselves together so as to form a hard felt.

Lesson 55

Specific Heat

"We may as well begin our lesson to-day with an experiment," said Mr. Wilson. "It will be a very simple one, but it will start us on our way. I have here a basin of cold water. We will test it with the thermometer to find its temperature. Now take the poker, red-hot as it is, and plunge it into the basin. After stirring it about for a short time, you may remove it from the water. Its heat has all gone ; it is cool. But what has become of the heat? The poker has given up its heat to the water, as we soon find, with the aid of the thermometer. This instrument at once tells us that the water is warmer than it was. It has taken in the heat which the poker gave out. The poker and the water are now at the same temperature.

"Suppose we proceed a little further. I have suspended in this kettle of boiling water a ball of iron, and another, exactly the same size, of lead. What is the temperature of the boiling water?"

"It is 212°F., sir."

"Quite right; and if we test the balls with the thermometer, they too will show the same temperature, 212°F. We will now remove both balls, and plunge them into equal quantities of water from the pipe. What will be the effect of the heated metal balls on this water?"

"I suppose in each case the heat will be given out by the ball and absorbed by the water—the water will be heated," replied Fred.

"Let us see," continued Mr. Wilson. "The thermometer, as usual, will quickly tell us of any change in the temperature of the water.

"Yes," he went on, after testing it, "the water in both basins has been heated, but, strange to say, the iron ball has made the water in the one basin hotter than the lead has made that in the other. This proves that the iron must have given out more heat than the lead.

"But the iron and the lead both obtained their heat from the same source—the boiling water. Hence it is clear that the iron is able to take in and hold more heat than the lead.

"The result would be very similar if we substituted any other kind of matter for the iron and the lead. We should find that some bodies have a greater capacity for holding heat than others. This is exactly what we mean when we speak of the specific heat of different bodies.

"We can now take another step. I have here some ice-cold water; the thermometer standing in it registers 32°F. I am going to measure equal quantities of this, and of boiling water from the kettle, and mix the two together in this basin. Let us see what the thermometer has to tell us about the mixture. The temperature of the mixture is 122°. Now the difference between 212° and 32° is 180°. The hot water gives up, and the cold water receives, exactly half of this, i.e. 90°. Hence the ice-cold water increases its temperature from 32° to 122°, and the boiling water lessens its temperature from 212° to 122°.

"It is important to remember that the result would be exactly the same if we mixed equal quantities of any liquid—oil with oil, or mercury with mercury. The quantity of heat which the hot liquid gives out in cooling through a certain number of degrees is just what is required to raise the temperature of the cool liquid through the same number of degrees.

"Let us next take equal quantities of different liquids, say mercury and water, the mercury being heated to a temperature of 212°, the water standing at 32°. On mixing these, and testing the mixture with the thermometer as before, we shall find the new temperature to be a little below 38°. That is, the water, in this instance, will have gained only about 6° in temperature, although the mercury has been lowered from 212° to the same temperature as the water, viz. 38°.

"That is to say, the mercury has lost 212°-38°=174°, and all this heat has been absorbed by the water for the purpose of increasing its own temperature from 32° to 38° (6°).

"If, on the other hand, we took water at 212°, and mercury at 32°, and mixed them in equal quantities, we should find the resulting temperature of the mixture to be about 206°. The water would part with only about 6° of its heat, but this would be sufficient to raise the temperature of the mercury from 32° to 206°, so that the quantity of heat which is sufficient to raise the temperature of mercury 174° will raise an equal amount of water through only 6°.

"This shows, by another method, that water has a greater capacity for taking up and holding heat than mercury. We say that the specific heat of water is higher than that of mercury."

Lesson 56

The Cotton Manufacture

In our country cotton has flourished ever since the first years of settlement, but our exports of the fiber did not begin till 1770. In that year the first shipment of 20,000 lbs. was made. The great invention of the cotton gin by Eli Whitney in 1793, and the cheapening of the process of cultivation, as well as of cleansing, increased our exports to 17,789,803 lbs. in 1800, and to 3,450,000,000 lbs. in 1890.

When, nearly three hundred years ago, the cotton manufacture was first introduced into Europe, all the work was done by hand. It is now almost entirely accomplished by machinery and steam. Abundance of cheap coal is therefore an essential, and this is commonly supplied by the coal-fields in the neighborhood of the great centres of manufacture.

If we examine a piece of calico side by side with some raw cotton-wool, we shall see, from the nature of the fabric, that the whole work of manufacture resolves itself into two great processes. The short, matted fibers of the raw cotton must be formed into lengths of yarn or thread, and these threads must be woven into a web.

It would be impossible to attempt to convey a notion of the intricate machinery by which the various processes are carried out. We must be content with trying to grasp the broad principles on which they are worked.

The first step, then, towards making the tangled fibers of the raw cotton into yarn must be to draw them out and separate them. This is done in a machine called a willow, which is practically a large box in which rollers, fitted with iron spikes, are made to revolve rapidly. The raw cotton is put into the box, and the spikes, as they revolve, catch it up, tear and loosen the fibers, and shake it free from dust and dirt. From the willow the loosened fibers are passed on to the carding machine, which consists of a number of revolving brushes made of iron wire. Carding is only another word for combing or brushing. The work of the carding machine is to brush out, and lay straight and parallel, the cotton fibers, just as a girl brushes out her long hair. The carded cotton passes out from this machine like a thin, white film, and is called a sliver. The slivers are taken to another machine, in which they are gradually drawn out and slightly twisted again and again by a process called roving, till they are longer, stronger, and finer than they were. In this state they are ready to be spun into yarn. In the spinning-machine the rove (as the loose thread is called) is lengthened and strengthened, by being still further twisted, and it leaves the spinner as yarn, ready for the weaver's loom. The strong sewingcotton, which is used for needlework, is made of several yarns twisted together.

Our lessons on flax and linen-making, in one of the earlier stages, made us familiar with the broad principles which underlie the process of weaving. You, no doubt, remember that in all woven fabrics the web consists of two sets of threads, arranged at right angles to each other, one called the warp, the other the weft or woof.

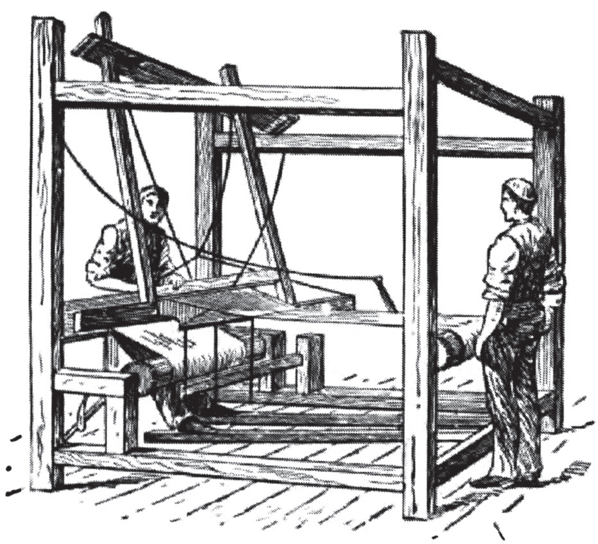
If we examine a large piece of calico as it comes from the draper, we shall see on either side a finished edge or border, which will not unravel. We call it the selvage. The material was woven in one long piece, probably hundreds of yards in length, but the width of the piece is the same throughout, and is marked by this selvage, or self-edge.

The threads of the warp are arranged by stretching a number of rests, or bobbins of yarn, side by side between two yarn-rollers, one in front, the other at the back of the loom. The warp, when finally arranged, tells the width of the intended fabric. The thread which is to form the woof is wound on a shuttle—a sort of reel pointed at each end.

The first thing, after seeing the warp arranged and the woof wound on the shuttle, is to strengthen the threads by giving them a dressing of that peculiar kind of size called starch gum, which we have spoken of many times as a preparation from baked starch.

This done, the weaver takes his place in front of one of the yarn-rollers, which is called the cloth-beam, and begins the work. We have omitted, however, to notice one point—an important one. Before the weaving begins, the warp is attached to a sort of movable frame, called a heddle, in such a way that the alternate threads can be raised or lowered at will. One set of the threads are raised while the alternate threads are lowered, and lowered while they are raised.

The weaver passes the shuttle, with its woof, from right to left between these two sets of threads—that is, over one set and under the others. Then the heddle is made to change the positions of these alternate threads, lowering one set and raising the others, after which the shuttle is returned between the two as before, and so the work goes on.



There is but one thread of the woof or weft, and it is carried from side to side by the shuttle. The fact of its passing each time between the alternate sets of warp threads forms the selvage at the sides of the cloth. It is important to remember that this is the mode of working the simple hand-loom. All our woven goods are now made in enormous, steam power-looms worked by machinery too intricate for us to consider here. But if we can follow the working of the hand-loom, we shall be able to understand the principle of even the ponderous machinery of our great cotton mills.

Lesson 57

The Effects of the Differences in Specific Heat

"Our last lesson on heat showed us that different bodies have different capacities for taking in and holding heat," began Mr. Wilson, "and we learned to speak of this as the specific heat of such bodies. We are now going to learn some of the effects of these differences.

"Let us begin again with a simple experiment. Here are two small test-tubes, one containing water, the other an equal quantity of mercury, both being at the same temperature, as may be seen by the small thermometer standing in each. I will plunge both of them into the kettle of water which is boiling over the spirit-lamp. The thermometers in the tubes will indicate their rise in temperature. As we watch, the mercury in the one tube is seen to reach 212°F (the temperature of the boiling water) in about half the time that the water in the other tube takes.

"We will now remove both tubes from the heat, and leave them to cool down from their present temperature (212°). The mercury cools twice as rapidly through the same number of degrees as the water does.

"Hence we see that water takes twice as long as mercury to reach a certain temperature, and is twice as long in cooling. The same thing would happen with the lead and iron balls, which we used in our former lesson. The lead cannot take up so much heat as the iron. It would therefore reach the temperature of the boiling water in much less time than the iron. As, moreover, it cannot hold so much heat as the iron, it has less to part with when it cools, and, consequently, the cooling goes on more rapidly than it would in the iron.

"We might expose a variety of substances to the same source of heat—say by placing them in front of the same fire—and we should find that some would rise in temperature more slowly than others. If we removed them in their heated state, at the same moment, into a cold room, those which had grown hot slowly would also cool slowly, and vice versa, because those which have a greater capacity for holding heat than others, have more to take up in heating, and more to part with in cooling, and must therefore take longer.

"Water, as we have seen, has a high specific heat. That is to say, in rising through any number of degrees in temperature, it necessarily takes in an immense quantity of heat, and hence it takes longer to get hot and longer to grow cool than other bodies.

"Think of the oceans, rivers, and lakes all over the world, with their countless multitudes of living inhabitants. It is this high specific heat of water which makes rapid elevation or depression of temperature in them impossible.

"Picture, on the other hand, an ocean of mercury, under the rays of a tropical sun. Even if it were otherwise habitable, the creatures in it could never live through such sudden changes in temperature as would certainly take place. Such a liquid would be quite uninhabitable.

"During the cold season of the year, on the other hand, the sea and all great bodies of water cool. But in cooling they have a great quantity of heat to give out for every degree they lose in temperature. Hence they cool very slowly, and while cooling, the heat which they give out tends to equalize the temperature of the adjoining land.

"Mercury has a low specific heat. A comparatively small quantity of heat is sufficient to raise its temperature through any given number of degrees. Hence it rises and falls in temperature very rapidly. It is this which makes mercury so peculiarly useful for filling thermometers."

Lesson 58

Coverings Of Mammals—Wool

The woolly fleece of the sheep is another modification of the common covering—hair. It has been used for making textile fabrics from very early ages, and for this purpose it is obtained from the animal, not only after its death, but also by shearing during its lifetime.

If we examine a handful of wool, we shall find it more or less wavy in appearance, while at the same time it is light and flexible, softer than ordinary hair, and very elastic.

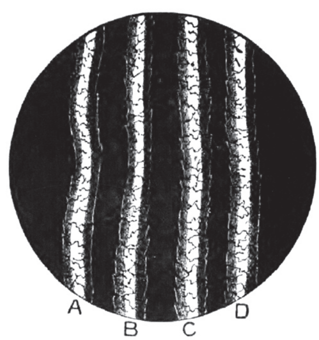
Our lesson on heat showed us wool as a non-conductor. We place our hand on some wool, and we at once feel a sensation of warmth. Why does the wool feel warm? It is not because this substance is warmer in itself than any other we may handle. The thermometer, as you are aware, would register exactly the same temperature wrapped in wool as in a cold-feeling linen handkerchief. But the wool, being a non-conductor, does not rob the hand of its heat as conducting bodies do, and for this reason it feels warm, to the touch.

The thick, yet light fleece of non-conducting wool is Nature's admirable provision for this one of her creatures—

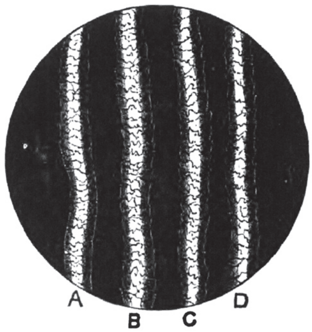
the sheep, which is destined for the colder parts of the temperate zones, where all the year round, in all weather, it spends night and day in the open air, its favorite haunts, even there, being the bleak and breezy uplands of the country.

If a fiber of wool is examined with the aid of a good microscope, rows of scales will be seen covering it, and overlapping one another, something like the scales of a snake's skin, except that the scales themselves project outwards, and thus give the fiber a more or less serrated appearance. This scaly nature of its fibers is one of the most important characteristics of wool. It is one, moreover, which is not met with in any other textile material; the fibers of flax and cotton are smooth.

Even wool itself varies in the nature and abundance of its scales, and it is this which constitutes the different equalities of the material.



In a specimen of Saxony or fine Australian wool, the fibers are always found to be rather short, and very curly or wavy in character. This class of wool is known as short-staple. If one of its fibers were examined under the microscope, it would show a profusion of scales. In some of the finest kinds there are no less than 2500 to the inch, and the fibers have a very serrated or saw-like appearance.



In the English wool the fibers are longer, coarser, and less wavy. It is generally described as long-staple wool. A fiber of this long-staple wool would show under the microscope a much smaller number of scales and serrations than the short-staple variety.

The word staple refers to the individual fibers of the wool. Hence long or short staple means simply long or short fiber.

Its properties as a soft, light, flexible, non-conducting substance make wool a valuable material for clothing purposes. It is made into a great variety of fabrics, but the particular kind of fabric depends entirely upon the profusion, or otherwise, of its scales.

Think for a moment of those highly serrated fibers of the short-staple wool, with their 2500 scales to the inch. Imagine a number of such fibers crossing each other in opposite directions, and pressed close together. What would happen?

The projecting scales would catch one in the other, and hold fast. Take a piece of flannel and a piece of broadcloth, and examine them side by side. Both are made of wool. The flannel may be easily separated, thread by thread, and fiber by fiber; the cloth is a closely-matted felt, which it is very difficult to pull asunder.

This difference is entirely due to the scarcity of scaly projections in the fibers of the flannel material, and to their profusion in the material of the cloth.

It is this one difference which causes wool to yield to the manufacturer two distinct classes of products. The long-staple wool, possessing few projecting scales, yields flannels, blankets, moreens, merinos, alpacas, serges, and all kinds of worsted goods. The short-staple wool, with its abundance of projecting scales, is admirably adapted to felting purposes, and is made into broadcloth, kerseymere, and a great variety of materials, known under the collective name of woollen goods.

Lesson 59

Wool—Its Manufacture

Our examination of the different coverings of animals has shown us that Nature not only provides each creature with a suitable coat, but arranges also for an increased growth of that coat during the inclement season of the year. The sheep's coat is no exception to the rule; it is at its thickest and best during the winter. Like all other creatures, however, it would begin to lose its coat, by a natural shedding of the wool, on the return of warm weather. Instead of leaving the wool, therefore, to fall out during the summer, the farmer cuts it off each spring. With him the sheep-shearing season is always a busy one, as the work must be done at the proper time, and will admit of no delay. Think what it must be to the Australian farmer. A single "squatter's " run in Australia is frequently many miles in extent, and the sheep on it are numbered by hundreds of thousands. Not only the quality of the wool, but the health of the sheep themselves, would be affected by delay in the shearing, and consequently there is great demand for men to do the work.

The shearing process is practically the same everywhere. The sheep are first driven into a shallow pond, and well washed, after which they are allowed to run about in the sunny fields to dry. The shearer then cuts away the wool with a large pair of shears, shearing upwards from the under parts of the body, to the sides, neck, and back.

All the wool from one sheep is called a fleece. The wool from different parts of the fleece varies much in quality—that from the breast, neck, and back being the best, that from the hinder parts the least valuable.

The raw wool is very greasy and very dirty; hence the first business in preparing it for the manufacturer is to thoroughly cleanse it. This is done by boiling it in great coppers, with plenty of soap to dissolve and separate the grease and dirt.

When this is done, the wool is usually dyed the required color, and then the fibers are torn asunder by means of revolving iron spikes, until they form a loose, fluffy down.

If we examine a piece of flannel or some other worsted fabric, we find it an easy matter to separate the material, thread by thread, just as we did the calico and linen. It is just as easy to untwist the threads themselves, and if we did this, we should find that the fabric is made by practically the same processes of spinning and weaving, as those with which we have already become familiar.

There is one material difference, however, in the treatment of the two sorts of wool. The short-staple, wavy, serrated wool is sometimes known as carding-wool; the long-staple as combing-wool.

In the combing process the long, loose fibers are merely drawn out and arranged side by side, as in the combing of cotton fibers. In the carding of the short-staple wool, care is taken to arrange the fibers side by side, in such a way that the ends of some and the roots of others lie together, and the teeth or serrations point in contrary directions. The result of this arrangement is that, when such threads are twisted to form yarn, the serrations catch one in the other, and prevent them from untwisting. The spinning and weaving processes are the same for woollen as for worsted goods, but when a worsted fabric leaves the loom, it is quite finished and ready for use. Not so the piece of cloth.

If we compare a piece of flannel with a piece of broadcloth, we find the warp and woof threads, which are so plain in the former, cannot be seen in the latter; the surface is a smooth, close, and glossy nap. This difference is brought about by the process of fulling or felting. In this process the cloth is folded and beaten with large, heavy hammers for many hours—even days. This causes the fibres of the wool to felt or mat together, so that the cross threads of warp and woof are no longer visible, the little serrations on the fibers being the real cause of the felting.

Of course, this folding and beating of the woven material tends to thicken it considerably, and at the same time makes it shrink, both in length and breadth.

After fulling, the nap of the cloth is raised in a curious way. A great number of the flower-heads (seed-vessels) of the teasel, a plant something like a thistle, are fixed to a large, broad wheel, which is made to pass very rapidly over the cloth, so that the teasels sweep its surface continually. The teasels are covered with little elastic hooks, and these, as they sweep over the cloth, catch up the loose fibers of the wool, and make them stand as a nap. This raised nap is then made smooth and level by means of shears, after which all that remains to be done is to damp, brush, and press it, so as to give it a soft, smooth, glossy surface.