MURCHÉ'S SCIENCE READERS

BOOK IV.

THE MACMILLAN COMPANY

SCIENCE READERS

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SCIENCE READERS

BY

VINCENT T. MURCHÉ

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

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PREFACE

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

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

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

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

Many of the trees mentioned in Lessons VII, XI, XIX, and XXI may be seen by taking a ten or fifteen minute excursion from the school, even in a city. Pieces of the various timbers may be procured from a cabinet-maker.

Different kinds of meat bones, cleaned, will serve to illustrate some of the points made in Lessons III, VI, VIII, X.

By all means secure from a butcher the heart of either a sheep or a beef for Lesson XVIII.

An aquarium consisting of a glass jar filled with water, and two inches of sand, in which is planted a bunch of water-plant, if placed in a good, preferably northern, light, will make an easily cared for home for various kinds of fish, snails, and fresh-water clams. Minnows are sufficiently transparent to show clearly the internal structure. Dace and goldfish may be kept in the same tank.

Turtles, salamanders, snakes, alligators, crayfish, earthworms, squirrels, mice, are also easily kept in any schoolroom. No pictures can ever take their place; moreover, the proper care of them is an education in itself.

L. L. W. Wilson,
Philadelphia Normal School.

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BOOK IV

Lesson I

Cohesion

"Well, how did you like your science lesson to-day, boys?" asked Mr. Wilson, as he overtook our two young friends, Fred and Willie, on their way home. The boys had been promoted to a higher class, and this was the first lesson of the new course. Mr. Wilson, their teacher, was a rare man for his boys, especially those boys who showed that they took an interest in their work. He had long been struck with the earnest attention these two boys paid, and the trouble they took to follow him intelligently, and he made up his mind to help them.

"I think, sir," said Fred, "we shall soon begin to feel at home, for I am sure, from what I saw to-day, our lessons in the lower classes will help us very much. We are going to try hard, for father has promised to send us to an Institute by and by, if we learn all we can now."

"Suppose you tell me something about to-day's lesson, as we walk along," said Mr. Wilson.

"Well," said Willie, "the first thing we

learned was that new word *matter*. We know now that the name *matter* means every substance that exists."

"I think I understand, sir," said Fred, "what you mean by molecules of matter, although it seems difficult to imagine particles so small that they cannot be seen even with the help of a powerful microscope. We learned from our lesson that matter of every kind—solid, liquid, and gas—is made up of extremely small particles, and these particles are called molecules. A *molecule* is the name for the smallest particle of matter that can possibly exist."

"Quite right, Fred," said Mr. Wilson. "If you will keep two things in your mind, you will be pretty clear about these molecules of matter.

"First think of the dissolved particles of a soluble substance. They are all in the liquid, but they have been divided up into such minute particles that they are invisible.

"Then think of our little experiment with mercury. We boiled the mercury in the tube, and as it boiled it passed away in vapor. But we could not see the vapor, because the particles had been divided up too small to be seen. These were molecules of mercury.

"We knew they were there, and we found them when we held the cold slate over the tube. The tiny drops, as they condensed, ran together again and again, till at last they were large enough for us to see."

"We learned, too," said Fred, "that, as all matter is composed of molecules, there must be a force of some kind, which holds them together, or else everything in the world would at once fall away to the finest dust or powder. This force which holds the molecules of matter together is called *cohesion.* It is so named because the word cohesion means holding together."

"That's very good," said Mr. Wilson. "Try and think of our experiments with the poker, and the pieces of lead, wood, glass, and chalk, and tell me what they teach us."

"Oh yes, I remember, sir," said Willie. "We can't break or twist the poker with all our trying. This means that the *force of cohesion* is so *strong* that we cannot separate the molecules from one another. We can bend the piece of cane and the lead, but they do not easily break. We say they are tough. The glass and the chalk snap quickly. There is *less cohesion* between their molecules than there is between the molecules of either lead, wood, or iron. We say the glass and the chalk are brittle."

Lesson II

Solids, Liquids, Gases

"May we walk home with you this afternoon, sir?" asked Fred.

"Certainly, my boys," replied Mr. Wilson. "I was thinking of putting my museum cupboard into your charge," he continued. "You could keep the things in order, dust them regularly, and help me with the experiments during the lessons. Would you like that?"

"Oh, thank you very, very much, sir," said both the boys at once. "We'll be very careful with everything."

"Now, what have you got to chat about as we walk along?" asked Mr. Wilson.

"Our lesson on the force of cohesion, sir," said Fred, "helps us to understand, better than we have ever done, why there should be three distinct states of matter—the solid, the liquid, and the gas.

"A solid is a body whose molecules are held strongly together. *It is a solid simply because the force of cohesion is very strong in it.* Even when we break a soft solid, like a piece of chalk, it does not fall to powder. It breaks into pieces, and these pieces still hold together."

"It was so easy, sir," said Will, "to compare the cohesive force in a liquid and a solid, when you set me to take the water out of the basin, a spoonful at a time. It was no trouble to separate the molecules of water from one another with the spoon, because they are not held together firmly, as the molecules of a solid are."

"Quite right, boys," said Mr. Wilson. "Now what have you to say about the gases?"

"The molecules of a gas soon spread themselves out till they seem to fill the room," said Fred. "This proves that gases are quite different from either solids or liquids. Their molecules have no cohesion at all; they actually repel each other. They are always trying to get as far away from each other as possible."

"Now I want you to try and tell me how the force of cohesion acts," said Mr. Wilson.

"The force of cohesion can act only when the particles are in close contact," said Fred.

"Do you remember," asked Mr. Wilson, "how I proved that?"

"Oh, I remember," said Fred. "It is useless to try and join the two edges of a broken plate or saucer, or any other solid body, by pressing them together, because we cannot bring all the particles into actual contact, and *without actual contact there can be no cohesion.* But it is possible to join two perfectly smooth and level sheets of glass by pressing them together. All their particles are in actual contact, and cohesion acts and joins them."

"Are we to understand, sir," asked Willie, "that cohesion acts only between the molecules of the same kind of substance?"

"Yes," said Mr. Wilson, "the molecules of solid bodies are held together by cohesion, and the molecules of liquids are also held together by cohesion. When we mix two glasses of water, they immediately mingle and form a compact whole, because the molecules are brought into actual contact with each other on all sides."

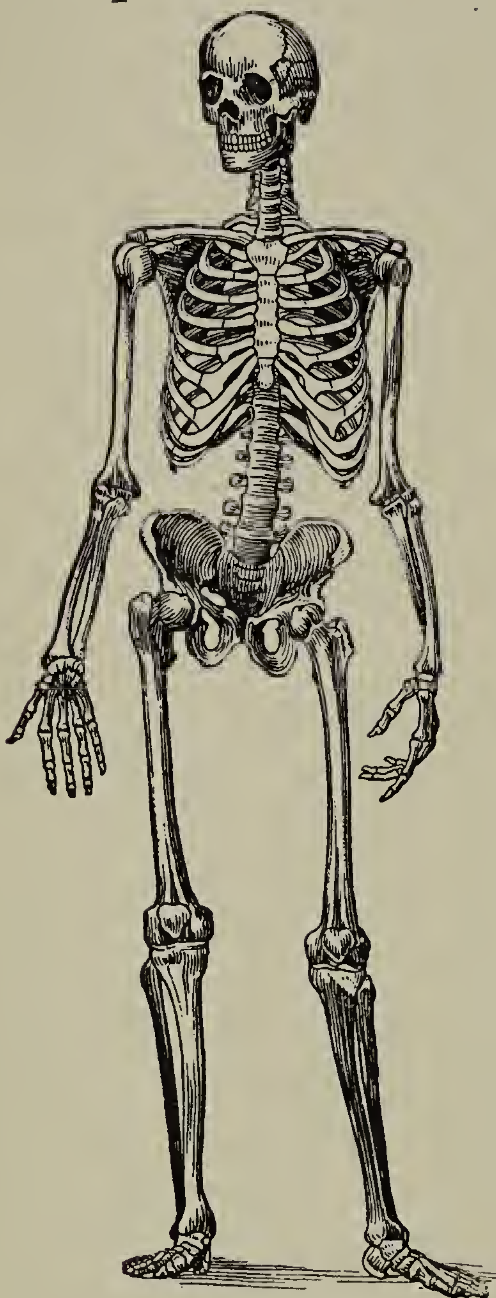
Lesson III

Our Bodies

We can feel, in every part of our body, portions of the hard, solid framework on which the body is built. This strong framework is called the *skeleton*, and consists of upwards of two hundred distinct and separate bones of various shapes and sizes, intended to give strength and solidity, and to support the softer fleshy parts. If you call to mind the various skeletons of animals you have seen, you will at once understand that in every animal it is the skeleton which determines the shape of the body. The skeleton itself suggests at a glance the well-known shape of the individual animal.

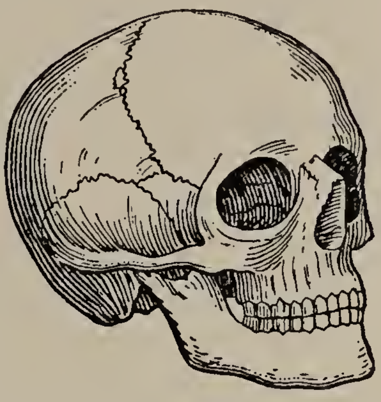
Let us examine our own skeleton, and see how it is made. We will commence with the head, which comprises two parts—the skull and the face.

The *skull* is a hollow box intended to hold and protect the brain. It is built of eight separate bones, most of them broad flat plates. They are joined together firmly at their edges, because, as they simply form a box, there is no need for these bones to move. The face comprises all the rest of the head that is not included in the skull. It is formed of no less than fourteen separate bones. The only thing calling for special notice in the arrangement of these bones is the provision, which is made by them for the protection of the eyes, by lodging those organs in great hollows formed in the bones themselves. These hollows are called the *orbits* or *sockets* of the eyes. Notice how providentially they are surrounded by the broad frontal-bone of the forehead above, the nose-bone between them, and the cheek-bones below. These effectually protect the delicate organs from

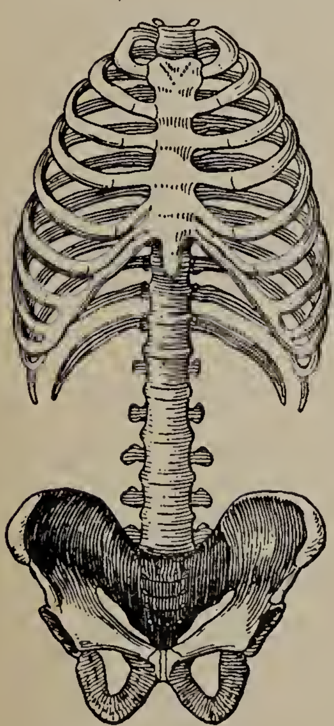


THE SKELETON.

injury. Only one of all these fourteen bones of the face is capable of movement. Which is it? The lower jaw-bone moves so as to open and close the mouth. It is attached on either side by a sort of hinge to the other bones of the skull.

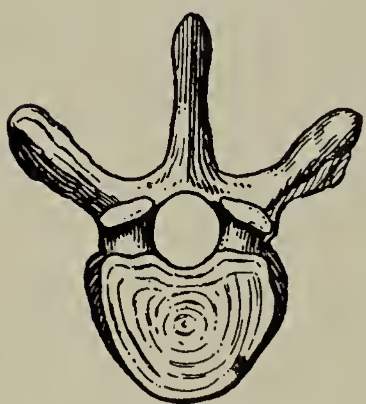

THE SKULL AND FACE.

Both jaws are armed with teeth for biting and chewing our food. We have during our lives two sets of teeth. The first, called the *milk teeth*, are twenty in number, and are shed while we are young. The others, known as the *permanent teeth*, last through the rest of our life. There are thirty-two permanent teeth in the complete set.


THE TRUNK.

The trunk is that part of the body which would be left if the head and limbs were lopped off. The main pillar of the body is the backbone, which extends from the neck to the bottom of the trunk. It is not actually a single bone, but a string of separate bones called *vertebræ*, and is called the *vertebral column*.

The vertebræ are joined together by thick smooth pads of gristle, which form springy yielding cushions between each bone and the one above it. The seven smallest and topmost vertebræ form the neck; they support the head. Next to these come twelve vertebræ, each of which supports a pair of ribs—one on either side. The ribs form a kind of hollow bony cage, which we call the chest. They are joined in front to the breast-bone. It is worth noticing that the vertebræ increase in size and solidity downwards. The bones at the base of the column are very thick, solid, and strong.


A VERTEBRA.

It is a curious fact, too, that the vertebral column of a *child* contains *thirty-three distinct bones;* but there are only *twenty-six* bones in the vertebral column of an *adult.* The explanation is this. As the child advances into adult life the four lowermost vertebræ grow together and form one piece, corresponding to the tail of the lower animals—in fact, a sort of rudimentary tail; and at the same time the five next above these also become welded into one piece to form the *sacrum.* The sacrum and the great haunch or hip-bones form a sort of bony basin—the *pelvis*—at the base of the column.

Lesson IV

The Woody Stems of Plants

"It was a great surprise to me, sir," said Fred, "to learn that the stems as well as the leaves of plants differ, according to the kind of seed from

AN ELM-TREE.

which they spring. Our last year's lessons taught us to look for net-veined leaves on a plant which grows from a seed with double seed-leaves, and for parallel-veined leaves on one which comes from a seed with a single seed-leaf. We learn from our lesson to-day that the seed with the double seed-leaf produces one kind of stem, and the seed with a single seed-leaf a totally different stem."

"Do you remember the other name for the seed-leaves, Fred?" asked Mr. Wilson.

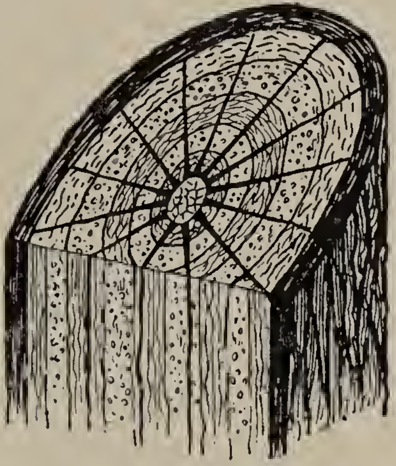
PALM-TREES.

"Yes, sir; they are called *cotyledons.* Those seeds which have only one seed-leaf are called *mono-cotyledons;* those with two seed-leaves are *di-cotyledons.*"

"Try and tell me all you can about the stem of the di-cotyledon." said Mr, Wilson.

"Most of the plants in every part of the world, sir, are di-cotyledons. They all have net-veined leaves; but some of them are herbaceous, and die down to the ground every season. These, of course, have no woody stem. The nature of the woody stem of the di-cotyledon can be easily understood from a piece of the stem or branch of one of our common trees. This always has a central pith, with the hard solid wood arranged round it in layers or circles.

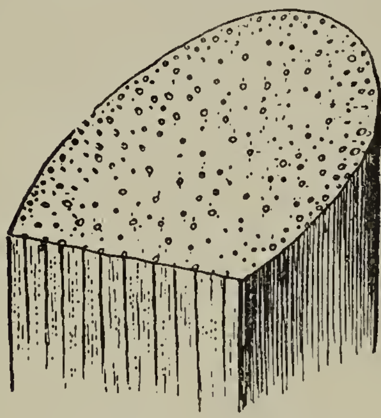
"You explained to us, too, sir, that when the tree was young this pith was soft, greenish, pulpy matter, and took up all the centre of the stem. It was through this central pith that the dissolved earth-food absorbed by the roots rose upwards to the leaves. It had then only one woody layer round it. Next year, however, and each year after, a new layer of wood was formed on the outside; and these rings of new wood compressed the pith, till at last it became a mere thread. The woody stems of all di-cotyledons grow in this way, by the yearly addition of a new layer on the outside. They are called *ex-ogens*. The word *exogen* means *growing outwards*."



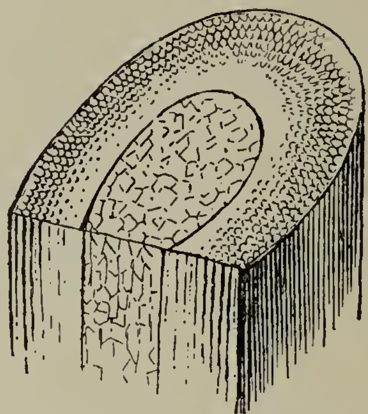
SECTION OF EXOGENOUS STEM.

"Very good, my boy," said Mr. Wilson. "Now, Willie shall tell us all he can about the stem of the mono-cotyledon."

"The woody stems of these plants are best

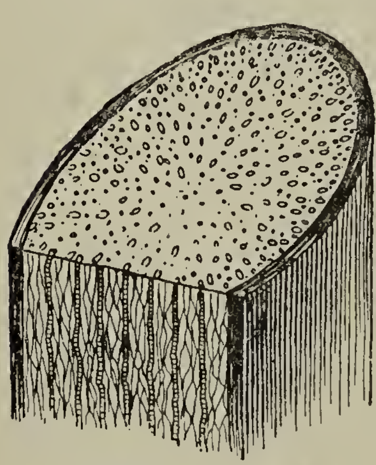


SECTION OF CANE.



SECTION OF BAMBOO.

understood, sir," said Will, "by examining a piece of cane or bamboo. The wood is always arranged in parallel fibres through the stem from root to top. There is a pith, but it is mixed up with the parallel threads of wood. The parallel bundles of woody threads pass upwards through the pith itself. In these stems the oldest and hardest wood is on the outside — not in the centre, as it is in the ex-ogens. The stem grows from within; the new wood is in the centre. Plants of this kind are called *endogens*, which means *growing from within*. These endogens or mono-cotyledons form a small class of plants.



SECTION OF PALM.

The palms, canes, and bamboos are the chief of them."

Lesson V

Capillary Attraction

"I can understand now, I think, sir," said Fred, as they walked home, "why porous bodies have the power of absorbing liquids. Our former lessons merely taught us that this absorption actually takes place. We saw the liquids rise in the porous bodies. To-day's lesson shows us the reason why they rise."

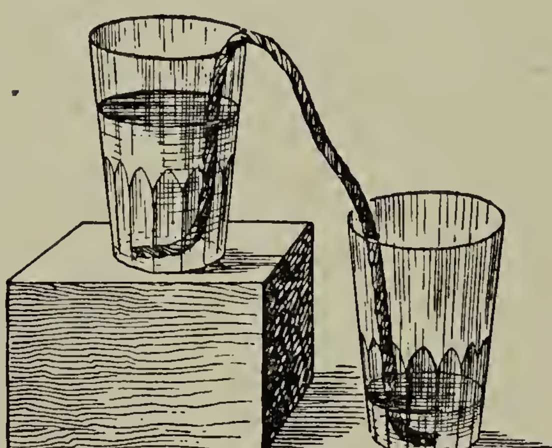
"Well, Fred," said Mr. Wilson, "suppose you try and explain what really happens."

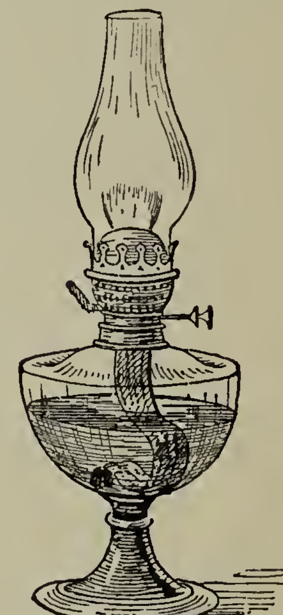
"I think I should begin, sir, by trying to tell the difference between the force of *cohesion* and the force of *adhesion*. Our lesson on cohesion showed us that it is a very difficult matter to join the particles of a solid, because, smooth as their surfaces may appear to the naked eye, the magnifying-glass proves them to be so rough and uneven that it is impossible to make them touch at all points, and without touching everywhere there can be no cohesion.

"On the other hand, it is quite easy to make a liquid and a solid join, because the liquid flows and fills up the inequalities in the surface of the solid, so that the two bodies touch everywhere, and the liquid holds to the solid."

"Does the force of cohesion accomplish this too?" asked Mr. Wilson.

"No, sir," said Fred. "We call the force which holds the liquid to the solid by another name—*adhesion*; and the liquid is said to adhere to the solid. The experiment which you showed us with the fine hair-tube, sir, is all due to this adhesive force between the liquid and the solid. The colored water rose in the tube by *capillary attraction*. The word *capillary* means *like a hair*.





"Capillary attraction takes place because of the adhesive force between the liquid and the sides of the glass tube. This adhesive force draws the particles of water upwards and makes them adhere to the sides of the tube."

"But you have not told us yet, Fred," said Mr. Wilson, "what all this has to do with the absorbing power of porous bodies."

"I am coming to that now, sir," said Fred. "Every pore in a porous body is really a little tube; and the liquids are absorbed into the pores by capillary attraction, just as the colored liquid rose in the capillary tube."

"That's capital," said Mr. Wilson. 'You've mastered this matter well, Fred. Remember, it is the same capillary attraction that raises the oil in the lamp wick for the supply of the flame; it is the same capillary attraction that emptied the tumbler of water when you hung the piece of loose wick over the edge of the glass; it is the same capillary attraction that allows the soil in the flower-pot to suck up water from the saucer in which it is placed."

Lesson VI

More about the Skeleton

The human skeleton, and the skeletons of most of the animals we have examined, are built upon one general plan as regards the limbs. There are two pairs of limbs. In birds the upper limbs are modified to form wings, but the structure even here is essentially the same.

Let us examine the human limbs now. The arm has thirty-two distinct bones, and consists of three parts—an upper arm, a fore-arm, and a hand; the leg also consists of three corresponding parts—an upper leg (thigh), a lower leg, and a foot. It contains thirty separate bones.

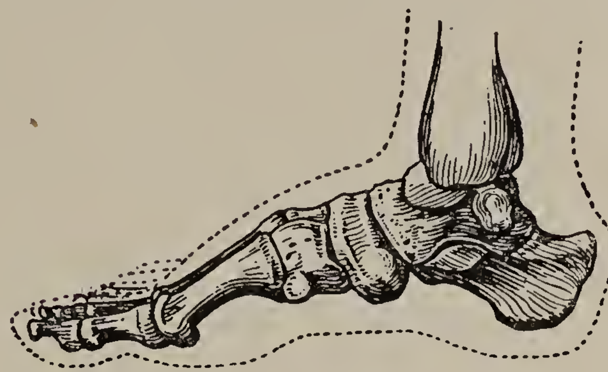
The upper arm and the thigh are each formed by a single long bone. The fore-arm consists of two bones (one larger than the other), jointed at the elbow to the bone of the upper-arm. The lower leg also consists of two bones (one larger than the other), jointed at the knee to the thigh-bone. The knee-joint, however, differs from the elbow-joint in having a small bone —the knee-cap—placed over the joint. There is no corresponding bone in the arm.

The hand and the foot are built on very much the same plan. The wrist of the one corresponds to the ankle of the other. The wrist has eight small bones; the ankle seven. The palm of the hand corresponds to the sole of the foot, and each of them has five bones running through it, which carry the fingers and toes respectively.

BONES OF HAND.

The hand has four fingers and a thumb—each finger being formed of three bones, the thumb of two. The foot, in its turn, has four toes and a great toe; the great toe having two bones, each of the others three.

We have only to consider the purposes for which the hand and the foot are respectively designed, and we must be at once struck with admiration for the manner in which each is adapted to its work. In the hand, flexibility and easy rapid movement, deli-


BONES OF FOOT.

cate touch, and firm grasping powers have to be secured. Hence the wrist bones are small, those of the fingers very long, while the thumb is placed so as to be able to move in the opposite direction to the fingers. In the foot, we need strength and solidity of support; consequently the whole of the bones are short, thick, heavy, and clumsy in appearance. The great toe has no grasping power, corresponding to that of the thumb.


SHOULDER JOINT.

The bone of the upper arm is joined at the shoulder to a large flat bone—the *shoulder-blade*, which lies behind the ribs. The shoulder-blade is kept in position in a wonderful way by the *collar-bone*. This bone stretches from the top of the breast-bone to the shoulder joint, its outer end being firmly fixed to the shoulder-blade. It is this bone which forms the prominent part of the shoulder. It acts as a rigid bar to brace the shoulder-blade up. The two collar-bones in front and the two shoulder-blades behind form what is known as the *shoulder-girdle.*

The thigh-bone is joined to the great haunch or hip bone.

Lesson VII

The Oak Stem

"I had often wondered, sir, at the beautiful markings of the various ornamental woods used by the cabinet-maker," said Fred, as they were putting the things away after the lesson. "I think I understand it clearly now."

"I want you to be quite clear as to those medullary rays," said Mr. Wilson. "In all these stems there are two kinds of matter. There is the hard, fibrous, woody tissue and the softer tissue of the pith. In the young tree you have seen that the stem is almost all pith, and that the pith is the channel for the upward passage of the sap.

SECTION OF OAK STEM.

As the new layers of wood are formed round it year by year, the pith becomes more and more compressed; and it sends out thin walls of its own substance, radiating to the outside of the stem, so as to separate the woody tissue into wedge-like blocks. These radiating walls of soft matter are the *medullary rays.* They carry on the work of the pith, and form channels for the flow of the sap."

"But the sap does not always rise through the medullary rays, does it, sir?" asked Willie.

"As the tree grows from the outside," said Mr. Wilson, "the older part of the stem is subject to more and more pressure. The walls of soft matter between the wedges of wood become thinner and thinner, till they are the finest sheets, and the medullary tissue itself has ceased to be living matter. After this it no longer carries up the sap. When the stem is cut across, only the thin edges of these partition walls are seen, and they appear to be mere lines."

"Thank you, sir," said Fred. "These are the lines then that the cabinet-maker calls the *silver-grain* of the wood."

"Yes, Fred, they are," said Mr. Wilson. "The beauty of the wood depends upon the closeness of its texture, and the skill of the workman in cutting it so as to expose this silver grain. Which part of the woody stem did you say was first formed?"

"The central part of the stem, sir, is the oldest wood in the tree."

"Tell me again what happens to this part as new layers are formed one by one round it?"

"The outer layers press upon it more and more, sir, and it becomes denser and denser."

"Quite true," said Mr. Wilson; "and it becomes the hardest wood in the tree. It is called *heart-wood.* Heart-wood is always selected where strength and durability are required. The heart-wood becomes darker and more deeply colored than the layers round it, and it is the graduation of coloring that makes our cabinet woods so beautiful.

"Where do we find the newly-formed wood in the stem?"

"The last-formed layer of wood is always found on the outside, just under the bark," said Willie. "It is called the *sap-wood.* It is formed from the sap which has passed upwards through the stem and leaves. The sap, after it has flowed back from the leaves, is deposited in this part of the stem, where it forms the new layer of sap-wood."

"A very good answer, my boy," said Mr. Wilson. "This sap-wood is at first soft, pulpy matter, and while in that state it affords a convenient channel for the upward passage of the sap, which can no longer rise through the dead flattened cells of the pith and the medullary rays."

Lesson VIII

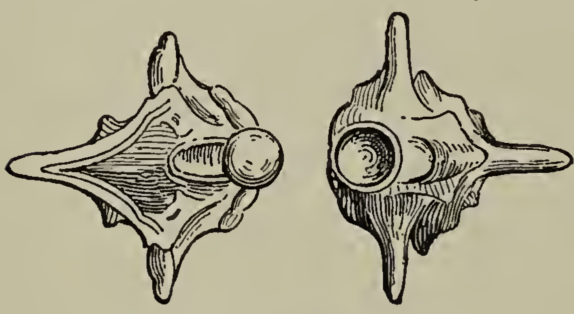
Joints

In our lessons on the human skeleton we found that some of the bones, such as those of the skull and face, are not meant to move. These bones are united firmly together.

The bones of the limbs, on the contrary, provide for every variety of movement. This freedom of action is due, partly to the large number of individual bones in the limbs, and partly to the manner in which they are arranged and jointed one with another. Wherever two bones are connected in such a way that they can move one upon the other, they form a joint. The variety of movement is brought about by a corresponding variety of joints.

I open and shut my hand, I bend and straighten my arm or my leg, and it is easy to compare these movements with the backward and forward movements of a door on its hinge. Such joints are known as *hinge-joints.* They are the most numerous in the body. We find them at the elbow, the knee, the wrist, and the ankle, and in the fingers and toes. We have already had occasion to notice the admirable arrangement of the thumb. It has not only a backward and forward movement, such as the fingers have; it can move also from side to side in a direction at right angles to that. It should be carefully noted that the remarkable freedom of movement in the thumb is not brought about altogether by the structure of the thumb itself. The thumb works upon a long bone, which forms the link to connect it with the wrist. It is the joint between this bone and one of the wrist bones which provides for the double movement.

Our lessons on the snake and its structure have made us already familiar with the nature of a *ball-and-socket joint*. You know that in joints of this kind the moving bone has a rounded knob—a sort of ball—at its extremity, and this ball fits into a cup-shaped hollow in the other bone. The ball of the one bone plays freely in the hollow cup of the other, and this allows of very extensive movement in any direction.

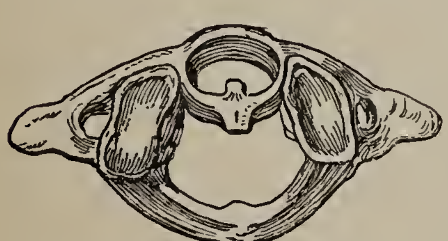


BALL-AND-SOCKET JOINT.

The bone of the upper arm and the bone of the thigh have each a round knob or ball, which fits and moves freely in a corresponding cup or socket in the shoulder-blade and hip-bone respectively. This kind of joint allows of the widest freedom,—a fact which is well illustrated in our drill exercises. The leg provides for the same kind of movement as the arm, but they differ in extent. We cannot swing the legs as freely as we can the arms. The reason is that the cup in the hip-joint is very deep, and the ball of the thigh-bone is deeply lodged in it. Consequently the movement there is not so extensive as at the shoulder joint, where the cup is shallow.

Now think of the head and its movements on the neck. We are able to move the head forward and backward, as in the act of nodding, and to depress it towards either shoulder. This, you will readily see, is the work of a *double-hinge-joint.* The joint is between the base of the skull and the topmost vertebra on which it rests.

But we have only to turn the head right



THE TOPMOST VERTEBRA.

SECOND VERTEBRA, SHOWING PEG.

and left, to be reminded that there is another movement provided for, besides that of the hinge. In the topmost vertebra which carries the skull there is a small hollow ring, into which fits an upright peg or pivot of the second vertebra. When the head turns right and left, it is this topmost vertebra which really moves round on the peg of the second, and in moving it carries the skull round with it.

Such a joint is known as a *pivot-joint.*

There is one very important arrangement that must not be lost sight of in connection with all these joints. The joints are designed for movement, and all movements must be smooth and easy. There must be no friction, no grating.

If we examine some piece of machinery, we shall find all the working surfaces perfectly smooth; and we know that the machinist is careful to keep these smooth surfaces well oiled, so that they may glide easily over each other. The movable bones are constructed on much the same principle. Their working surfaces are covered with a smooth coating of gristle, and each joint is enclosed in a membrane, which has the power of preparing and pouring into it a peculiar oily fluid known as *synovia,* or *joint-oil.* In this way nature provides not only the machinery, but the joint-oil to lubricate it, so that it may work easily and smoothly.

Lesson IX

Properties of Bodies

"Are you coming with me, boys?" asked Mr. Wilson, as he passed out of the playground gate, and in a moment Fred and Willie were trudging along by his side.

"Well," said he, "what do you think of the force of cohesion now?"

"I can see, sir," said Fred, "that it has more to do with solid bodies and their properties than I thought it had. In our early lessons we learned something about the properties of bodies. We are now able to say not only that a body has certain properties, but to tell the reason why it has these properties. If I were to scratch a piece of lead, for instance, with an iron nail, a boy in one of the lower classes might say that I was able to do it because the iron is harder than the lead. So it is, but he would not be able to say why the iron is harder than the lead.

"We can now tell this from the force of cohesion. When the force of cohesion in a solid is great, the molecules are held very closely together, and the body is hard. When there is little cohesion, the molecules are more loosely held together, and the body is soft. It is because the particles of the soft body are held loosely, that a hard substance is able to force them aside, as it does when it scratches them.

"We learned, too, that some bodies are brittle and break with a blow; some are tough and will not break; some are flexible and bend easily without breaking; and some are elastic and will not only bend, but will even spring back to their original shape when let go.

"Our old lessons taught us all this, but we can now go back to the force of cohesion to find the reason why certain bodies have these properties. When the cork, whalebone, lead, cane, and wire are bent and twisted, their molecules are forced out of their proper position. The whalebone, cork, and cane spring back to their former shape again, because each molecule takes up its old position."

"I have been thinking about the metals, sir," said Willie. "Most of the metals are very tenacious; and it is this property which renders them so useful. Their tenacity, I suppose, is entirely due to the force of cohesion between their molecules."

"It is, Willie," said Mr. Wilson. "A body is brittle when it possesses very little cohesion; it is tenacious when cohesion in it is strong. It is only the tenacious metals that are malleable and ductile. When a piece of metal is beaten out thin, or drawn out into wire, it really means that its molecules have been forced into different positions, and because they do this without losing their cohesion, the metal holds together. No metal can be malleable or ductile unless there is a very strong force of cohesion between its molecules."

"I remember you told us too, sir," said Fred, "that cohesion will account for the different weight of different bodies. In a heavy body the force of cohesion is stronger than in a light one; the molecules are held more closely together."

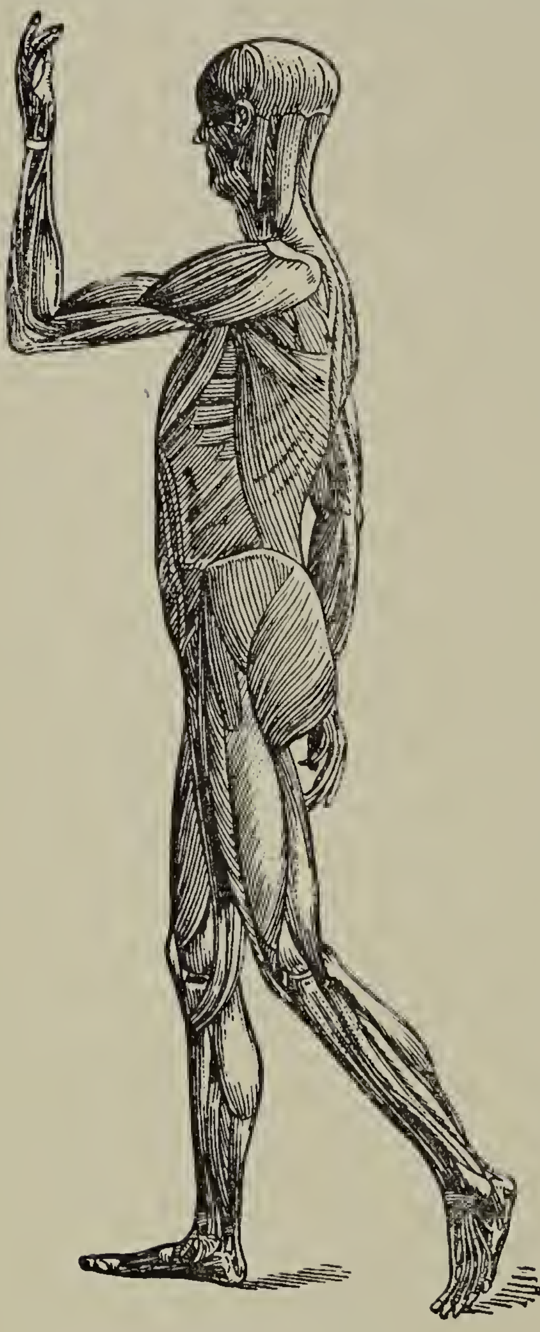
"Quite true," said Mr. Wilson; "and as a result of that, more matter is massed together into a given bulk, than if there were less cohesion."

Lesson X

How the Bones Move

Our lesson on the joints showed us the bones of the body in action—some moving with a simple backward and forward hinge-like movement, some swinging round in a circle by means of a ball and socket, and some, again, rotating on a peg or pivot. But have you asked yourselves why these bones do not slip out of their places with their work? Let me tell you the reason. At each joint there are strong gristly bands, called *ligaments*, which hold or bind the bones together, while at the same time they do not interfere with their freedom of movement.

We will now turn our attention to the force which puts this machinery in motion. If the white skin all over the body were stripped off, the red flesh would be seen beneath. This red flesh is *muscle.* The *muscles* are the agents by which all the movements of the body are carried out. Hence where the greatest power of movement is required, there we find the largest and strongest muscles. In some parts of the body, as in the legs and arms, the muscles are placed in large solid-looking masses round the bones. In other parts we find the muscles extended between the bones. The skull has a very slight covering of muscle beneath the skin, for the simple reason that the bones of the skull do not move, and hence muscles are not required.

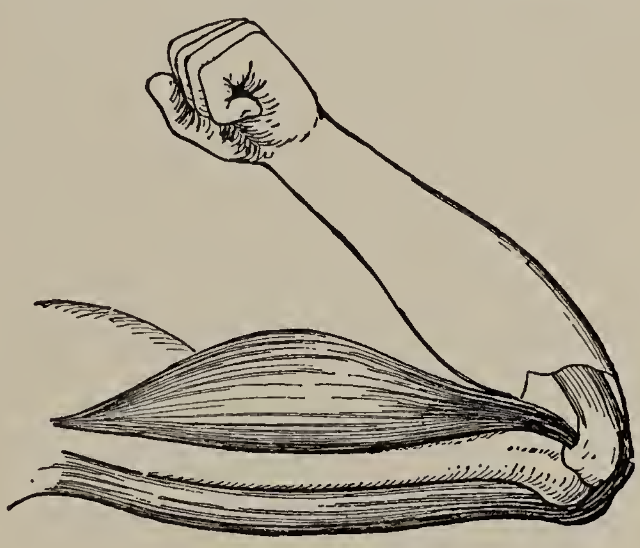


THE MUSCLES.

A piece of lean flesh from the body of any animal would be found on examination to consist of separate bundles of flesh, arranged side by side in such a way that each has the power of moving or sliding about independently of the rest. These separate bundles of flesh are the muscles.

A muscle consists of a thick, solid middle part, which is called the belly, and two tapering ends. As a rule the muscle is attached to two bones—one fixed, the other movable. It is not joined directly to the bones. The tapering ends usually terminate in tough, whitish, leather-like cords, which we call *tendons*. It is the *tendon* which *binds the muscle to the bone.*

We have now to inquire how the muscles act. The substance of which they are formed is very elastic; but their elasticity is that of sponge or cork, not that of india-rubber. You remember of course that cork and sponge contract or shrink up with pressure, and expand or spring back when that pressure is removed. India-rubber, on the other hand, expands when pulled, and contracts when let go. The muscles then contract when they are interfered with.



BICEPS MUSCLE.

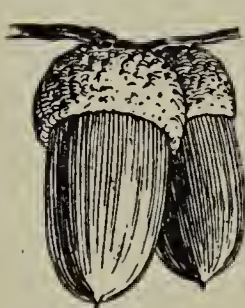
You will understand the action of the muscles if you straighten the right arm, place the left hand on the fleshy part of it above the elbow, and then bend it upwards to the shoulder.

That part which swells up under your hand as the arm bends, is the great *biceps muscle.* It is connected at one end with the upper arm, and at the other with the fore-arm. When it contracts it becomes shorter and thicker. This is why you feel it swell up under your hand. Of course, as it becomes shorter, it draws up the fore-arm. There are more than 500 distinct muscles in the body, and this is their common manner of working

Lesson XI

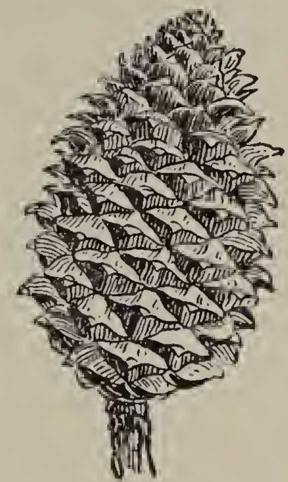
The Oak and the Pine (a Comparison)

"In our last lesson on trees we took the oak as the representative of the di-cotyledons or exogens," said Mr. Wilson. "There are a large family of timber trees—spruces and pines—which are usually classed with the exogens, but they differ from the oak and other timber trees in many important particulars. Let us find out these points of difference.



Here are some acorns. These, you know, are the fruit of the oak tree. Take some of them in your hands and remove the seed from the outer shell. If you open it carefully you will see at once why it is called a di-cotyledon. It has the usual double seed-leaves.

"Now look at this pine-cone. This, you know, is the fruit of the fir and pine family of trees. Notice that it consists of a number of dry hard scales. Each scale is a single fruit. It is the ripened pistil of the flower; but the pistil in this instance, instead of being a hollow receptacle for the seed, is simply a leaf, with the seed attached to its upper surface.



"As the cone ripens, this pistil-leaf becomes a dry scale, which curls up, and sheds its seed, leaving it to blow away or fall to the ground.

"The firs and pines are often called cone-bearing trees, because they are the only trees which bear fruit of this kind.

"What is the first distinction we have found then between the oak and the pine?"

"The fruit of the oak," said Fred, "is a *nut* which we call an acorn, and *its seed is a di-cotyledon;* the fruit of the pine is a *cone with dry scale-seeds.*"

"We will next examine the stems of the oak and the pine," said Mr. Wilson. "I have a good specimen of each of them here. If you look into them closely, you will not be able to find any difference in the appearance of the two. In each stem there is the same central pith-spot, with the same ringlayers of wood round it, and the same outer covering of bark.

"But there is a difference between them, and as it is not one which you can find out for yourselves, I must tell you what it is. The pines and the firs are resinous trees. Their stems yield the inflammable substances known as turpentine and resin. It is easy to detect the resinous smell in these woods. The oak stem is not resinous. It yields no liquid of any sort. Hence, you see, we have a second distinction between these two families of trees.

OAK LEAVES AND ACORNS.

"But we must pass on now to the leaves. Here are some oak leaves. Take them in your hands and examine them. Now describe them."

"They are like most of the common leaves," said Willie, "and consist of a blade and a foot-stalk. There are ribs crossing the blade, and a network of veins running all over it."

"Quite correct," said Mr. Wilson; "they are the usual leaves of the di-cotyledon; and, moreover, the microscope would show us the breathing pores, studded all over the blade.

"Now look at the pine leaves," he continued. "Here they are. They are more like green spikes than leaves. They have nothing of the shape of other leaves. They are called needle-shaped leaves. They grow in a cluster, and there are from two to five of them to form the cluster. They have small scales at their base. Thus, you see, the difference in the leaves of the two trees makes another distinction."

PINE LEAVES AND CONES.

"Are not the firs and pines evergreens, sir?" asked Fred.

"Yes, they are," said Mr. Wilson, "with the single exception of the larch. This, like most other trees, sheds its leaves in the autumn. All the rest of the pine and fir family are evergreens, and in this again they differ from the oak."

Lesson XII

Gravity

"We know that if we let a ball, a stone, or a body of any kind drop from our hands, it must come to the ground," said Mr. Wilson. "Now which of you has ever seen a balloon floating in the air? You all have. Very well. Perhaps one of you may have seen the men in the balloon throwing something out?"

"I have seen them throw the sand out to lighten the balloon," said Willie.

"Quite true," said Mr. Wilson; "and what became of the sand?"

"It fell to the ground."

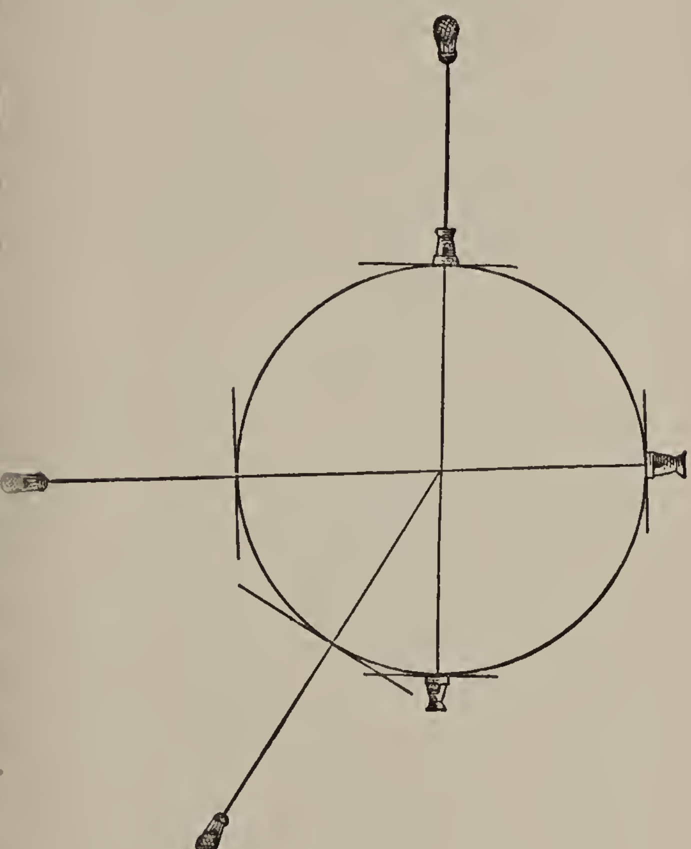
"Yes, Willie, all bodies fall if unsupported; and they always fall in one direction—downwards, towards the ground.

"What do we call the direction opposite to this?"

"Upwards. 'Up' means towards the sky; 'down' means towards the ground. I can throw a ball upwards to a certain height, but it must fall downwards to the ground again."

"Now I want you to think for a few minutes about this earth on which we live," continued Mr. Wilson. "You know that it is a great ball, and that you and I and everybody live and move about on the outside of the ball. I will draw a circle to represent the earth. Suppose we wish to show some very tall building, towering up into the sky; I must represent it by a line drawn perpendicular to the earth, that is, perpendicular to the circle itself, without troubling whether it looks upright on the board.

"But we must not forget that other people, in other parts of the world, have high buildings too. Suppose we draw some more. You see they all point in different directions, but they are all perpendicular to the circle, which represents the earth.



"Now watch what I do next. I will draw a straight line through each of these perpendicular towers, and produce them through the circle. What do you see now?"

"Every one of these lines passes through the centre of the circle, sir," said Fred.

"Quite right, but the tops of these towers all point towards the sky, and the bottoms of them are all on the ground. In other words, the tops point up, and the bottoms down.

"Now think once more about the man in the balloon. Let him drop another stone, while you watch it fall. We will draw a line to show the direction of the falling stone.

"Now produce this line. What do you see?"

"This line too passes through the centre," said Fred.

"Now I think we can understand," continued Mr. Wilson, "that 'up' always means towards the sky; 'down' always means towards the centre of the earth.

"So then we have learned at last that all bodies, when unsupported, fall downwards, and that means towards the centre of the earth. But why should they fall, and fall always in this one direction? They fall because the earth attracts or draws them towards itself. There is a force which acts from the centre of the earth, and draws all other bodies towards that spot. We call this force *gravity.*

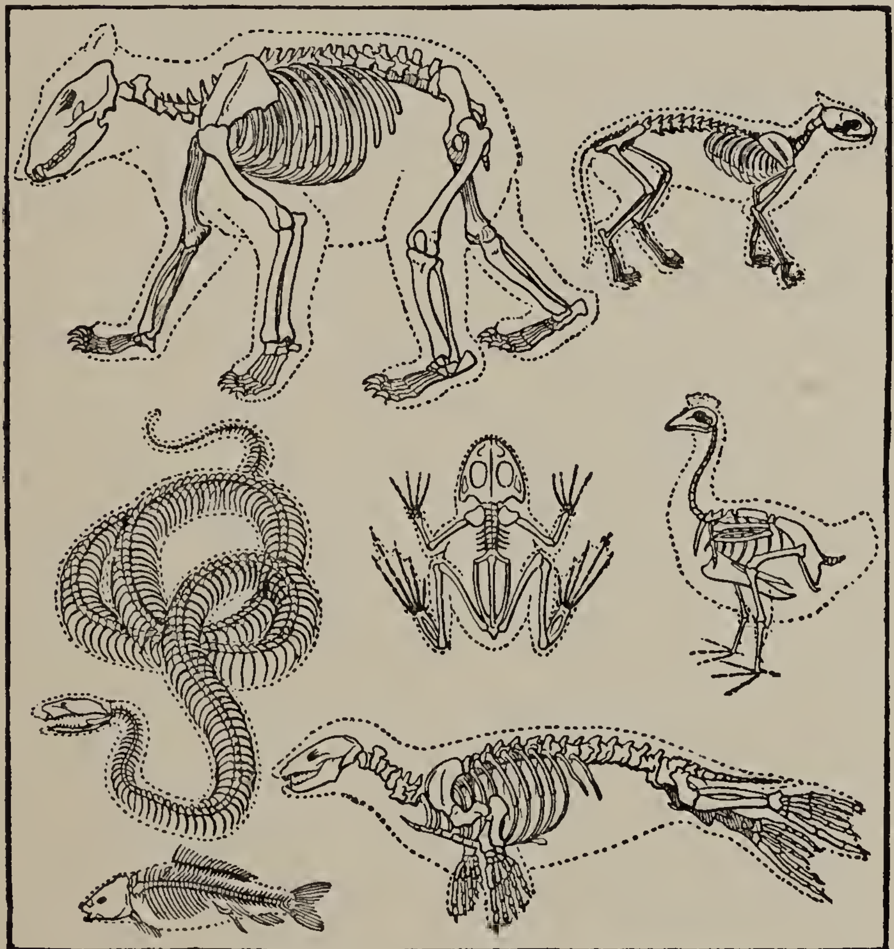
"It is the force of gravity which causes the feeling of downward pressure when we hold different bodies in the hand. The earth is trying to draw them downwards towards itself. We say they are heavy. It is the force of gravity which gives all substances weight. The very word gravity means weight.

"I daresay you are wondering," continued Mr. Wilson, "why the earth should draw some bodies more than others. It is because the earth attracts bodies in proportion to the amount of matter which they contain; and some bodies, as we have seen, contain more matter than others."

Lesson XIII

Vertebrates and Invertebrates

"I want you to think about some of the animals of our former lessons," said Mr. Wilson.



"Cats, dogs, sheep, horses, birds, snakes, frogs, and fishes are all alike in one respect, and all differ from such animals as bees, butterflies, beetles, and spiders in that same one respect. You know you have a backbone; you can feel the bony knobs or projections down the middle of your back; and you have lately been learning many things about the hard bony skeleton, which supports and gives shape to your body. We ourselves are like the cat, dog, sheep, bird, snake, and fish in this respect, for they too have a backbone and an internal bony skeleton.

"Butterflies, beetles, spiders, and hosts of other animals have no backbone at all. This distinction enables us to make our great classification of the animal kingdom. We arrange all animals in two groups—those which have a backbone, those which have not a backbone.

"If you think for a moment about this backbone, you will be able to tell me why the name is not a good one."

"It is not a single bone all in one piece, sir," said Willie; "it is a string or column of separate bony rings, which fit closely together."

"I think, too, you can tell me how many of these bony rings you have in your own backbone," said Mr. Wilson.

"I have thirty-three now, sir; but when I become a man there will be only twenty-six, because some of the bones grow together."

"Quite right. Most of the animals we meet with have more of these separate pieces in their backbone than we have. You, of course, remember that snakes have a very great number. What is the object of so many separate pieces?"

"It is to give freedom of movement, sir," said Fred, "for although each bone can move only to a slight extent, this long chain of bones gives the whole column great flexibility."

"Very good, Fred. Now tell me the name which we give to these separate bones."

"We call them vertebræ, sir."

"Right. You must try and remember that the name comes from the Latin word *verto*, which signifies 'I turn,' and then you will see the reason why it is given. By means of these vertebræ we and other animals can turn, move, or bend our backs and necks freely.

"As the backbone is made up of vertebræ, it is sometimes called the vertebral column; and all animals which have a backbone are called *vertebrate* animals or *vertebrates*. They form the first sub-kingdom in the animal world. The other sub-kingdom comprises all animals which have not a backbone. They are called *invertebrate* animals or *invertebrates*. 'In' means 'not.'

"You called these vertebræ bony rings, Fred. Why did you give them this name?"

"Each vertebra, sir, is pierced through from top to bottom with a rounded hole; and as the bones fit together, these holes also fit to each other, so as to form one continuous tube through the column. This tube is called the *vertebral canal*, and sometimes the *spinal canal*. The spine is another name for the backbone."

"All this is very good, Fred," said Mr. Wilson. "Can you tell me anything more about that canal?"

"The upper part of the canal, sir, opens out into the cavity of the skull. The brain fills the skull, and part of it, called the *spinal cord*, passes out from the skull and runs through the spinal canal. It is the great nerve of the body."

"Just so; and now remember," said Mr. Wilson, "that this arrangement is not only true as regards ourselves, but for all vertebrate animals. Every animal that has a backbone has also a skull, containing a brain and a nerve-cord running from it through the spinal cavity.

"Now I want to notice how the vertebræ of different animals are joined. Can you tell me how our own are joined?"

"Each vertebra rests upon a pad of elastic cartilage, sir," said Fred. "These pads allow a certain amount of movement, but prevent one bone from grating against another."

"Quite right, Fred; and this is the arrangement in most of the vertebrate animals. Now let us think for a moment about the vertebræ of the snake. How are they joined?"

"They are joined by ball-and-socket joints, sir; these joints give the creatures their extreme flexibility, and their rapid gliding movement.

"In fishes each vertebra has a sort of cup or socket on either side, and it is only the rims of these cups which fit together, the hollow being filled with a sort of fluid."

Lesson XIV

Timber

"The different varieties of wood furnished by our timber trees owe their value to special characteristics, such as their hardness and durability, the beauty of their grain, or the ease with which they may be worked and polished. As a rule we may judge of the hardness of wood by its action when it is put into water. Some, such as ebony and lignum-vitæ, are so heavy that they sink in the water. Spanish mahogany and oak float, but the upper edge of the wood is on a level with the surface of the water. Yellow pine-wood floats higher out of the water than these, larch higher than the pine, and common poplar higher still. What is the explanation of this?"

"The ebony and lignum-vitæ are the heaviest of these woods, poplar the lightest."

"But why are some bodies heavier than others?"

"Because the force of cohesion binds their molecules more closely together. There is more matter in them."

"Exactly. The molecules of the ebony and lignum-vitæ are very densely packed; the substance of the poplar-wood is loose compared with them. But what has this to do with the hardness of the wood?"

"It is a general rule that when the molecules of a body are densely packed, owing to a strong force of cohesion, the body is not only heavy but hard. This explains why we are able to judge as to the hardness of different woods by placing them in water. Ebony and lignum-vitæ represent very hard woods; poplar is a very soft wood. The mahogany, oak, pine, and larch show varying steps between the two extremes."

"The strength and durability of timber depend mainly upon the part of the tree from which it is cut, but the age of the tree must also be taken into account. It is important to remember that trees, like animals, grow till they reach maturity, but after that they begin to decay.

"The age for reaching maturity depends on the nature of the tree, as well as on the soil and climate. The tree which is felled at its maturity yields the best timber. At this period the whole of the trunk, except of course the new sap-wood, is equally good. In a young tree the heart-wood is always the best; but after the tree has passed maturity, this heart-wood is the first to decay. In the young tree, on the other hand, the sap-wood is always the worst part of the timber, and is liable to decay quickly. But after the tree has reached its maturity, even the sap-wood becomes good useful timber.

"The usefulness of timber, moreover, depends upon the proper seasoning of the wood. Newly-felled timber is unfit for use. It is not only weak, but it is liable to warp, twist, and change its form. In this state it is known as green wood. The outer surfaces, acted upon by the air, crack and split more than the inside. All timber requires to be well seasoned to make it durable. It must be cut up by the saw while green, and exposed to the air for a long time. The result of this exposure is gradually to dry the whole of the wood. The surrounding air first absorbs all moisture from the surface, and then as the outside dries, the air by degrees finds its way to the inside, and the whole becomes uniformly dry.

"With some woods this seasoning or drying is done in an artificial way. The wood is placed in a drying-room, and a current of warm dry air is passed over it. This hot dry air soon absorbs all the moisture from the wood, and seasons it almost as well as years of exposure would have done."

Lesson XV

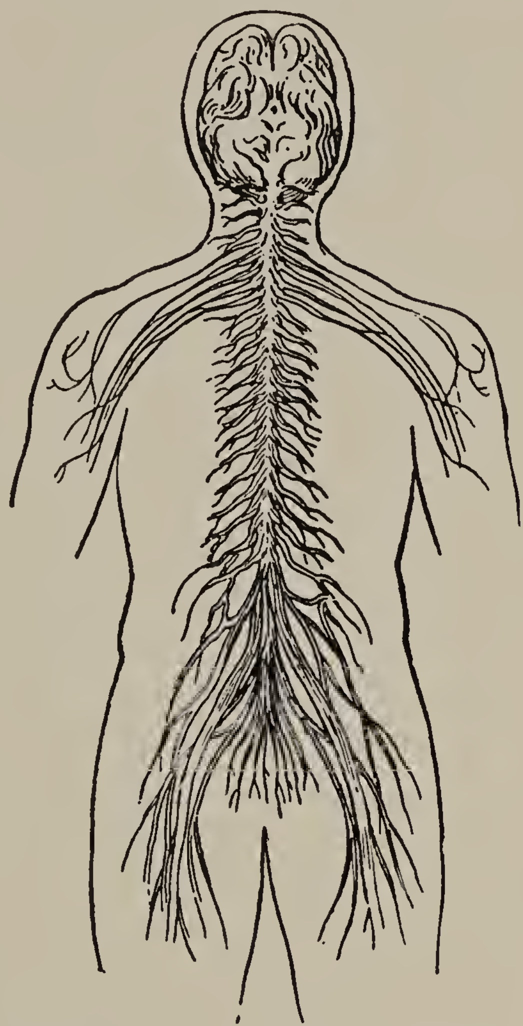
The Nerves

You know that the skull is merely a hollow box intended to hold and protect the brain. You know, too, that this box rests on the topmost vertebra, to which it is jointed by a double-hinge-joint. In the floor of the box, and just where it rests on the vertebra, there is a round hole ; and in this vertebra, as well as in every one of the vertebræ in the column, is a corresponding hole.

These vertebræ standing one above the other, as we might stand a string of reels, form a long continuous tube from the bottom of the column upwards to the skull. We call this tube the vertebral canal, or the spinal canal.

The brain fills the whole cavity of the skull, and a portion of it extends downwards from the skull and fills the spinal canal. This part is known as the spinal cord.

This brain matter is totally different from the muscles or flesh. It is a soft grayish-pink substance, more like marrow than flesh. From the brain and spinal cord extend outwards through the body long, white, silvery-looking threads—the nerves. Some of these nerves spread themselves all over the surface of the skin, and it is through them that we are able to feel the hardness or softness, the heat or cold, the roughness or smoothness of various bodies. Others spread themselves among the muscles of the body. They are the foremen or overseers who set the muscles to work.


BRAIN, SPINAL CORD, AND NERVES.

When we wish to lift our hand or turn our head, it is the nerves that make the muscles do our bidding. If the nerves were destroyed or injured (as they are sometimes by paralysis), we should find ourselves quite unable to lift the limb, however much we might wish to do it.

But whence do the nerves get their orders? The brain is the chief centre. The nerves may be aptly compared to a multitude of telegraph wires stretching into every part of the body. They carry messages to and fro.

Let me give you an idea of the kind of messages they carry. What would you do if some one, without your seeing him, placed a hot poker near your hand? You would instantly draw your hand away. To you this would appear the simplest of actions, but in reality the nerves have been very busy. Some of them first carried up a message to the brain, to say that the hand was being burned; then the brain sent back, by another set of nerves, an order to the muscles to pull the hand away. The muscles would not act without this order.

But besides being the overseer of the muscles and their work, the brain is the seat of the will, the intellect, the memory, the emotions and affections. Moreover, it is by the brain and its nerves that we see, hear, smell, taste, and touch.

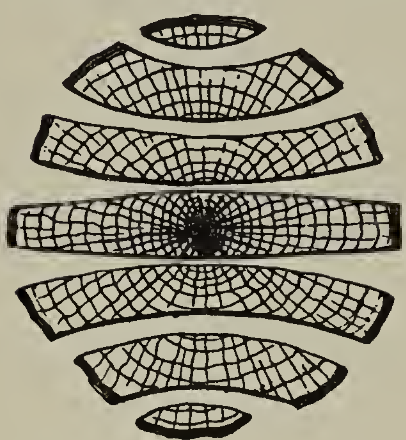
Lesson XVI

Timber—Its Shrinkage and Preservation

Our last lesson on timber dealt with the methods of seasoning the wood to render it fit for use. During the seasoning process the wood shrinks, but always according to a natural law. The amount of shrinkage in length is so small that it may be altogether disregarded. The shrinkage takes place in the breadth of the plank.

If we think of the structure of the exogenous stem we shall see at once the reason for this. The woody fibres are arranged lengthwise down the stem in irregular circles, and these fibres are bound together by the radiating plates, known as the medullary rays or the silver grain. This silver grain is not of the same nature as the woody fibres. It resembles the pith in structure. As the drying process of the seasoning goes on, the woody fibres contract or shrink in bulk. But they can only shrink by tearing away, at the same time, the substance of the medullary rays. That is to say, the shrinking of the woody bundles finds relief by splitting the timber in the direction of the medullary rays. This explains why timber, after it is cut, and before it is properly seasoned, always cracks and splits on the outside more than the inside of the mass.

It is interesting to note the behavior of a trunk of one of the stronger exogenous woods, such as oak or beech, when it is cut up into planks. Imagine a trunk cut lengthwise by the saw into seven planks. After the planks had been properly seasoned, the middle one would be found to retain its original thickness in the centre, but the edges of the board would be thinner. The breadth of the plank would remain the same as at first. The medullary rays, being closer together towards the centre of the trunk, offer greater resistance there to the tearing than



at the edges. The planks on either side of the middle one would, from the same cause, become bent out of shape, or pulled round into a convex from the centre of the trunk, and each board would be narrower.

Timber, even after it has been well seasoned, is liable to decay from many causes. Moisture and changes in temperature are its worst enemies. They not only lead to the decay of the wood, but they encourage the attacks of insects and worms, and the wood gradually crumbles away. Where timber structures have to be exposed to changes of air, light, heat, and moisture, something must be done to protect them from the effects of all these.

All woodwork is covered with a coating of paint or tar for this very purpose. Both these substances are impervious to water, and will not allow the wet to penetrate into the wood. Tar itself, moreover, is a powerful preventer of decay. This explains why, in fixing a wooden post into the ground, we soak the lower end in tar, or stand it in pitch; and why ships, boats, and barges are always kept well painted and tarred.

Another enemy to timber structures is dry rot. The simplest and best way of preventing this is to saturate the wood in oil.

Lesson XVII

Cohesion in Liquids

"We have seen something of the effect which the force of cohesion has on the molecules of a solid body," said Mr. Wilson. "I want now to study this same force in its effects on the molecules of liquids. In a solid the force of cohesion is so great that the molecules cannot shift about. Those, which to-day form the extreme end of this iron rod, will not to-morrow move into the middle, but will remain where they are.

"In liquids there is very little cohesion. The molecules of a liquid are free to move about, roll one over the other, and change their places. Here is a tumbler of water. See, I can move this stick about through the water with scarcely any effort, because the molecules of the water are easily pushed aside.

"Come to the front, Fred," he continued, "and do the same with this basin of peas. The peas yield readily to the pressure and give way.

You have only to imagine the water made up of extremely fine round molecules, many million times smaller than a pea, and you will quickly understand it all. The molecules of the

water, having little cohesion between them, move freely as the stick pushes them aside.

"I have here another tumbler half full of molasses. Notice what happens when I slant it on one side. Take the tumbler of water in one hand and the tumbler of molasses in the other and slant both of them. You see the molasses moves very slowly.

"Now stir the two. It is much more difficult to move the stick through the molasses than through the water. Why is this?"

"I suppose it is because there is more cohesion between the molecules of the molasses than between the molecules of the water," said Fred, "and therefore they separate more slowly."

"Quite right," said Mr. Wilson. "We call liquids, which are like molasses in this respect, *viscous liquids*. Can you think of any of them?"

"Tar, glycerine, liquid gum, and castor-oil would all act in the same way," said Fred.

"There are some liquids, on the other hand," said Mr. Wilson, "such as alcohol, ether, and benzine, that have less cohesion than water. Their molecules move about very freely indeed. We call them *mobile liquids*.

"Now let us take another step. Your very early lessons taught you that one of the differences between a liquid and a solid is that the liquid has no shape of its own, but always takes the shape of the vessel which holds it. We are now in a position to see the reason for this.

"The reason is two-fold. First, the molecules of the liquid, having little cohesion, are free to move about. Secondly, the force of gravity acts upon each individual molecule, and draws it downwards towards the bottom of the vessel.

The molecules cannot stand in a heap, because those above press on those below, and push them into every corner of the vessel. They force one another downwards and outwards in this way until they meet with the bottom and sides of the vessel. This is why a liquid can have no shape of its own, but at once takes the shape of the vessel which holds it.

"Those same early lessons taught you that, although flour, or saw-dust, or sugar may be piled up in a heap in a basin, it is impossible to make water stand in a heap.

"The reason is that the force of gravity draws the molecules of the water downwards, and as they have little cohesion, they do not resist, but roll and tumble one over the other, until the surface is level. The force of gravity is greater than the force of cohesion. The saw-dust, on the contrary, stands piled up in a heap, because the force of cohesion between its particles is greater than the force of gravity."

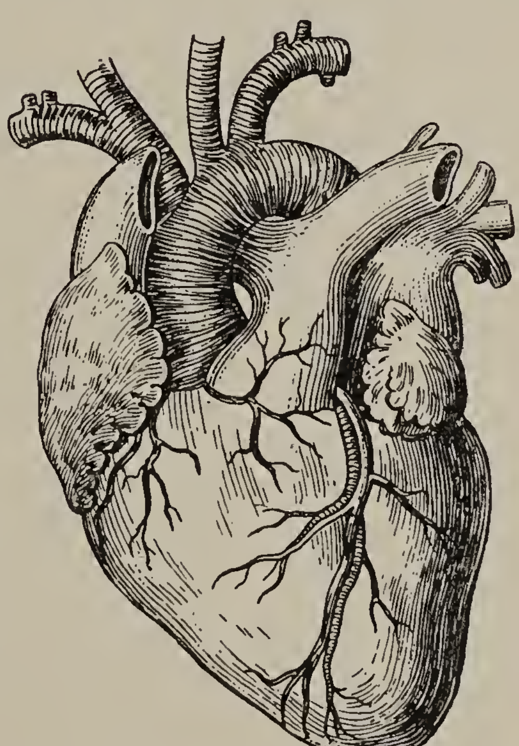
Lesson XVIII

Circulation of the Blood

We have studied the body as a living machine. This machine requires to be nourished, or it cannot do its work. It is the great work of the blood to feed the tissues in every part of the body. This explains why blood is found in all parts of the body. We cannot prick ourselves even with the finest needle without drawing blood.

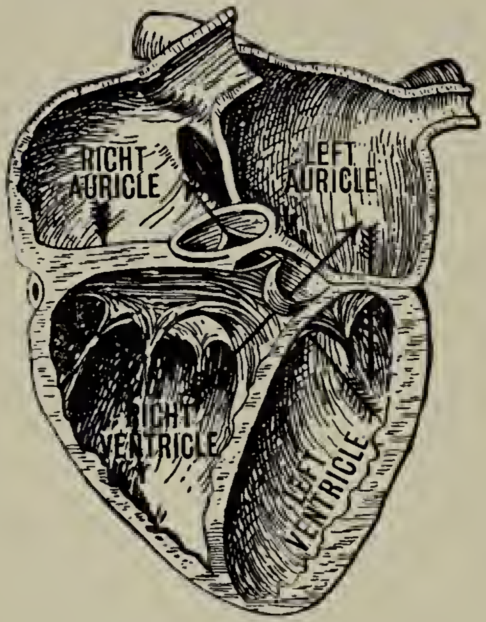
One of the first things to learn about this blood is the fact that it does not rest stagnant as water does in a bottle ; it is always on the move. It flows through the body in a continuous stream, round and round, returning to the same spot again and again. This incessant onward flow of the blood through the body is known as the *circulation of the blood.*

All the blood in the body is contained in pipes or tubes, which we usually call blood-vessels. Taking the arm and hand as an illustration, it is clear that there must be a flow of blood down the arm to the fingers, and a return flow up the arm again. Those vessels which convey blood down the arm towards the hand are called *arteries ;* those which carry it back are *veins.* But what causes the blood to keep up this incessant



flow? It is pumped through the body by the heart.

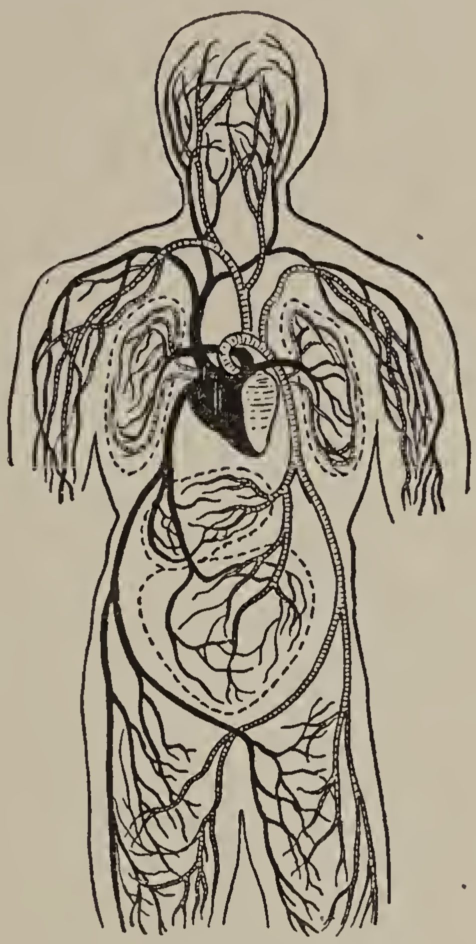
The heart is a pear-shaped organ, about the size of one's fist. It is situated in the middle of the chest, is made entirely of muscle, and contains four chambers of equal size. The two upper chambers are called *auricles*, the two lower ones are named *ventricles;* so that there is a right and a left auricle, and a right and a left ventricle. Each auricle communicates with the ventricle below it by means of a hole in the partition which separates them; but there is no communication of any kind between the right and left sides of the heart.



SECTION OF THE HEART.

It is the work of the veins to carry back the blood from all parts of the body to the heart. These veins, beginning at first as mere hair-tubes, unite again and again as they get nearer to the heart. All the blood from the upper parts of the body is brought back to the heart at last by one great vein; all that from the lower parts by another.

These two great veins open into the right auricle of the heart. I told you the heart is a muscular organ; and you know it is the nature of a muscle to contract when it is interfered with. There are certain nerves whose business it is to act as overseers of the heart, and see that it does its work. How vigilant these nerve overseers must be! The heart, under their control, begins its work at the very commencement of life, and never rests for a single moment till death comes.


PLAN OF THE CIRCULATION.

This work is always done in one way. Auricles and ventricles do not work together. Both auricles begin to contract at the same moment; but while this is going on the ventricles, left to themselves, expand. The instant the auricles cease working, the ventricles begin; but while the ventricles contract, the auricles are expanding. Hence, when the auricles are contracted to their smallest size, the ventricles are stretched out to their fullest; and when the ventricles, in their turn, finish their contraction, the auricles are expanded to their utmost.

The auricles, at the moment they commence to contract, are stretched to their fullest extent, and have been filled with blood from the two great veins. The act of contracting must squeeze the blood out of the auricle. It cannot return, because of the great mass of blood behind in those veins. It flows onward into the right ventricle, which has expanded to receive it.

The ventricle is no sooner filled than it begins, in its turn, to contract, and so force out the blood. As it contracts it closes the orifice between it and the auricle above, so that the blood is prevented from returning. It finds an easy passage along a great vessel which opens out from the ventricle, and leads away from the heart to the lungs; and that is the course it now takes.

This great vessel is called the *pulmonary artery*. It conveys the blood from the right ventricle of the heart to the lungs. The blood, after passing through the lungs, is collected and brought back again by the *pulmonary veins.* These veins open into the left auricle, and the rest of the work is just a repetition of what took place in the right side of the heart. The auricle expands to receive the blood, and when full begins to contract. As it contracts it drives the blood from the left auricle into the left ventricle, through the hole between them.

When the ventricle next contracts, this hole closes, and the blood cannot return. There is a great artery—the largest artery in the body —opening out from the left ventricle, and the way through it is open. Hence the blood flows along in that direction.

This artery is the *aorta*. It branches out into smaller arteries, and so carries the blood through the body. The smallest of these branching arteries break up at last into still finer tubes, —so fine, indeed, that they are the merest hair-tubes. They are called *capillaries*, from a Latin word which means "a hair." These unite again and form the commencement of the veins, so that the capillaries form the link between the smallest arteries and the smallest veins.

Lesson XIX

Timber—Its Uses

The trunks of all our trees yield wood. The only distinction between timber and wood is that the timber trees are so large that their trunks may be sawn up into pieces not only long, but wide and thick as well. Such pieces of wood we call logs or balks of timber. They may be used in that state, or they may be sawn up into planks. In any case, by the term timber we name great beams or planks of wood, which, from their size and quality, are fit to be used in engineering and building. For all such purposes strength and durability are, of course, the primary objects.

Amongst the chief of the timber trees are the ash, beech, cedar, elm, pine, hornbeam, bass-wood, mahogany, oak, poplar, teak, etc. The various ornamental woods used by the cabinet-maker form a class by themselves, and are not included under the head of timber. Among these are the birch, box, cherry, ebony, maple, rosewood, satin-wood, walnut, etc.

ASH LEAVES AND FRUIT.

The special qualities of each individual wood render it specially fitted for some particular kind of work. Let us examine a few varieties of wood.

1. *The Ash.*—This wood is prized for its great toughness and elasticity. It is coarse in texture and of considerable strength. It is much used in building and engineering. It

is the principal wood used by the wheelwright, on account of its elasticity. He makes the spokes of wheels and the shafts of carriages of this wood. For the same reason it is specially fitted for all purposes where severe shocks and

ASH.

wrenches have to be provided against. It is the best wood for making hammer-shafts and the handles of tools generally.

2. *The Beech.*—This wood is almost as strong as oak, but it is specially distinguished for its closeness of grain and the even smoothness of its surface. It polishes readily, and is a beauti-

BEECH.

ful wood when it is so cut as skilfully to expose the silver grain. It is much used for furniture, and it is also largely employed, because of its closeness, toughness, and strength, for making cogs for mill-

LEAVES OF BEECH.

BEECH-NUT.

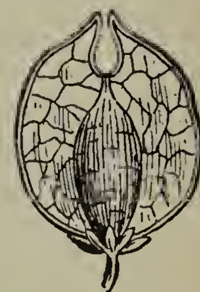
wheels. For purposes such as these it requires to be kept very dry, for it quickly decays in damp situations. It is, on the other hand, a remarkable fact that when it is used for purposes in which it is kept constantly in water, beech-wood shows considerable endurance.

ELM.

3. *The Elm.*—This is a rough, cross-grained wood of remarkable strength and toughness. It is specially suitable for all sorts of rough purposes, as it is less liable to split by the driving of bolts than other woods.

Elm is very durable under water, but it rapidly decays if it is subjected to frequent changes from wet to dry. Hence it is not a good wood for exposure to the atmosphere in a climate such as ours. Its great defect is its great liability to warp and twist and get out of shape, while as regards strength, rigidity, toughness, and endurance, it is certainly inferior to oak.

ELM-LEAVES.



FRUIT OF ELM.

The wheelwright makes the nave of his wheel of elm-wood; it is also used for making pulley-blocks, and heavy, naval gun-carriages.

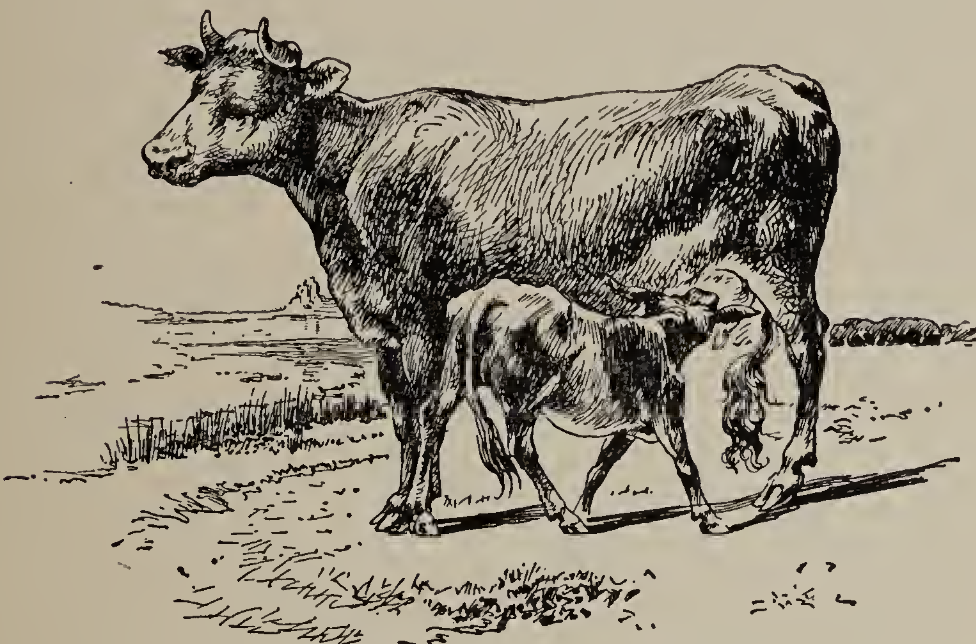
Lesson XX

The Vertebrates

The great sub-kingdom of vertebrate animals includes such widely differing creatures as the horse, pigeon, herring, frog, and snake—creatures which it would be impossible to study in one group. We must find out in what points the various members of the sub-kingdom differ, and that will help us to a further classification.

Boys and girls living in the country may have seen the young calf sucking milk from its mother's body. All must have seen the little kittens doing the same thing.

The Latin name for the small bag from which they draw the milk is *mamma*, and as all animals which nurse their young are



provided with this, we give them the name of mammals.

If we put our hand on any of these animals, we feel that their bodies are warm. They have warm blood. A fish and a frog always feel cold and clammy, because their blood is not warm. You know too that the color of the blood of a horse, a sheep, a cow, or a pig is red.

If we examined the heart of a sheep, a horse, a rabbit, or any one of these mammals, we should find it to consist of four distinct chambers

—*two auricles and two ventricles*, exactly the same as our own. All mammals, too, breathe through lungs as we do. We ourselves belong to the class—mammals.

You have all seen the hen with her little chickens. How does she rear them? She, and birds of all kinds, lay eggs, and sit close upon them to hatch them with the warmth of their own body. The little ones break the shell and come out when fully formed, and the parent bird feeds them, but not with milk. She searches about for little morsels of solid food, which from the first the young ones are able to eat.

Birds, like mammals, have two pairs of limbs, but the front pair are specially fitted for flying. We call them wings.

If we place our hand on a bird of any sort, we feel that its body is warm. It has warm blood, like the mammals; and like them, too, it breathes through lungs, and the heart consists of four chambers.

Mammals have almost every variety of covering for their bodies; but birds of all kinds are clothed with feathers.

Now I want you to think of the snakes of our earlier lessons. These animals belong to the class called *reptiles*, which includes lizards, tortoises, and turtles, and the great crocodiles and alligators of the tropics. The word *rep-*

tile means *creeping thing.* It is not a good name, for all these animals do not creep, and some of them are extremely nimble and agile.

Reptiles produce their young from eggs. But although they breathe through lungs, as birds and mammals do, *their blood is cold;* and the heart has generally *three chambers only.* Some, however, of the more vigorous among the reptile family have four chambers in the heart. That is to say, there is a partial division of the ventricle, which amounts to the same thing.

The frog-like animals form a class by themselves, and are known as *Batrachia.* They include frogs, toads, and newts. They are hatched by the heat of the sun from eggs which the mother has laid in the water. They commence life in the water, breathing, like fishes, through gills. The heart has only *two chambers*—an auricle and a ventricle.

You know that the young frog, or tadpole, gradually loses its fish-like form, develops lungs instead of gills, and legs to walk and hop about on the earth. It then leaves the water and enters upon a new life, breathing air through lungs, like all other land animals. Its *blood is cold;* the heart of the fully-developed frog has *three chambers*—two auricles and one ventricle.

Last in the list of vertebrate animals come the fishes. They produce their young from eggs.

They breathe all their life through gills, and the heart has only *two chambers*—an auricle and a ventricle. They are *cold-blooded* animals, with no covering for the body but scales. They have a sort of rudimentary limbs called fins, which serve to propel them through the water.

Lesson XXI

More about Timber

1. *The Fir.*—The fir and pine family are perhaps the most valuable of all our timber trees, because they are plentiful, and therefore cheap. The wood of these trees is not so strong nor so durable as many other kinds of timber, but it is easily worked.

SCOTCH FIR.

The family comprise a great variety of trees. The most valuable among them are the larch, the pitch-pine, and the firs and pines of Norway, Sweden, Russia, Germany, and our country.

These trees are all resinous, and yield resin, turpentine, and tar. The pine-woods of our continent are said to be rich enough to supply the whole world with turpentine and resin.

The white and yellow pine of the Canadian forests is not one of the strong or durable

LEAVES AND FRUIT OF PINE.

CANADIAN PINE.

woods, but it is much in demand in some countries because it is so easily worked. Engineers make great use of this wood for models and patterns. Its smoothness of surface, its comparative freedom from knots and from the liability to warp, as well as the ease with which it can be cut, make it specially suitable for this purpose.

The Scotch fir yields a very valuable timber, little inferior to oak. It is obtained from Scotland, Sweden, Norway, and Russia, and is frequently named red pine, red deal, and Riga fir. The spruce and silver firs are used largely for making ladders, masts of ships, scaffolding, etc.

2. *Hornbeam.*—Iron-wood, from the closeness of its grain and the remarkable toughness

HORNBEAM.

LEAVES AND FRUIT OF HORNBEAM.

of its fibres, is employed by engineers for the teeth of cog-wheels. It is also used for making mallet heads. For these purposes the wood is superior to all others, owing to its stringy structure and its great cohesive strength.

3. *Mahogany.*—This is a beautiful close-grained wood, capable of taking a high polish. It is remarkably free from liability to shrink, warp, or twist. It is superior to all other woods in its readiness to take a firm hold of glue. It is highly valued for furniture making, but will not stand exposure to the weather. The wood of the limbs or branches is preferred for ornamental purposes, because the grain is closer, richer, and more variegated than in the trunk itself. The mahogany tree is the king of all the forest trees. In comparison with this giant most other trees look insignificant.

The best wood is that known as Spanish mahogany, which comes from the West Indies.

4. *Oak.*—The hardy oak is one of the strongest and most durable of woods. It suffers less than any other from water, or the changes in climate. It stands first among the hard-wooded timber trees for its general usefulness. It is highly prized for ship-building purposes. It is also invaluable for making roofs; for which purpose its lightness, com-


LEAVES AND FRUIT OF OAK.

OAK.

TEAK.

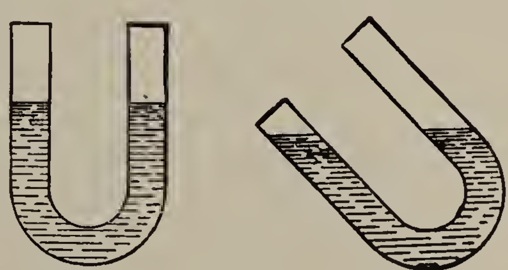
bined with its strength and durability, specially fit it. It is well adapted also for the staves for casks, and for carriage wheels. Indeed, it is the best possible wood for all purposes where lightness and strength are required in combination.

5. *Teak.*—Of all the hard woods imported into this country, teak is the most valuable. It is useful for all purposes in which we employ oak. It is equally durable, and is not subject to decay through exposure to a hot climate, nor from worms or insects. It is largely used in shipbuilding, and in making gun-carriages.

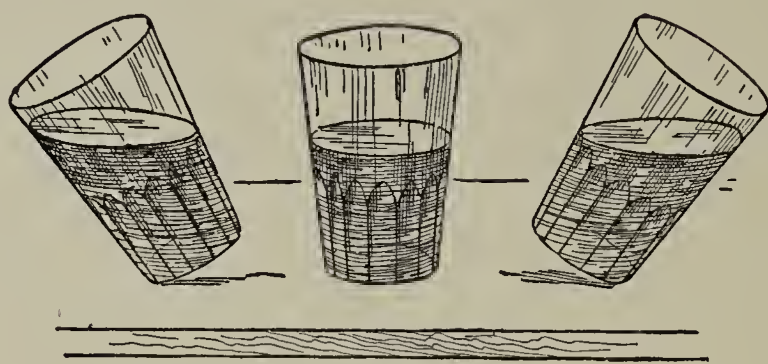
Lesson XXII

Further Properties of Liquids

"One of the first things we learn about water is that it flows," said Mr. Wilson. "We rarely see water still. The slight cohesive force between its molecules enables it to move easily, and as a consequence wherever we meet with water, it is almost always on the move. It moves, or flows along, in the streams and rivers just as we see it flow along the gutters in the road. Let us see if we can discover the reason for this constant flowing. I have here a glass tube bent round in the form of the letter U. I will fill one arm of the tube with water. Notice



what happens. The water, you see, passes at once into the other arm. It flows till it reaches exactly *the same height in both arms* of the tube, and there remains level. Here is a tumbler of water standing on the table.



What do you notice about the surface of the water? The surface of the water remains level while the tumbler stands on the level surface. Now watch what takes place when I tilt the tumbler on one side. The water at once runs towards that side, and then remains level. You will perhaps see this better with the garden watering-pot. Here is the pot. We will fill it to the brim with water.

"Now, Fred, come to the front, and tell us where the water stands in the spout."

"It stands at the top of the spout, sir, just on a level with the water in the pot itself."

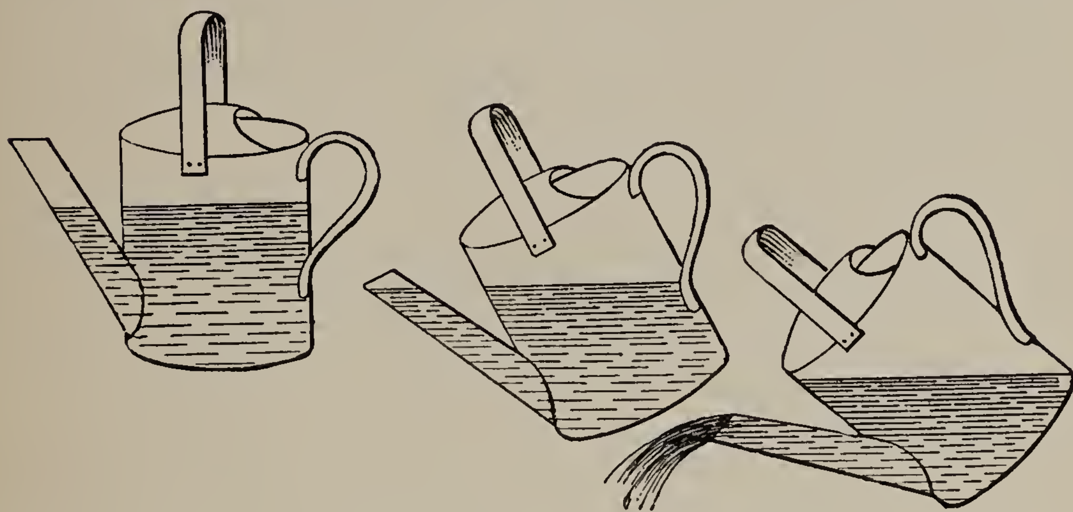
"Is the water flowing (moving) now?"

"No, sir; it is quite still."

"Pour some of it away, and then tell us how high the water stands in the spout."

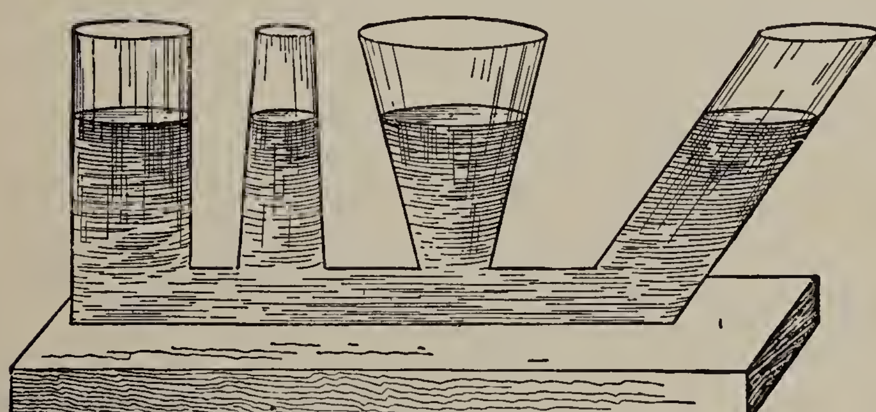
"It is not so high as it was, sir, but it is exactly on a level with the water in the pot."

"Quite right," said Mr. Wilson, "and at that level it remains perfectly still. Now tilt the watering-pot, as we tilted the tumbler, and



let us see what will happen. The water in both spout and pot now stands level and still again, although the pot has been tilted; but if we tilt it a little more, the water will run out of the spout, in trying to get on the same level with that in the pot.

"*Water flows to find its own level.* It will



flow till that level is found. When water is at rest its surface is always level.

"Fountains are constructed on this principle. All that is required is a cistern of water in some elevated position, with a pipe leading downwards from it. The water will flow down the pipe, and at the lower end rush upwards in a jet, trying to rise to the same level as the cistern from which it flowed.

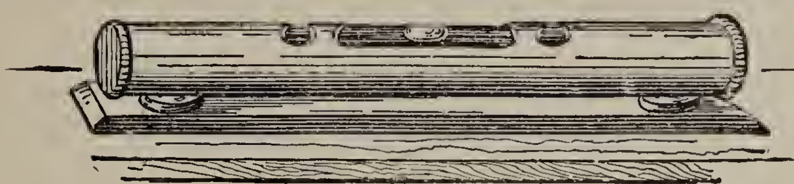
"It is on the very same principle that towns are supplied with water from the water-works.

The reservoirs are placed on elevated ground, and the water which leaves them rushes on through the pipes, trying to find the level from which it started.

"This property of liquids," continued Mr.

Wilson, "is turned to account in the spirit-level. If you examine the instrument you will see there is a small glass tube in it filled with liquid. On a horizontal surface the liquid in the tube rests level. When it is tilted ever so little, the liquid flows towards that side. Workmen use this instrument to test the level of their work.

"The liquid in it is not water but alcohol.



It is called a spirit-level. Can you tell me why alcohol is used in preference to water?"

"Alcohol is a very mobile liquid," said Will. "It flows much more freely than water."

"Quite true, my lad," said Mr. Wilson. "A dense liquid would flow too slowly to be of use in this instrument. There is one other property of water which I want to illustrate to you now. I have here a bottle with a cork that fits it exactly. I will remove the cork, and fill the bottle with water to the top of the neck. Now, Fred, take the bottle and push the cork in again. You can only force the cork in by forcing some of the water out, to make room for it. The water itself refuses to be squeezed into a smaller space. This is one of the most important and useful properties of water. For the present it will be sufficient for you to remember that *water and all liquids are incompressible.*"

Lesson XXIII

The Invertebrates

In dividing the animal kingdom into two sub-kingdoms, vertebrates and invertebrates, we were at first guided by one distinction only. We simply inquired whether the animal had a backbone or not. This has already led us to find out other distinctions. We know now that those animals which have no backbone, and are therefore called *invertebrates*, are further distinguished by having no internal bony skeleton, no skull, and no brain and spinal cord, such as are found in the vertebrate animals.

But there are other points of difference which we must now consider. All the vertebrate animals have red blood, although in some (the reptiles, Batrachia, and fishes) the blood is cold. In mammals and birds the blood is warm; but all the invertebrate animals have *cold, colorless blood.*

Think next of the mouths of a mammal, a bird, a snake, a frog, and a fish. They all move vertically—that is, up and down. Now many of the invertebrates have no jaws at all. Whenever they have, *the jaws always move horizontally,* not up and down.

Again, we have seen that some of the vertebrates breathe through lungs, others through gills. But how does the air, in every case, reach these breathing organs? It is taken in at the mouth. Even the fish takes in the water with its mouth, and passes it backwards over the gills, which rob it of the air it contains. Not one single invertebrate animal uses its mouth in breathing. Some breathe through holes in their sides; others through long slits in the neck; others, again, through the tail. But they have *neither lungs nor gills.*

Let us next turn our attention to the limbs. None of the vertebrate animals have more than four limbs; but those invertebrates which have limbs at all, usually possess more than four. Thus all insects have *six legs;* spiders *eight;* shrimps, crabs, and lobsters have *ten.* Many of the insects, in addition to six legs, have also two pairs of wings.

Now I want you, lastly, to consider the young of the various members in the vertebrate group.

You could not mistake a kitten for a young snake, a bird, a fish, or even for some other mammal. Why? Because the young ones always resemble their parents. The baby boy has the form of a man; a calf is merely a little cow; a chick is a tiny hen. They grow bigger as they grow older, that is all. This is true of all vertebrates with the single exception of the Batrachia. These all commence life as tadpoles, in the water, and are not like their parents.

A young invertebrate is often a very different sort of creature from its parents. You remember that the parent insect lays the egg, and that the larva or grub which comes from it is totally unlike its parent. Think of the caterpillar side by side with the butterfly; the ugly grub or maggot of the bee, fly, or wasp, side by side with the parent insects.

The egg produces the grub, the grub becomes the pupa, the pupa changes to the perfect insect.

Lesson XXIV

Pressure of Liquids

"Fred and Willie, I shall want you to come to the front this morning," said Mr. Wilson, "and help me with one or two experiments. You shall begin, Fred, by holding this tin box in your hands, while Will places in it some of these bricks, one by one.

"What do you notice, Fred?"

"The box is getting heavier than it was, sir," said Fred, "and every brick adds to the weight."

"What do you mean by weight?"

"I mean the *downward pressure.*"

"Quite right, Fred; the top brick presses upon the one below, and this transmits the pressure to the bottom of the box. The whole weight is pressing on the bottom; the bricks do not even touch the sides of the box.

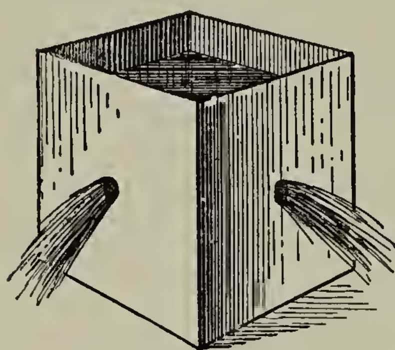
"Now we will remove the bricks and pour water into the box.

"What do you notice now as the water rises?"

"The downward pressure increases, sir, just as it did when we put the bricks into the box."

"Yes, the upper layers of water (like the upper bricks) press upon those below, and they transmit the pressure through to the bottom of the box. *Liquids press downwards.*

"Now stand the box on the table, and I will bore a hole in the side of it. The water, you see,



runs out in a stream. Let us plug up this hole and make another on the opposite side. See, the water flows out through this hole too. We will plug up this, and I will bore a hole in each of the other sides. Now watch what happens when I remove the plugs. The water streams out sideways in four different directions.

"What does this prove?"

"It proves that *water presses sideways* as well as downwards."

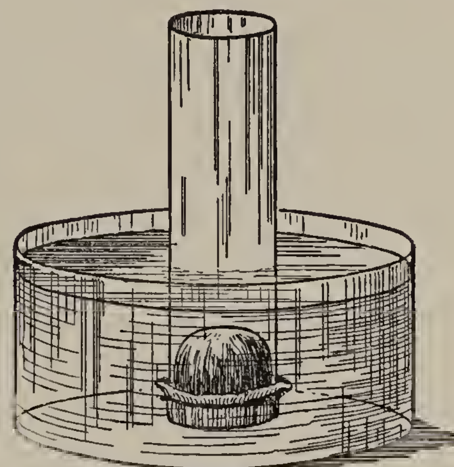
"Right. The upper layers of water (like the upper bricks) press on those below. The bricks transmit their pressure in one direction only—downwards. The water, on the other hand, transmits its pressure not only downwards but sideways as well.

"Now, Willie, you shall lay this flat piece of wood on the water in the bowl, and try to force it down. What do you notice?"

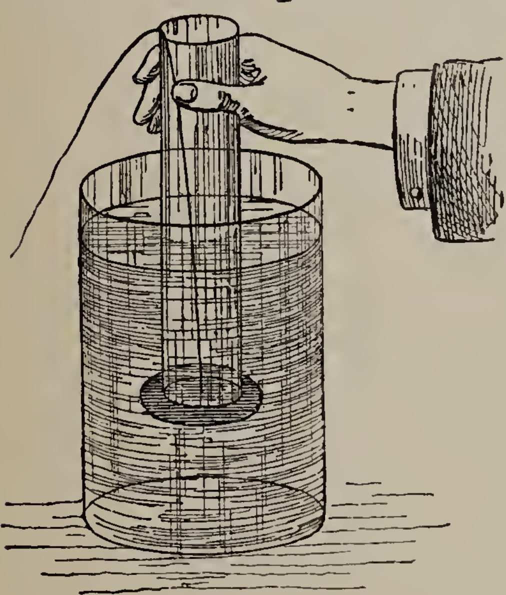
"It is not easy to force it down, sir; something seems to be trying to force it up."

"You are quite right, my boy; the *water* *presses upwards* as well as in other directions, and it is forcing the wood up.

"Let us try something else," said Mr. Wilson. "I have here a glass cylinder, with a piece of bladder tied over it at one end, so as to hang from it like a bag. You shall plunge this into the water. What do you see?"



"The bladder is forced upwards inside the cylinder, sir, as I push it down into the water."



"What forces it up?"

"I suppose it is the water pressing upwards, sir, as before."

"Right, again, my lad. Now we will remove the bladder from the end of the cylinder, and cover it instead with this thin disc of tin. There is a piece of fine cord attached to the centre of the disc, and this we will pass up through the cylinder. I keep the disc close against the bottom of the cylinder while I lower it into the water, and then I let go the string. Notice what happens. Does the disc fall away?"

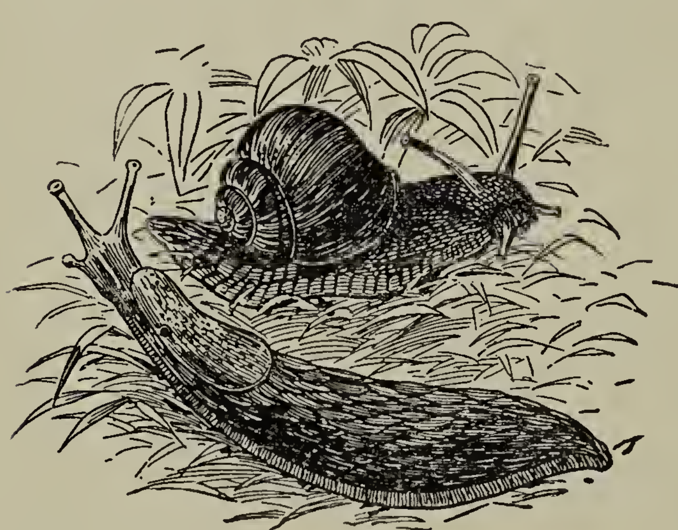
"No, sir; it remains close to the bottom of the cylinder, as it was at first. It must be kept there by the upward pressure of the water."

"Quite right," said Mr. Wilson; "it is the upward pressure of the water that does it; and now we understand that liquids press downwards, sideways, upwards,—in fact *in all directions.*"

Lesson XXV

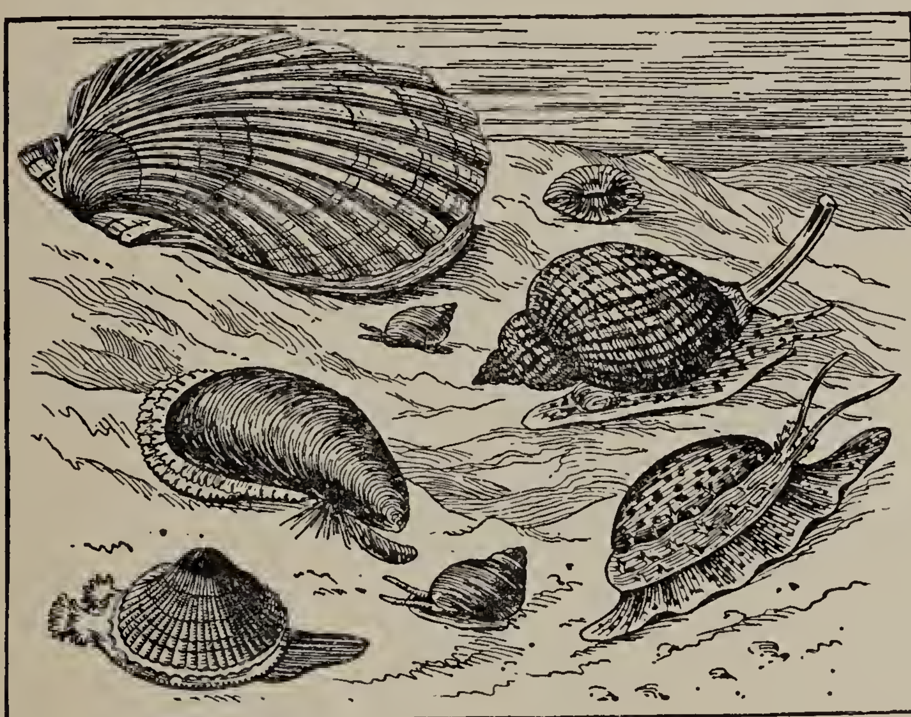
Classification of Invertebrates

The invertebrates are arranged in six great subdivisions. Let us examine them one by one, commencing with the *soft-bodied animals.* These have a soft, fleshy body, sometimes naked and defenceless, like the slug; sometimes covered with a protecting shell, which the creature manufactures for itself. Indeed the shell is really part of the animal; the animal cannot leave it; it is not a mere house.



SLUG AND SNAIL.

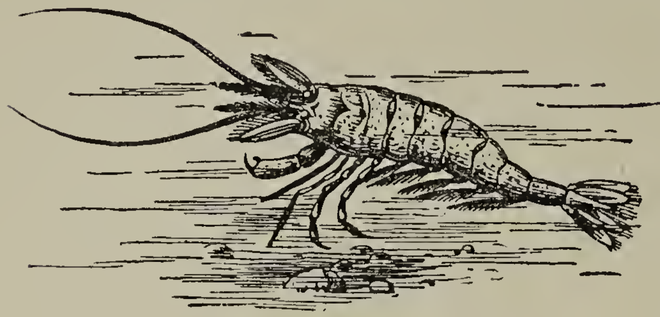
The vast majority of these soft-bodied animals have their home in the water. They are found in every part of the world, abounding in ponds, lakes, rivers, and seas. Some, such as the cockle, bury themselves in the sand ; some bore holes in the soft rocks ; others, like the mussel, are found in the shallows near the shore ; but by far the



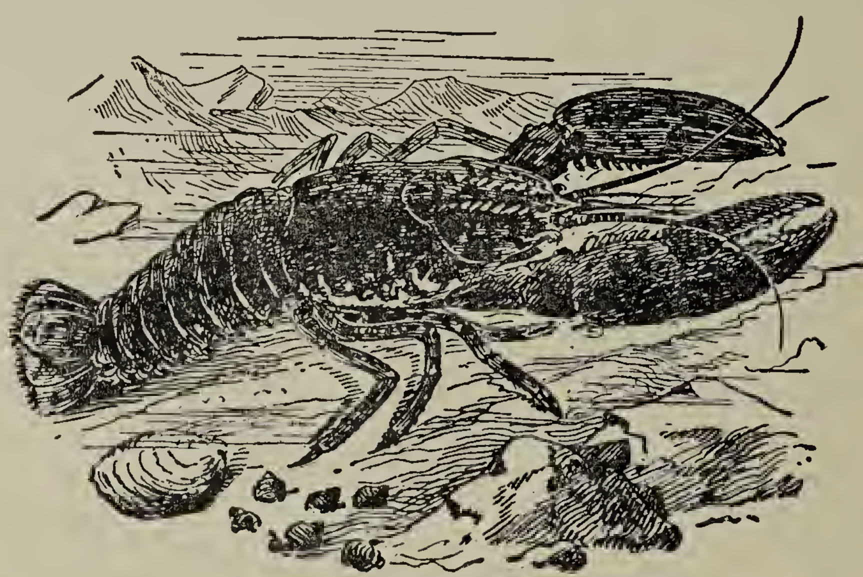
greater number make their dwellings in the very depths of the ocean.

The shells which these animals make for themselves are sometimes in one, sometimes in two pieces. The whelk, periwinkle, cowrie, and snail have shells made all in one piece. We call them *uni-valves.* Mussels, oysters, cockles, and scallops have shells made of two parts. We call these *bi-valves.*

Slugs and snails, although originally water animals, have been fitted to live and breathe on land. They breathe through slits in the neck; and glide slowly along on a broad, fleshy foot. They live on vegetable food, and the upper jaw is provided



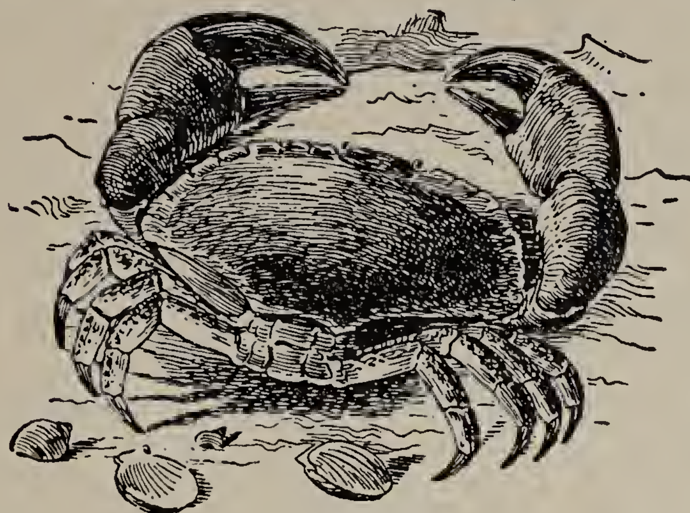
SHRIMP.



LOBSTER.

with several rows of teeth, which act as a rasp to grind off their food.

Let us next consider the *jointed animals*, Their bodies are formed of ringed segments, and their limbs are jointed, and in several parts. Insects and spiders belong to this group, which are countless in number. But the class also includes shrimps, lobsters, crabs, centipedes, and millipedes. The two last may be often seen

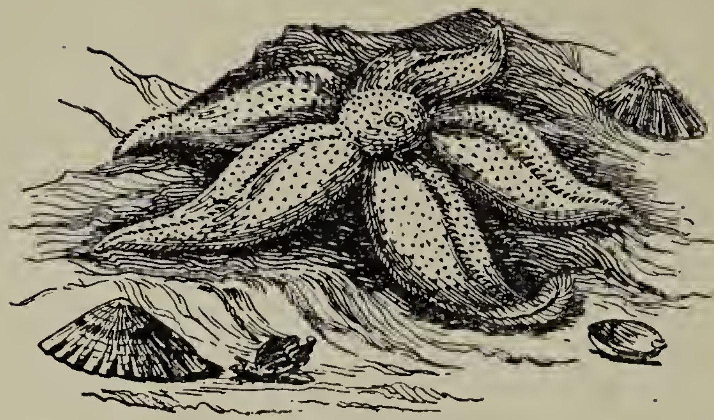


CRAB.

under old boards, or hidden away beneath dead leaves and stones in the garden.

Insects have six legs; spiders eight; shrimps, crabs, and lobsters ten. In the insects the segments are easily seen, but the coat of the spider is soft, smooth, and leathery. The body of the insect is in three parts; that

EARTHWORM.



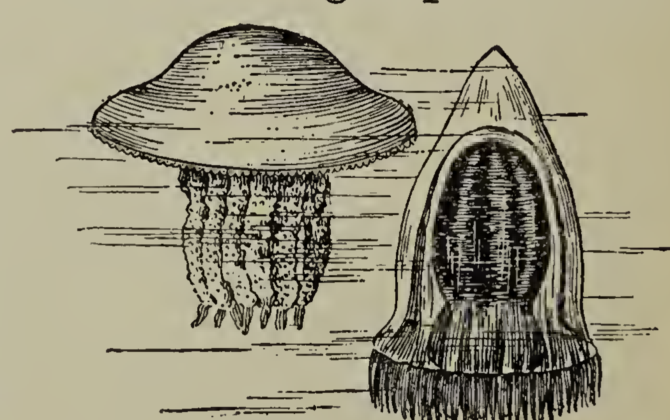
STARFISH.

of the spider is in two.

The next group of invertebrates are the *worms*. They include the common earthworms, seaworms, lugworms, and leeches.

SEA-ANEMONES.

Next to these come a small group, of which the *starfish* may be taken as a sample. First of all, it is badly named; it is not a fish. The group includes sea-urchins, sea-cucumbers, and others, all of them having some-



JELLY-FISH.

thing of the form of the starfish. Below these is another class, which includes *jelly-fish*, *corals*, and *sea-anemones*—all inhabitants of the water.

SPONGE.

The last and lowest group in the animal life of the world are represented by the *sponges*. We may call them the first animals.

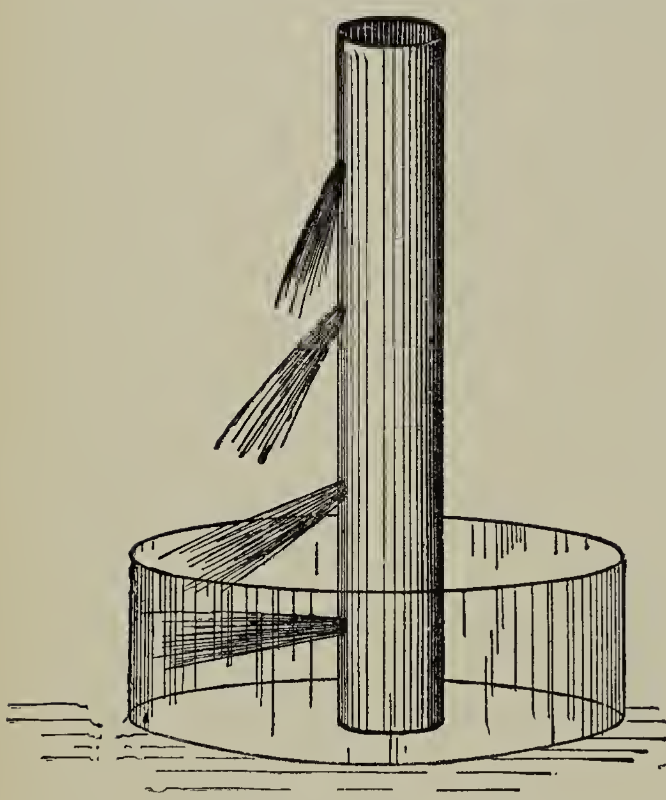
Lesson XXVI

More about the Pressure of Liquids

"We are now in a position to inquire a little further into the subject of liquid pressure," said Mr. Wilson. "You remember that, in one of our recent lessons, we proved, by pouring water into a tin box, that liquids press downwards; and the more water we put in the box the heavier it became. This is just what we might expect; and it proves that *the greater the depth of water, the greater the pressure downwards.*

"Suppose we have another experiment. I have here a long, round, cardboard case, which I have plugged up at one end, so as to make it water-tight. Fred shall come and hold it while I fill it with water.

"If I bore a hole in the side, the water will flow out. Now notice; I will bore several holes, one below the other. The water flows out through each. But are all the streams alike? Look! the top stream flows quite gently compared with the rush of the bottom one; and each one, from the top downwards, flows with greater force than that above it.

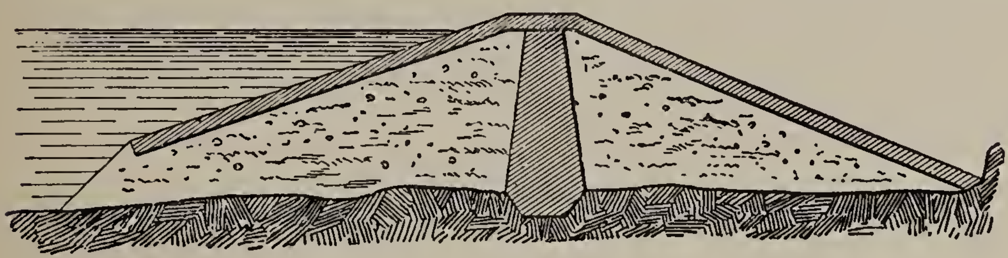


"Now what does this prove?"

"It proves that the pressure of the water sideways increases with the depth, sir."

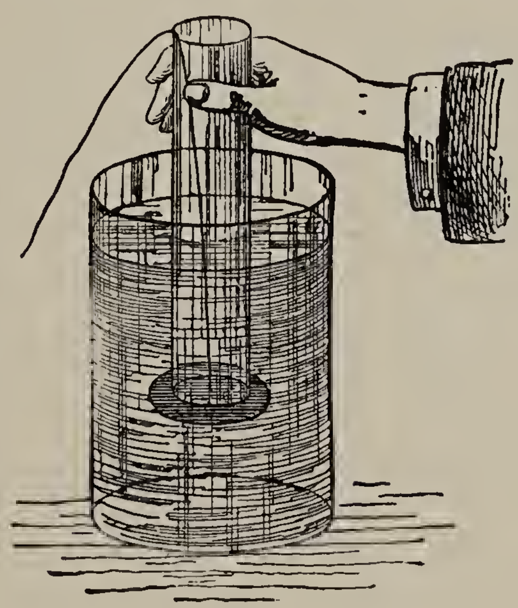
"Quite true, Fred. It is for this reason that, in constructing canals, reservoirs, and embankments, the walls or banks are made thicker at the bottom than the top. *The greater the depth of water, the greater the pressure sideways.*

"Here I have the glass cylinder and disc, which we used before, in one of our experiments.



When I lower the cylinder and disc into the water and let go the string, what happens?"

"The disc remains close to the bottom of the cylinder, kept there by the upward pressure of the water, sir."



"Exactly. Now I will pour water gently into the cylinder. This water does not run out at the bottom, you see. It gradually rises in the cylinder. What does that prove?"

"It proves that the upward pressure of the water against the disc is greater than the weight of the water in the cylinder above it."

"You are quite right, my lad. Suppose, now, we pour some more water into the cylinder. The water continues to rise in it till at last the disc falls away. It required the downward pressure of all that water in the cylinder to overcome the upward pressure on the disc.

"Now lower the cylinder and disc again, but to a greater depth, and I will pour in water as before. This time more water is required in the cylinder to detach the disc. What does that prove?"

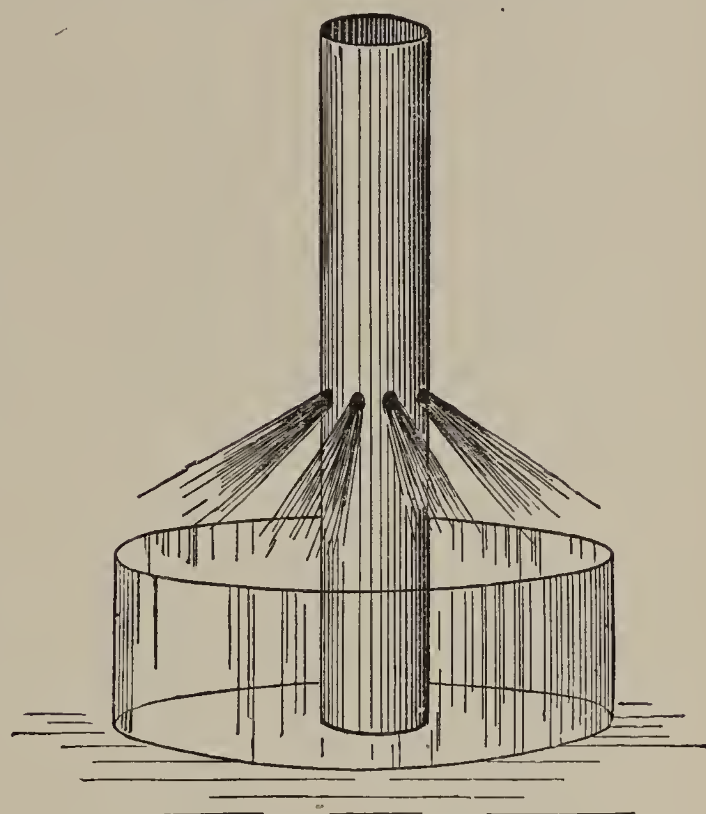
"It shows plainly, sir, that the upward pressure of the water is greater than it was before; it requires a greater weight of water pressing downwards in the cylinder to overcome the upward pressure on the disc."

"Just so," said Mr. Wilson; "and now I think we clearly understand that *the greater the depth, the greater the pressure downwards, upwards, and sideways.* In other words, the pressure in all directions increases with the depth.

"Now before we leave the cylinder and disc, I want to show you another little experiment. We will lower them as before into the water and let go the string. The disc remains close to the cylinder. Notice that I may move it about wherever I please, horizontally, in the water, and the disc does not fall away.

"The pressure upward *is always the same at the same depth.*

"Now I will raise it a little in the water, and the disc falls away, because the upward pressure is not so great at that depth as it was when lower in the water.



"Let us return to our cardboard case. I will first plug up all the holes, and then pierce it with a circle of holes at the same level. If we now fill it with water, we shall see that equal streams flow from all the holes with equal force.

"This means that, at the same depth, the pressure downwards and sideways is equal. Our experiments therefore prove that, *at the same depth*, water, and, of course, *all liquids press equally in every direction.*"

Lesson XXVII

Digestion

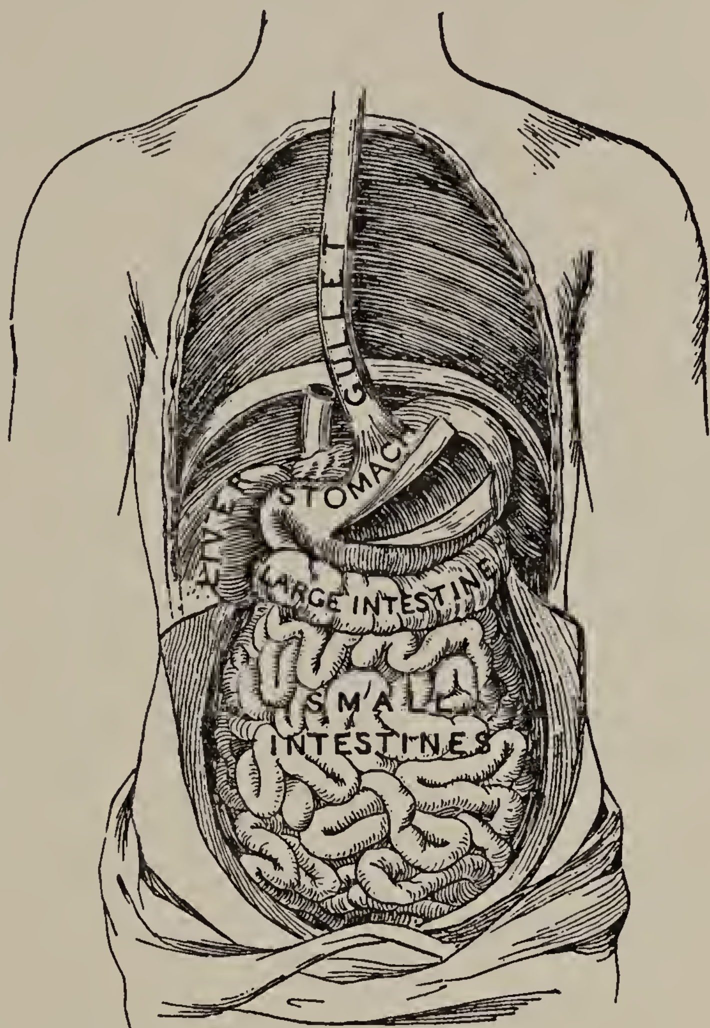
The body is a working machine, and every act of our daily life destroys some of its substance. The muscles as the movers of the body, the brain as the centre of thought and intellect, the eyes, nose, ears—all parts of the body perform their work, but in the very act destroy some of their own substance. These tissues of the body must be renewed as they are destroyed, or the body would lose in weight and strength. It is the blood which does this work of building up what is worn away.

But whence does the blood get its materials for this work? The food which we take supplies the materials. The blood is actually made from the food which we eat. The food is changed into blood by the process of digestion.

Let us glance at this work of blood-making. The first part of the work takes place in the mouth. We call it *chewing* or *mastication.* You know that, as this work goes on, the food is moistened by a fluid in the mouth.

This fluid is called *saliva,* and is poured out from the lining membrane of the mouth. It has the power of changing starch into sugar. Starch, you know, is insoluble, but sugar is soluble. Bread and many of the things we eat contain starch. *The saliva changes this starch into sugar;* the sugar is soluble, and is easily absorbed into the blood.

When the food has been properly masticated, it is swallowed and carried by the *gullet* into a bag or pouch called the *stomach.* In this pouch it is rolled and churned about to still further break it up, and all the time a fluid called *gastric juice* is oozing out from the sides of the stomach itself to dissolve it. This *gastric juice dissolves* the *lean meat* and the *glutinous parts of bread* on which the saliva has had no effect.



The inner lining of the stomach is crowded with a network of blood capillaries, and these vessels suck up the fully dissolved matters of the food as the gastric juice continues to act upon them.

The stomach at its right-hand extremity becomes a narrow pipe, and forms the commencement of a long tube—the *intestines.* This tube if stretched out would measure five or six times the length of the person, but it is so folded and doubled upon itself that it is easily packed in the space provided for it below the stomach.

Resting on the intestines is a great organ, the *liver*. This organ is always at work preparing a fluid called *bile*, which is required for the complete digestion of the food. The bile, as it is prepared, passes into the tube of the intestines, and there mixes with the food that has come from the stomach.

Bile has the power of acting on *the fatty parts* of the food, and dissolving them, just as the saliva and gastric juice dissolve the other parts.

As the food passes along the intestinal canal, these dissolved fats are absorbed into the blood, and, with them, all that is of use. Only the undigested remainder is cast off as useless.

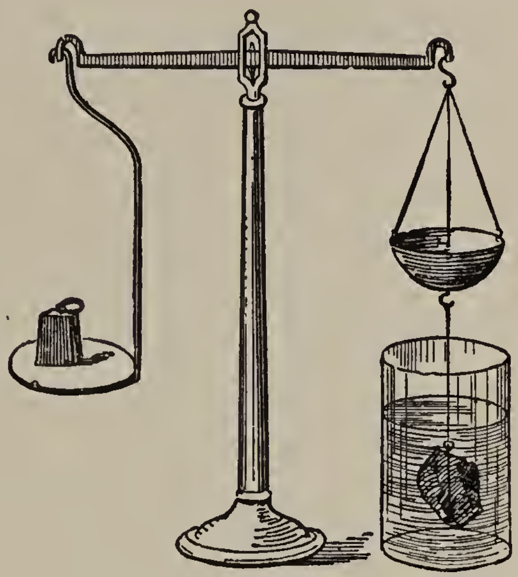
Lesson XXVIII

Buoyancy of Liquids

"We have seen that water and all liquids press downwards, sideways, upwards—in fact in every direction," said Mr. Wilson, "and that at the same depth the pressure is equal in every direction. I want now to direct your thoughts towards the pressure of liquids in one direction only—upwards. There is much to be learned from this.

"I have here a small square block of flint glass.

I will attach this piece of silk thread to it. Now Fred shall come to the front and hold it suspended by the thread. He will tell us at once that he feels a downward pressure as he holds it. What causes that downward pressure?"



"It is the pressure of gravity, sir, or the weight of the block itself."

"Quite right. Now I want you to hold the thread in such a position as to let the glass block dip into this bowl of water. Tell us what you notice now, Fred."

"I can feel the water pressing the glass up, sir," said Fred. "It does not seem to weigh so heavy now."

"Well, suppose we try to find out what all this means. We will begin by weighing the piece of glass. It weighs exactly three ounces. This means that when we hang it from the thread it presses down with a weight of three ounces.

"Now I am going to suspend the piece of glass from the scale-pan by means of the thread. We still require the three ounce weight in the other scale to balance it. It still weighs three ounces. The two arms of the balance are horizontal, "Now place the bowl under it, and let the glass dip into the water. What do you see?"

"The scales do not balance now. The weight scale sinks."

"What does this prove?"

"It proves that the glass does not weigh three ounces now, sir."

"Quite right; let us see what it does weigh. I will take out one of the ounce weights, and now, you see, the arms of the balance once more rest in the horizontal position.

"The glass, we know, is pressing downwards with a weight of three ounces, but the water is pressing upwards, and it is this upward pressure of *the water which seems to rob the glass of one-third of its weight.*

"Suppose, before we go any further, we try the same experiment with a piece of brick and a piece of sulphur.

"Each of these substances loses half its weight when suspended in the water.

"Now if I detach the glass, the brick, and the sulphur from the thread, they will all sink to the bottom of the water. Why do they sink?"

"The downward pressure of their weight is greater than the upward pressure of the water."

"We have learned then that *all solid bodies weigh less in water than in air*, but some, such as glass, sulphur, brick, and of course such bodies as stone and metal, sink to the bottom if unsupported. We call these heavy bodies."

Lesson XXIX

Mammals

Animals which nurse their young form a very large and important class. They comprise individuals which differ from each other in nature, habits, food, and therefore in structure.

Mammals are divided into orders.

Considered as an animal, man stands at the head of these orders. He is the only two-handed animal, and forms the sub-order *Bi-mana*. There is another sub-order which makes a very near approach to man, although the members of it differ widely from each other. They form a separate group, and are distinguished by their hand-like feet, each having a thumb for grasping, exactly like the thumb of the real hand. It is this distinction that gives the name *Quadrumana,* which means four-handed animals.

It is not merely the possession of two hands instead of four, however, that places man so much higher than this leading group of the brute creation. We have only to compare the head of one of the great four-handed animals with the head and brain of a man. It is intellect that makes man something more than a mere animal.

Man is the only animal that stands and walks erect. The four-handed animals all move about

with an awkward stooping gait, resting their fore-hands on the ground at each step. If you notice the enormous length of their arms you will see that they are specially fitted for that kind of locomotion.

This four-handed structure is no mere accident; it was designed to meet the wants of these animals, all of whom live mostly in the trees, and require hands for grasping.

The Quadrumana arrange themselves naturally in different groups. First we may take the monkeys, which are the smallest and least savage of the whole sub-order. They are distinguished by their long tails, and also by cheek-pouches inside the mouth for storing away food till it is wanted. Most of them, too, have bare patches of hardened skin where they sit (callosities, they are called).

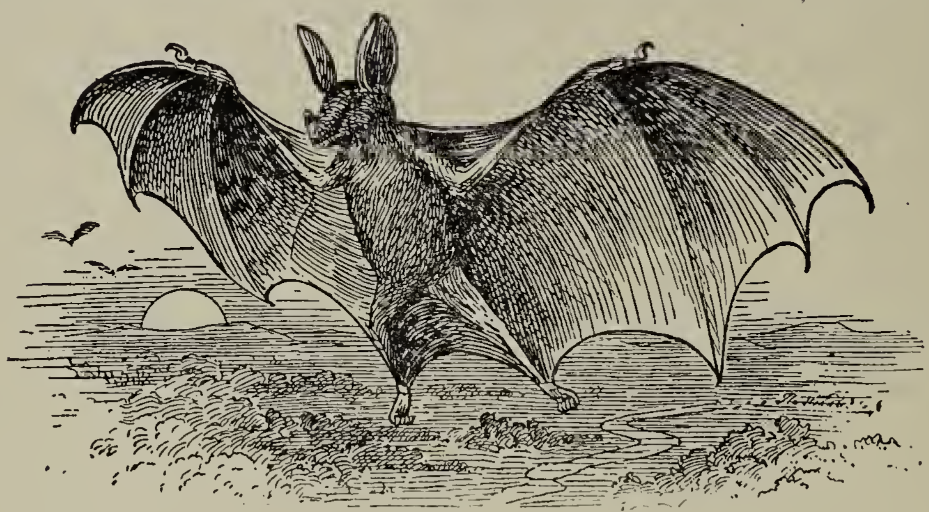
The monkeys of the New World mostly use their long tails as a fifth hand in climbing trees and swinging from bough to bough. They may be distinguished from those of the Old World by the position of the nostrils, which, in their case, open in long slits on the sides of the nose. The monkeys of Asia and Africa have the nostrils at the end of the nose.

The baboons form another group, and are extremely fierce and formidable. They too have cheek-pouches and callosities. They are distinguished by their very short tails.

The largest of the Quadrumana are the apes, or man monkeys. These have no tails, no cheek-pouches, no callosities. This group includes the gorilla, the chimpanzee, and the orang-outang. The gorilla is an extremely savage and powerful beast, and often reaches the height of seven feet.

The *wing-handed animals* usually follow the Quadrumana as the next order. They include the various members of the bat family. These animals live on insects which people the air, and they must therefore have the power of flight. To provide for this the two hands are modified to form wings. The fingers are lengthened to an enormous extent, and a thin membrane stretched between them forms a wing.

We will next look at another class of insect-



BAT.

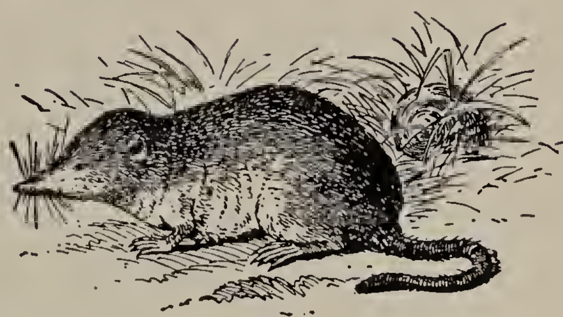
eaters, of which the mole is a type. The insects which form the food of these animals (mostly beetles and their grubs) are found in the ground, and so are the slugs, snails, and earthworms, with which they vary their diet.

MOLE.

If you think over our earlier lesson on the mole, you will doubtless remember that he is provided with teeth specially fitted for crushing his prey, and with fore-paws for digging in the ground.

The hedgehog and the shrew belong to the

HEDGEHOG.



SHREW.

same order. They too are insect-eaters.

Lesson XXX

Floating Bodies

"Our last experimental lesson," said Mr. Wilson, "taught us that when we immerse a solid body in the water, the water, by its upward pressure, tries to bear or buoy it up. Certain bodies, it is true, sink in the water when unsupported, but this is because they are heavier than the water. The same bodies would refuse to sink if they were placed in a heavier liquid, say mercury. Here is some mercury in this bowl. Pieces of stone, tin, iron, silver, copper, and lead all rest on the surface of this liquid.

"You shall come to the front and help me again, Fred. I want you to place this piece of cork and these pieces of wood in the bowl of water. They rest on the surface of the water.

"Now try and force them down to the bottom. They will not remain there; they immediately rise to the top again.

"Here is a bladder filled with air. It rests lightly on the water. Try and force it down. It springs upwards to the surface again.

"The upward pressure of the water forces all these things up. It tried to do the same with the piece of glass the other day, but the glass was too heavy. Its weight overcame the upward pressure of the water, so that it sank.

"We call this upward pressure of water its *buoyancy*, that is, its power of buoying bodies up, so as to make them rest on its surface. Bodies which rest on the surface of a liquid in this way are said to float. But why do they float?"

"They float because the upward pressure of the liquid is greater than their downward pressure or weight, sir."

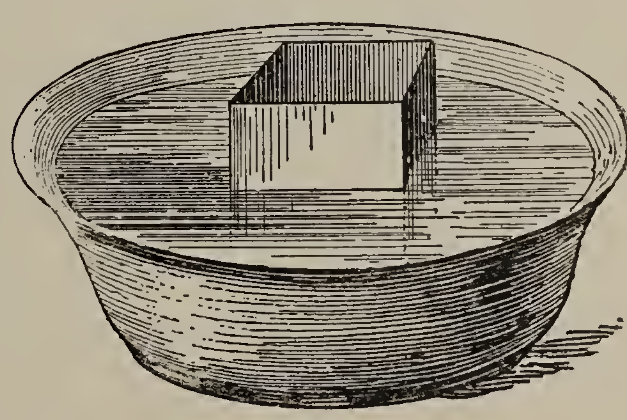
"Quite right, Fred. Now I want you to notice the way in which the various bodies float. The bladder rests lightly on the water, the cork sinks into it a little way, the pine, beech, and oak woods sink lower down. Let us see what all this means.

"I have here a small tin box, in one side of which I have bored a hole. The box is filled with water up to the hole. I will suspend the piece of glass from the balance, and let it dip into the water just as we did before. Note carefully what happens. You know that the glass loses one ounce in weight when it dips in the water. What do you see now?"

"Some of the water is running out of the hole into the basin below, sir."

"So it is. But why should it run out? I will tell you. The water and the glass could not occupy the same space, so some of the water runs out at the hole as the glass dips down, to make room for it. *The piece of glass forces out exactly its own bulk of water.*

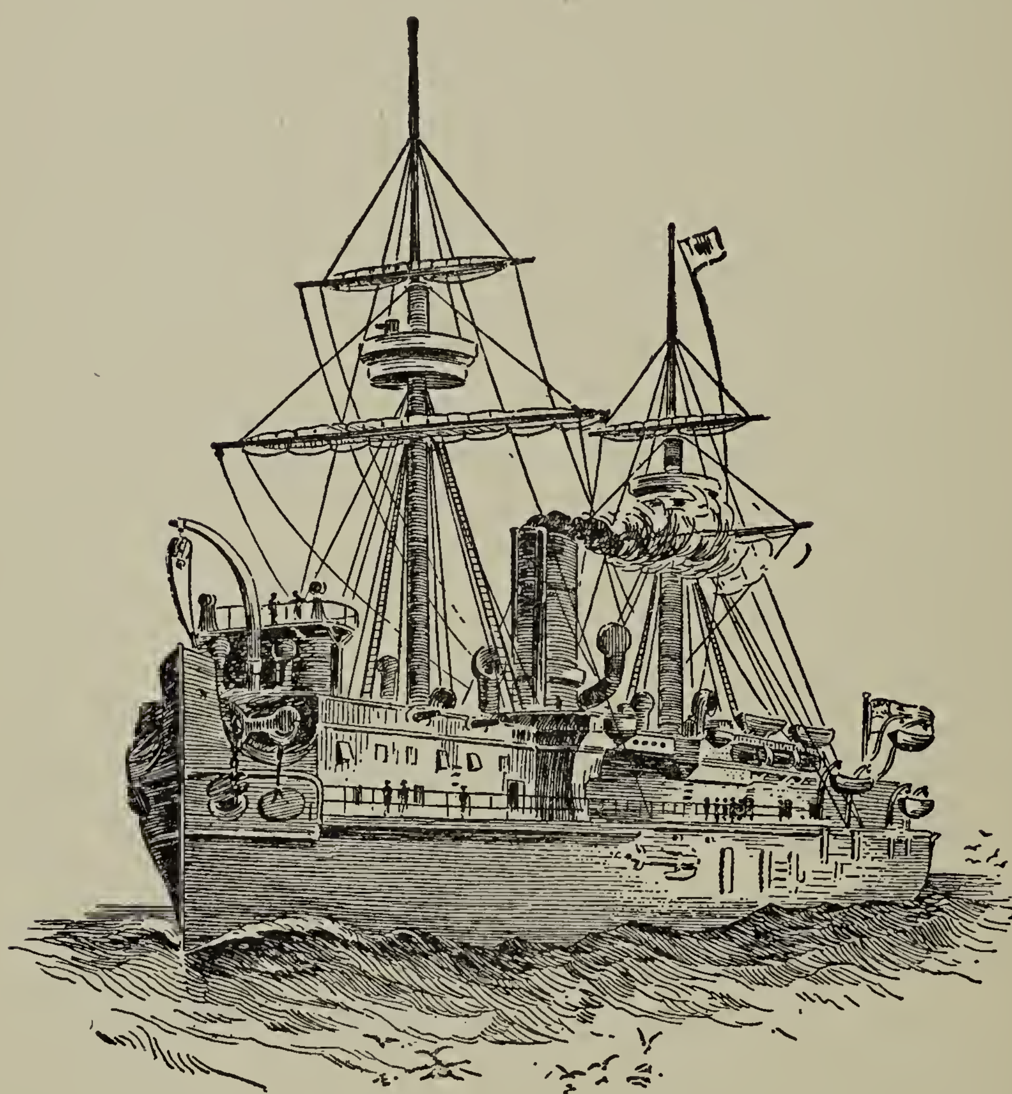
"If this water were collected and weighed, it would be found to weigh just one ounce—exactly what the glass lost in weight. That is to say, *the upward pressure of the water is equal to the actual weight of the quantity of water which the body displaces.* If the body were equal in weight to its



own bulk of water, it would float with its upper surface on a level with the surface of the water It would, in fact, displace a quantity of water equal to itself, bulk for bulk.

"You know that a piece of iron sinks in the water, because it weighs much more than its own bulk of that liquid. But I put this canister in the water, and it floats. Why is this?

"The canister, although made of heavy metal, is hollow and filled with air only. It weighs



much less than its own bulk of water, and thus the water can buoy it up. This explains why our great iron ships float on the sea. They are lighter than the water, bulk for bulk, and the buoyancy of the water makes them float."

Lesson XXXI

Air has Weight

"Suppose we have a talk about the air this morning," said Mr. Wilson. "The air, you know, is a material substance. It is a gas. It surrounds our earth, and covers the tops of the highest mountains. We live and move about at the bottom of an ocean of air, just as fishes and other animals do at the bottom of the sea.

"This ocean of air, being a gas, has no surface. You remember, no doubt, that one of the points that distinguish gases from liquids is that, while liquids always keep a level surface, gases have no surface at all. This air extends far beyond the mountain tops—probably fifty miles upward—perhaps even beyond that.

"People who go up in balloons find that the air becomes thinner as they ascend, until it is very difficult, and at last quite impossible, for them to breathe; and yet the greatest height ever reached in a balloon is about seven miles.

"Now I want you to think for a moment of one of the lightest substances we have met with in our lessons—that thin, fleecy eider-down.

"Picture to yourselves a mass of this light, fleecy down, piled into a great heap, reaching upwards for miles. Light as the down is, it has some weight, and the upper portion must of necessity press upon that which is beneath it. What do you think would be the result of this?"

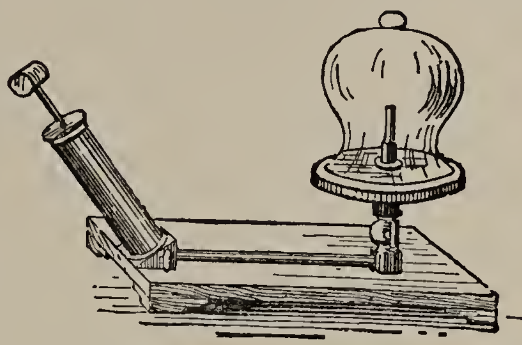
"The lowest part of the heap would be pressed downwards by the weight of that above it, sir. It would be packed close and dense."

"You are quite right," said Mr. Wilson, "and it is just so with the air. This, being a material substance, has weight. That is to say, every particle of air is attracted or drawn down to the earth by the force of gravity. The layers above press upon those below, so that the air at the foot of a mountain is always denser and heavier than that at its summit."

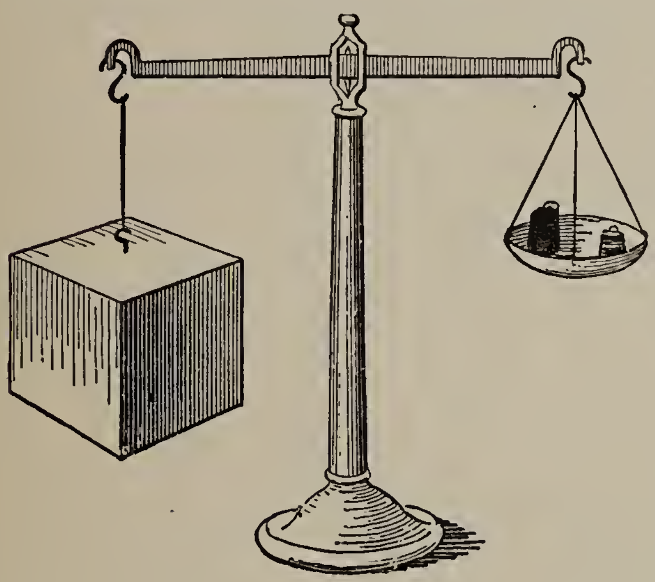
"It is the same with water, sir," said Fred. "You proved that the pressure of water is always greater at the bottom than near the top."

"I am glad you can see the connection, Fred, between the water and the air in this respect, for the two are very similar. *Air, like water, is a material substance and has weight.* It is the weight in each case which presses downwards.

"Let us have another look at this instrument. I showed it to you once before. It is called an air-pump. I do not intend to enter into any explanation of the air-pump at present. That will come in a lesson by itself later on. All I want you to know about it now is that, with the help of it we are able to remove the air from a vessel, and leave it empty. If we were to take a square box measuring a foot each



way, we should find, by first weighing it, then exhausting the air from it, and then weighing it



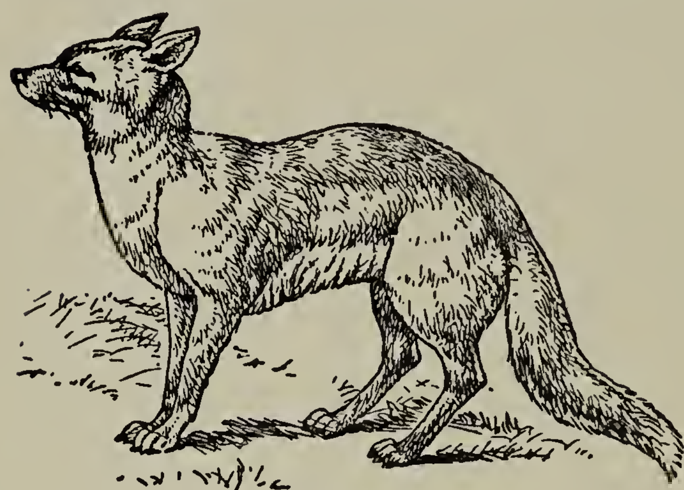
again, it would lose rather more than one ounce. That is to say, *a cubic foot of air weighs about one ounce.*

"But if we took our square box and the air-pump up the side of a mountain, and repeated the experiment, we should find that the cubic foot of air would not weigh an ounce there ; and it would weigh still less as we approached nearer the top, because the air becomes lighter and thinner as we ascend."

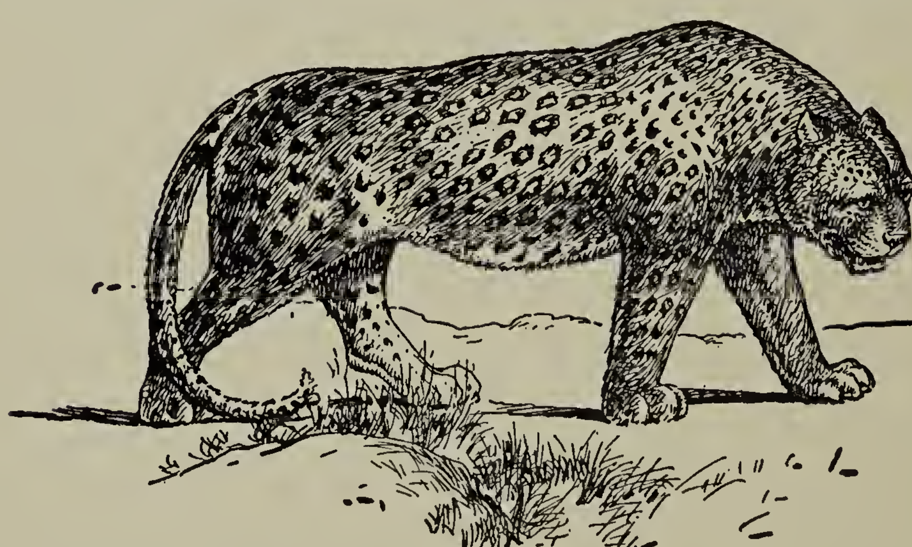
Lesson XXXII

More about the Mammals

The flesh-eaters form a large and important order of the mammals. They live, as their name indicates, entirely on the flesh of other animals. They are extremely fierce, strong, and swift, for they are hunters; and they have teeth and claws for seizing and tearing their prey. The animals of this order are usually arranged in groups, according to the manner in which they walk.



JACKAL.



JAGUAR.

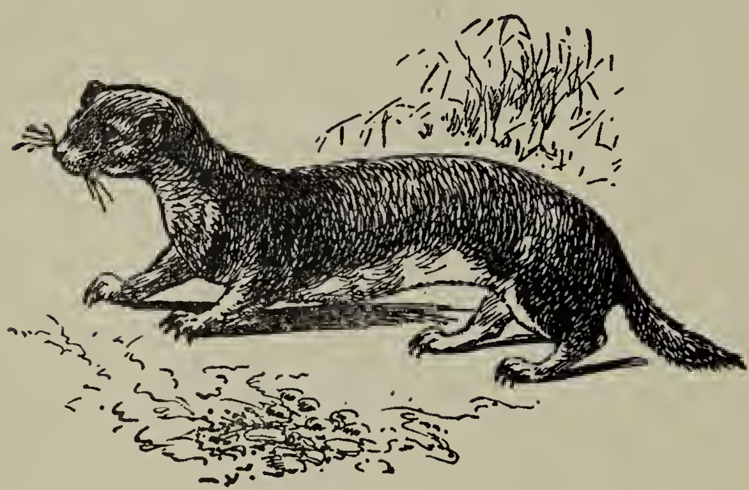
The first group are the *toe-walkers.* These are well named, for they walk on their toes only; the rest of the foot does not touch the ground. They include the various members of the cat and dog families. Among the cats are the lion, tiger, leopard, panther, jaguar, puma, ounce, lynx, and

BEAR.

our common domestic cat. The dog family includes the wolf, fox, and jackal.

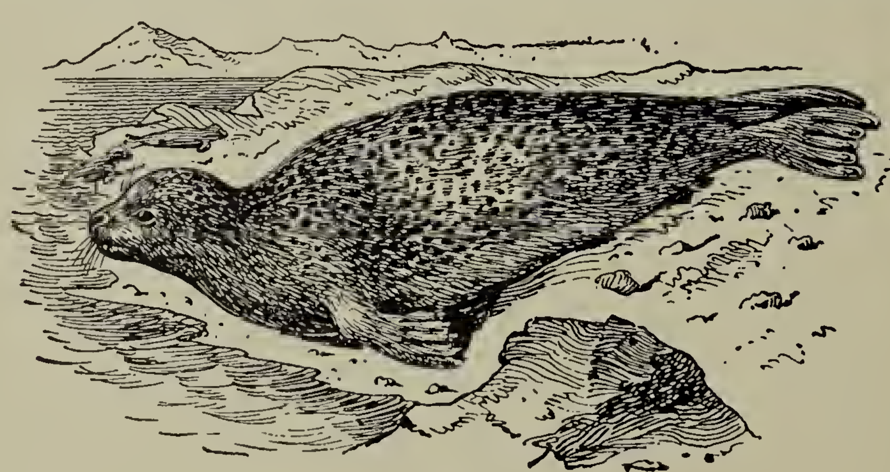
The *sole-walkers* form the next group. They are distinguished from the group already mentioned by the form of the feet, and the use they make of them in walking. They plant the whole sole of the foot flat on the ground at each step. The bear, racoon, and badger families are included in this group.

There is a large group, known as the *weasel family*, which form a sort of link between the toe-walkers and the sole-walkers. They include the weasel, marten, sable, polecat, ferret, and stoat. Some of them are sole-walkers and some toe-walkers; but they are all distinguished by an unusual length of body and a shortness of legs, as well as by their boldness, ferocity, and agility. These fierce little creatures, many of them not bigger than a rat, fearlessly attack animals of twenty times their size and strength.



WEASEL.

Last among the flesh-eaters come the *fin-walkers*. These animals, which include the seal and walrus, find their food in the water, and spend a great part of their lives in that element. Their limbs are short, and make admirable



SEAL.

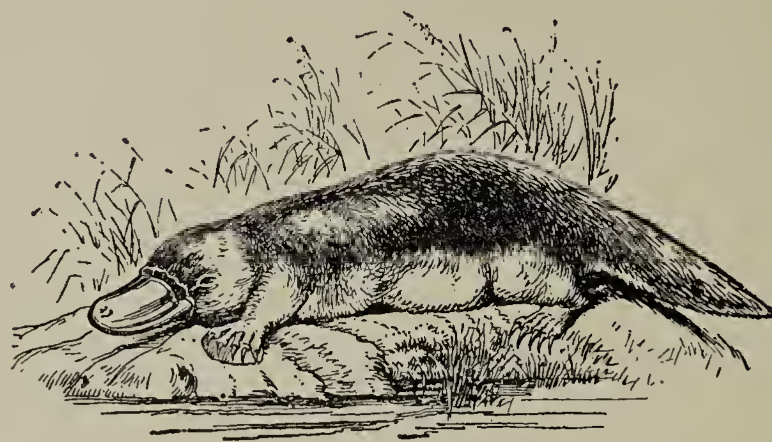
paddles for swimming, but their movements are very limited and awkward on land.

Leaving the flesh-eaters we come next to the *gnawing animals.* These live entirely on vegetable food, mostly roots and nuts and the bark of trees. They are distinguished by the peculiar form of their incisor teeth, which, in these animals, become four sharp chisels, specially adapted for gnawing their food. You remember, no doubt, that these teeth, formed as they are of the hard enamel outside, and the softer dentine beneath, are able by their own work of gnawing to keep a sharp cutting edge. The order is a very large and numerous one, and comprises more than one-third of the mammalia. The rabbit, hare, mouse, rat, squirrel, dormouse, beaver, guinea-pig, and porcupine belong to this group.

RAT.

The *toothless animals* form the next order. It is a small but very curious one, and the members of it are all foreign animals. It includes the ant-eater, sloth, and armadillo, and the curious duck-bill of Australia. None of these animals have canine teeth; some have no incisors; others no teeth at all, hence their name.

They live on worms and insects, as well as slugs



DUCK-BILL.

and other soft-bodied animals.

Lesson XXXIII

Pressure of the Atmosphere

"Come, boys," said Mr. Wilson, "I've got a plaything. I want to be a boy again. You, of course, know what it is. It is a leather sucker. I have had it soaking in water for some time, so that it is quite ready for us. Suppose you come here, Fred, and try it on this slate.

"Ah! I thought you would know how to use this toy," he continued, as Fred pulled the string and lifted up the slate. "The leather seems to have stuck to the slate, but we know that is not the case, because leather is not an adhesive substance. Tell us what you did to make the leather hold to the slate like this, Fred."

"When I put the sucker on the slate I pressed it down close, sir; that is all," said Fred.

"Quite right; and in pressing it you squeezed out all the air from between the leather and the slate. There is nothing between them, not even a little air. There is air outside, but there is none under the sucker. This is the whole secret. The sucker is held fast to the slate by this outside air pressing down upon it.

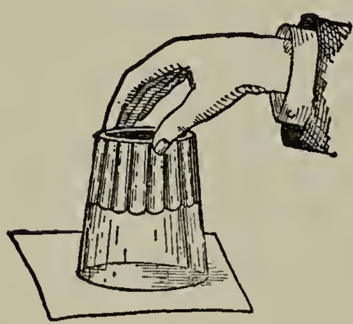
"We will now remove the sucker, place the slate against the wall, and in that position try it once more. Yes, the sucker again holds fast, and of course it is the air that is pressing it to the slate just as before. If I hold the slate overhead, or slant it in any direction, the result will still be the same. The sucker will hold fast, and in each case the cause will be the same—the pressure of the air on the outside of it.

"This being so, what have we discovered?"

"*The air presses equally in every direction*, sir; for it does not matter how the slate is placed, the sucker always holds fast."

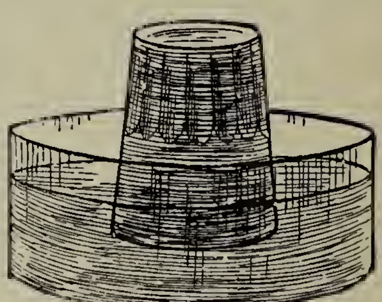
"Now watch what happens when I bore a hole in the sucker," said Mr. Wilson. "The sucker is at once released. Some air rushed in through the little hole, as soon as it was made, and this air pressed upwards with as much force as the outer air was pressing downwards.

"Let me show you another experiment now," he added. "I have here a tumbler filled to the



brim with water. I will place this piece of writing paper over the glass, and invert it. When I remove my hand the paper remains close to the glass, so that the water cannot run out. What is the cause of this?

"The air presses upwards on the paper and holds it close to the glass. This pressure of the air, too, must be considerable, for the water in the tumbler is heavy, and would naturally fall if unsupported. Now I will place the tumbler, inverted as it is, in this bowl of water with the lower end just below the surface. When I remove the paper, what do you see?



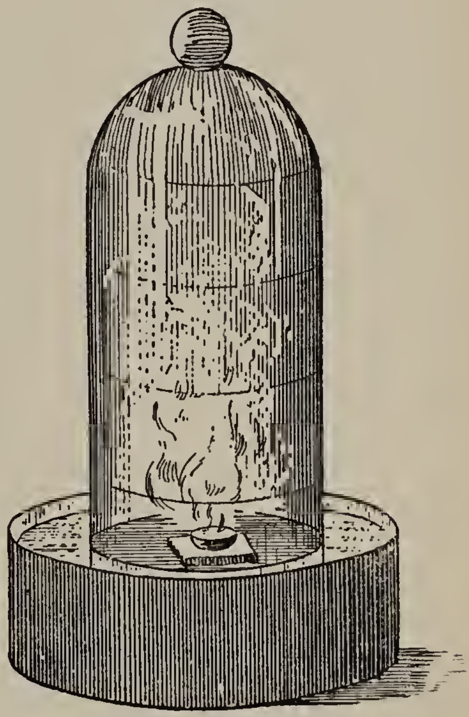
"The water still stands in the tumbler, although there is now no paper to keep it in. There is only the water in the basin.

"Shall I tell you why the water does not rush out of the glass? It is because the air in the room is pressing downwards on the surface of the water in the basin, and this downward pressure is transmitted in all directions by the water itself. The water in the basin presses upwards upon the water in the tumbler, and prevents it from running out."

Lesson XXXIV

The Atmosphere—What it is

"We have learned a great many facts about the atmosphere as a material substance—about its weight, and its pressure in all directions," said Mr. Wilson. "We have now to study it from another point of view.



"I have here a large glass bell-jar. The jar of course contains air. I will place a small piece of phosphorus on this little tin plate, and float the plate in this bowl of water. Now I will light the phosphorus with a taper and cover it quickly with the bell-jar, resting the bell just below the surface of the water. The phosphorus burns with an intensely bright flame in the jar, and gives off dense white fumes. We must wait till these fumes clear off, and then you shall tell me what you observe."

"Some of the water from the bowl has gone into the bell-jar, sir," said Fred.

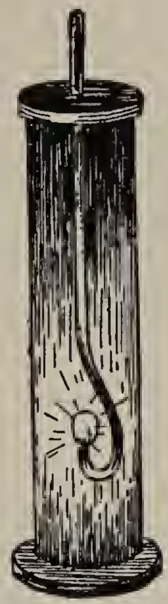
"So it has, Fred. If you come here you will see that the bell-jar is marked by lines into five equal parts, and the water now fills one of those parts. Some of the air has made room for this water, for the jar contains now only about four-fifths of the original quantity.

"Our next business will be to find out what we have in the jar now. Is it the same as it was before the experiment? Remove the stopper of the bell-jar, and plunge this burning taper into it. You see *it is immediately extinguished.*

"Suppose I light a piece of phosphorus and lower that into it. The result is the same; it goes out immediately. The gas, therefore, which is now in the jar is not air as it was at first. One-fifth of its bulk has disappeared in the burning, and the remaining four-fifths is a gas which puts out a flame. It will not allow anything to burn in it. We call this gas *nitrogen;* it forms four-fifths of all the air around us.

"I have something else now to show you," he continued. "Here are some gas jars. If I hold them up they appear empty—that is to say, you would expect to find nothing in them but ordinary air. I shall soon, however, be able to prove to you first that they are not empty, and also that what they do contain is not air.

"Let us begin with this one. I will light a splinter of wood, and as soon as it is well lighted, I will blow out the flame so as to leave only a red spark. Now notice what happens when I uncover the jar and plunge the splinter into it. The spark immediately *bursts into a flame again and burns with a very brilliant glow.* It burns much more fiercely and brightly than it did in the air.



"Let us next take one of the other bottles. Here is a piece of charcoal. I will first make it red-hot, and then plunge it as before into the jar. The result is the same: the charcoal burns with greater fierceness and brilliancy immediately it is lowered into the jar.

"Lastly, I will lower a piece of phosphorus into the jar—this time without even lighting it. The phosphorus takes fire instantly, and burns with such a dazzling brightness that we cannot bear the sight of it, and we turn our eyes away.

"I think we have now done enough to prove that these jars are not empty, and also to prove that what they do contain is not air. I filled the jars myself with a gas which we call *oxygen.* One of these days you shall see me make some oxygen. At present you must be content to learn what it is, and how it acts.

"You saw that all the substances we put into it burn much more fiercely than in the air.

Oxygen is a powerful supporter of burning. It forms one-fifth of the bulk of all the air all over the world. It formed one-fifth of the bulk of the air in the bell-jar, and it was this gas, oxygen, which disappeared. The burning phosphorus went out immediately all the oxygen was used up, and nothing was left but the other gas, nitrogen, which formed the remaining four-fifths.

"In the atmosphere the one part of oxygen is mixed with four parts of nitrogen merely to dilute or weaken it. Burning would go on too rapidly in an atmosphere of pure oxygen.

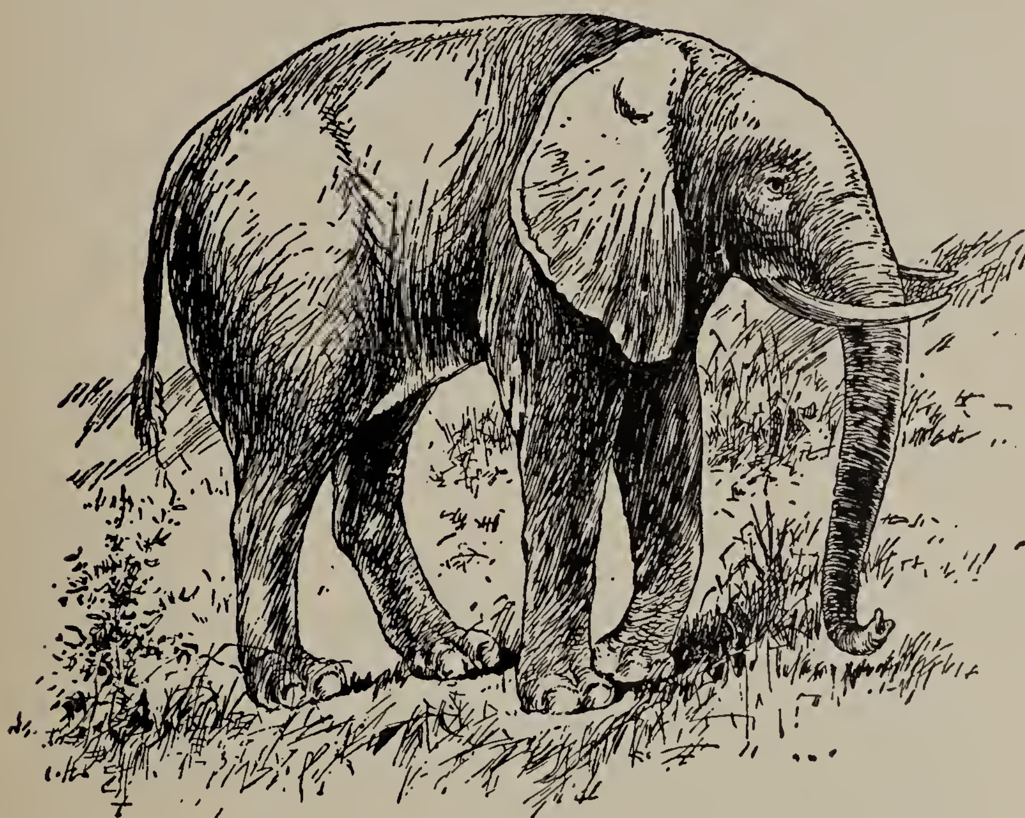
"We shall have to learn presently that we and all animals live by burning. Our bodies are daily and hourly burning away. If we lived in an atmosphere of oxygen, we should burn away too fast, and live too rapidly, like the flames we saw just now. But an atmosphere of nitrogen, on the other hand, would not do, for in it there could be no burning, and without burning there could be no life. *Oxygen diluted with four times its bulk of nitrogen* makes just the atmosphere required."

Lesson XXXV

More about the Mammals

The *hoofed animals* are without doubt the most useful order of the mammals. The members of this very large group have their toes enclosed in hard horny cases, which we call hoofs. They are all vegetarians.

The number of toes varies in the different members of the family. It is usual to arrange them as *odd-toed* and *even-toed* animals.



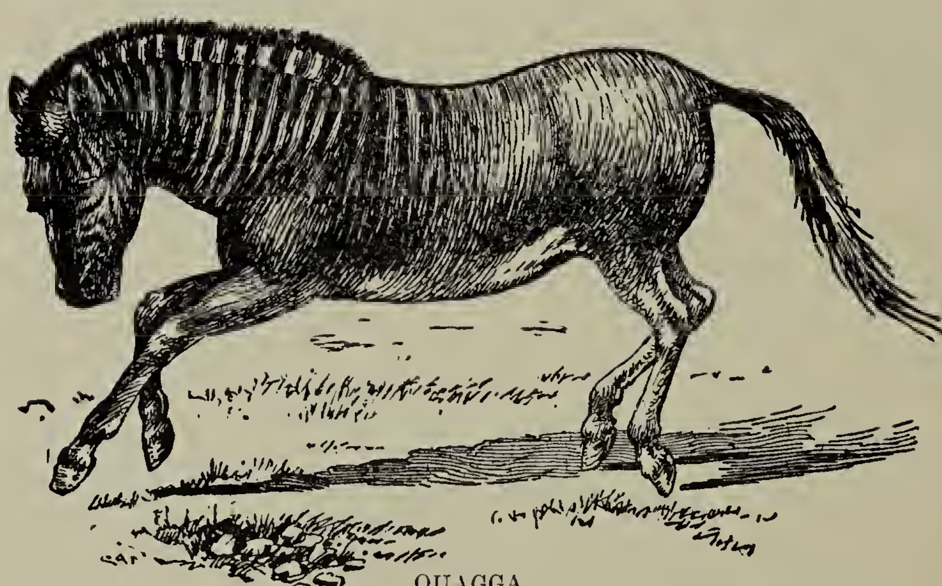
AFRICAN ELEPHANT.

The tapir has three toes on the hind foot and four on the front foot; the elephant has five toes on each foot.

The elephant's feet are most admirably adapted for supporting the enormous weight of body, and for transporting the ponderous mass lightly, easily, and without jarring. This is accomplished by means of a hoof, composed of separate horny plates, which seem to act on the principle of an ordinary carriage spring. Every one who, for the first time, sees an elephant walking, is always

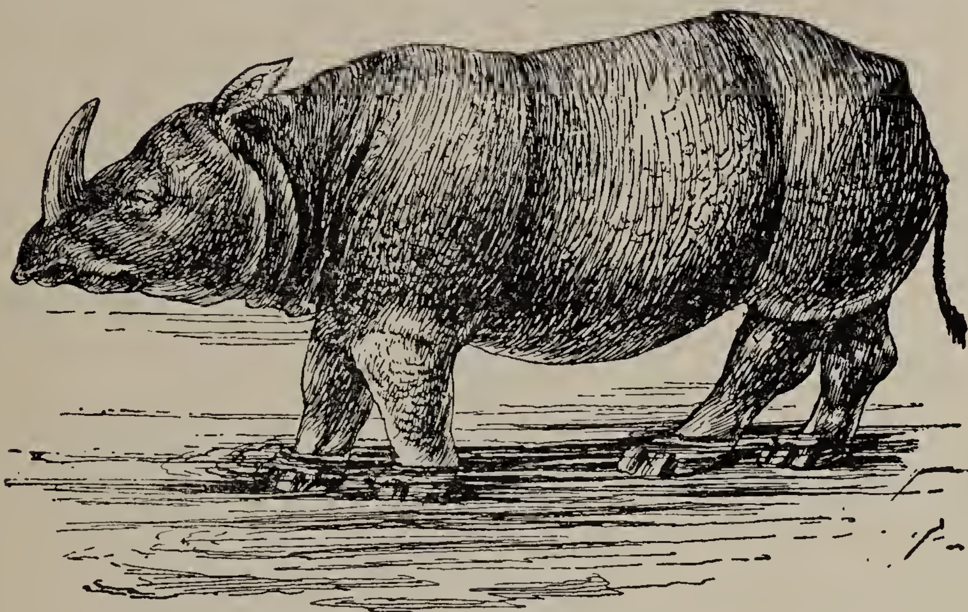
TAPIR.

struck with surprise that the foot does not fall heavily on the ground, but swings forward lightly with an easy sweeping step.



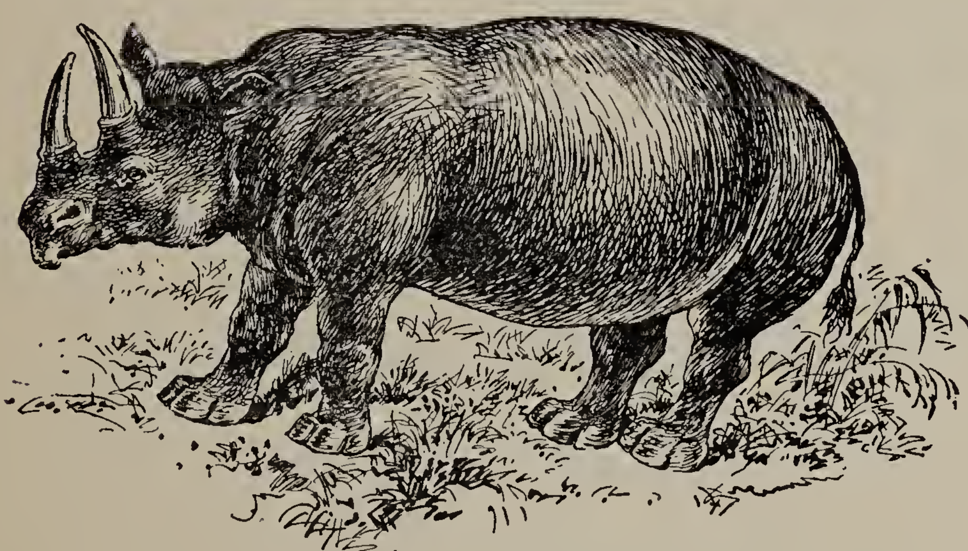
QUAGGA.

The horse, ass, zebra, and quagga belong to a group known as *single-toed animals*. The hoof encloses a single toe, and on this one toe the



INDIAN RHINOCEROS.

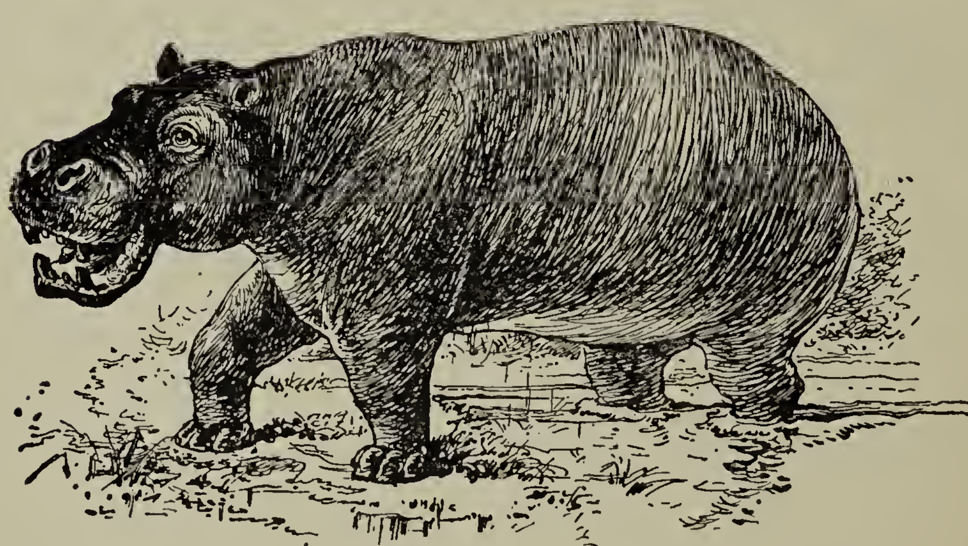
animal walks. The rhinoceros is an odd-toed animal, but his foot is in three pieces.



AFRICAN TWO-HORNED RHINOCEROS.

The largest group of this hoofed order are the even-toed animals. The camel and the giraffe have two toes; the hippopotamus, hog, sheep, goat, ox, deer, and antelope have four toes.

ARABIAN CAMEL.



HIPPOPOTAMUS.

In all, except the hippopotamus and the hog, the two hinder toes are very small. The animals walk on the two front toes only, which form a split or divided hoof, or, as we sometimes call it, a cloven hoof. The four short well-developed toes of the hippopotamus all touch the ground in walking. They do not form a cloven hoof, but are encased in rounded black hoofs.

GIRAFFE.

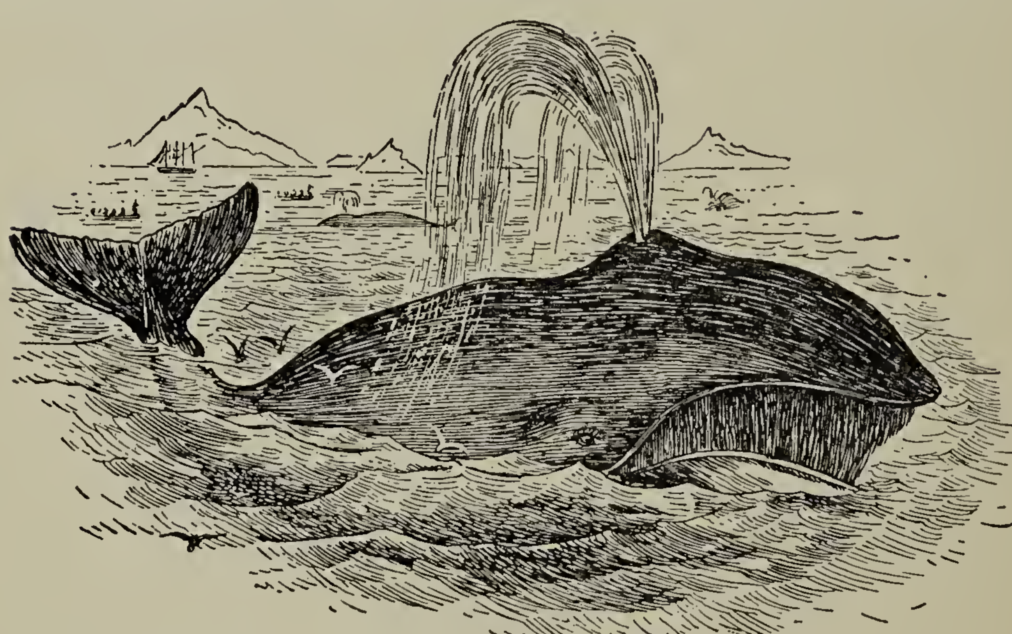
All the even-toed animals, except the hog and the hippopotamus, form a distinct class by themselves—the *cud-chewers.* They are distinguished by the pad in the upper jaw in place of the incisor teeth, and by having four stomachs specially constructed for chewing the cud.

The elephant, rhinoceros, hippopotamus, tapir, and hog are sometimes classified by themselves as thick-skinned animals. They are distinguished by the thickness of their skin and the

ANTELOPE—SPRING-BOK.

bulkiness of their body.

The next order are the *whale-like animals.* This order includes the whale, porpoise, and dolphin. These animals live in the sea, have a fish-like form, with short fin-shaped fore-limbs, and the hind limbs are entirely wanting.



GREENLAND WHALE.

They are mammals and not fishes. They suckle their young, they have warm blood, they breathe through lungs, and cannot breathe in the water.

The last order of the mammals are the *pouched animals.* We have hitherto taken the structure of the limbs or teeth as our guide in arranging the various orders. This order is formed on an

KANGAROO.

entirely different basis of classification. The animals which comprise it have one common characteristic—a curious pouch in which the young are carried for some time after their birth. The kangaroo of Australia and the opossum of America belong to this order.

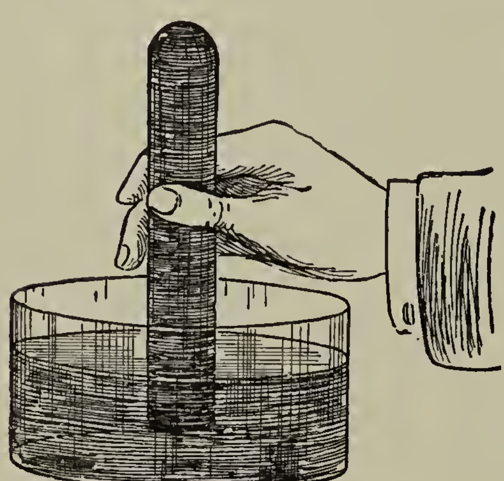
Lesson XXXVI

Weight of the Atmosphere

"I want you to think about our experiment with the tumbler inverted in the basin of water," said Mr. Wilson. "That will help us to learn something new this morning. But first of all, you must tell me what you saw while I held the tumbler in the water."

"The water stood in the inverted tumbler," said Fred. "None of it ran out. It was kept there by the downward pressure of the air on the water in the basin."

"Quite right," said Mr. Wilson. "See, I will repeat the experiment with this test-tube. The water stands in it as it did in the tumbler.

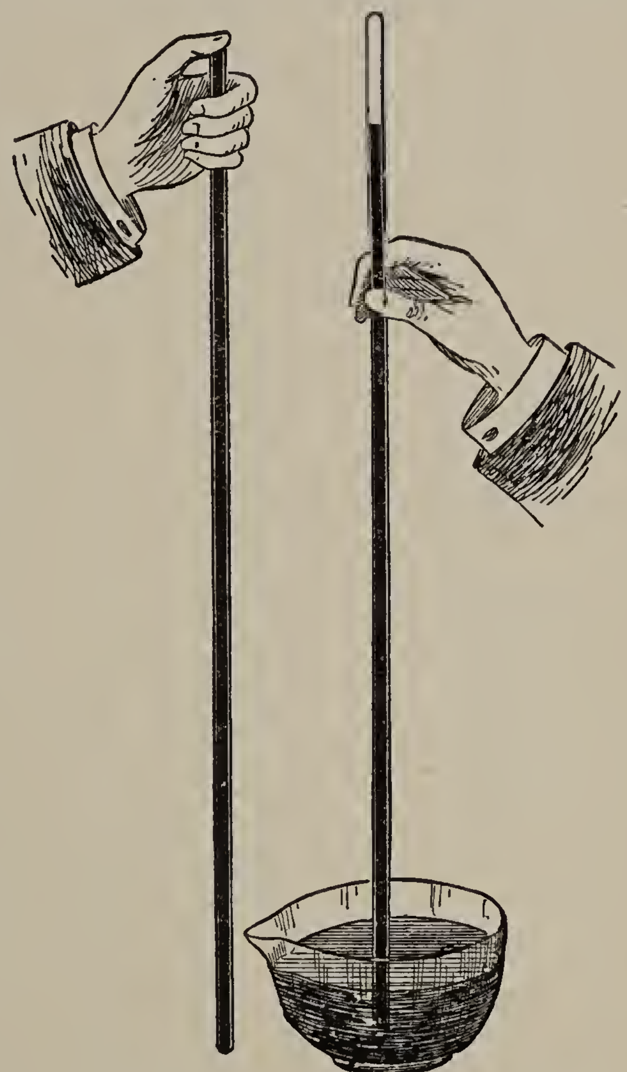


"Suppose we now try it with another liquid—mercury. I will fill the tube with mercury, close it with my finger, and invert it in this little bowl of the same liquid. The mercury, you see, stands in the tube just as the water did, and for the same reason. It is held up by the downward pressure of the air.

"Now let us try it with this long glass tube.

I will fill the tube with water and invert it in the bowl of water as before. None of the water flows out.

"Let us try the same thing with mercury. I fill the tube, close it with my finger, and invert it in the usual way in this little bowl of mercury. What has happened?"



"Some of the mercury has run out of the tube into the vessel. There is no mercury in the top of the tube."

"What is there, then? Air? There can be no air in that upper space, because we filled the tube with mercury, and the mercury has simply dropped down. It is an absolutely empty space. We call it a *vacuum*.

"Let us see whether the mercury will fall any lower in the tube. No, we cannot make it fall, so long as we keep the lower end in the vessel of mercury. If we take the tube out, all the mercury at once runs down it; but if we refill it and invert it again, the mercury will stand at the same height as before.

"Come to the front, Fred, and hold the tube steadily in the bowl. I will measure with a tape the column of mercury, from the top to the level of the liquid in the bowl below. It measures, you see, as nearly as possible *thirty inches.*

"We must find out what all this means. But let us first learn why the mercury stands at all in this tube. We have here a long thin column of mercury thirty inches high. This mercury is a very heavy liquid metal, and its weight presses downwards. If it could it would run down the tube into the bowl below. As it does not run out, there must be something to prevent it.

"Try and picture a very long tall column of air, of exactly the same thickness as the mercury in the tube, but reaching many miles upwards, to the very extreme limit of the atmosphere. Imagine, if you like, that this long thin column of air is contained in a tube, reaching all the way up from the surface of the mercury in the bowl.

"This long column of air then presses downwards, by reason of its own weight, upon the surface of the mercury in the bowl.

"What else is pressing down upon it as well as this column of air? The mercury in the tube is also pressing down upon it; it is trying to get out of the tube and cannot. *The downward pressure of the air prevents it.* The column of air and the mercury in the tube press downwards with equal force, and balance each other like two equal weights in a pair of scales."

Lesson XXXVII

Birds

Birds form an important class of the vertebrates, with special characteristics of their own.

They produce their young from eggs, but do not nurse them; they have hard horny beaks to serve instead of teeth; their fore-limbs are modified into wings; their feet are claws. Like mammals they have warm red blood; their heart has four chambers; and they breathe through lungs. This great class consists of several distinct orders.

VULTURE.

First among these orders come the *flesh-eaters* or *birds of prey*. They are the fierce, powerful, blood-thirsty hunters of the air. They live on the flesh of other animals, and are provided with strong hooked beaks, and powerful talons to seize and rend their prey. The order includes the eagle, falcon, hawk, condor, vulture, and owl. The owl is a night prowler; all the rest hunt their prey in the daylight.

It is well to compare the owl with the cats and other night-prowling beasts. The eyes in each case are made to see best at night. An owl in the daytime presents a curious appearance from its blinking eyes, which cannot bear the daylight. It spends the day in some dark secluded spot, and never comes out till after dusk, when it preys upon rats, mice, and other night animals.

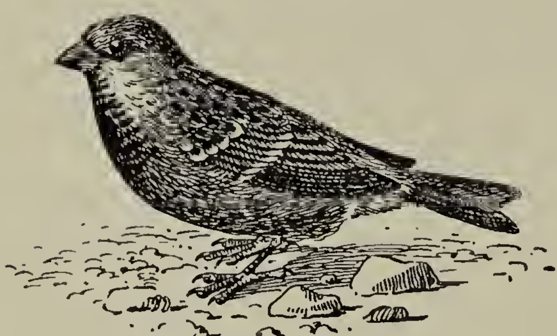
OWL.

The eagle and the other members of the order are distinguished by their powerful piercing eyes, which can bear the most brilliant sun without blinking. They sight their victim from an enormous height, and swoop down with unerring aim upon birds on the wing, poultry feeding in the field, and even upon rabbits, hares, and young lambs.

PARROT.

The second order are the *climbers*. These have strong muscular legs, and each foot has two toes pointing forwards and two backwards. These birds live entirely in the trees, and their claws enable them to climb easily and cling firmly. Many of them use the beak as well as the feet in climbing. They do not walk well. Among the climbers are the woodpecker, cuckoo, parrot, and cockatoo.

The next order are the *perchers*; and of these we may take the common sparrow, robin, thrush, and blackbird as examples. They have three toes pointing forwards and one backwards. They are meant for a tree life, and when on the ground move about with a series of little short hops. They cannot walk. You, of course, remember the peculiar and admirable arrangement of the leg and foot tendons, by which these birds are enabled, merely by their own weight, to rest securely on a twig or branch even when asleep.



SPARROW.

ROBIN.

This order includes most of the common birds of our own woods, as well as the gorgeous birds of paradise and other foreign birds.

The *scratchers*, or *poultry birds*, form the next order. They derive their name, scratchers, from their habit of scratching or scraping in the earth to find their food. For this purpose they are provided with stout strong legs, and the claws are short and armed with blunt nails. These birds feed largely on grain, which they swallow whole because they have no teeth to masticate it. The work of crushing the food is done in a strong internal muscular bag, the gizzard, through which all the food must pass.

PHEASANT.

In addition to the common fowls, this order includes the pigeon, dove, partridge, pheasant, quail, turkey, and peacock.

Lesson XXXVIII

More about the Atmosphere

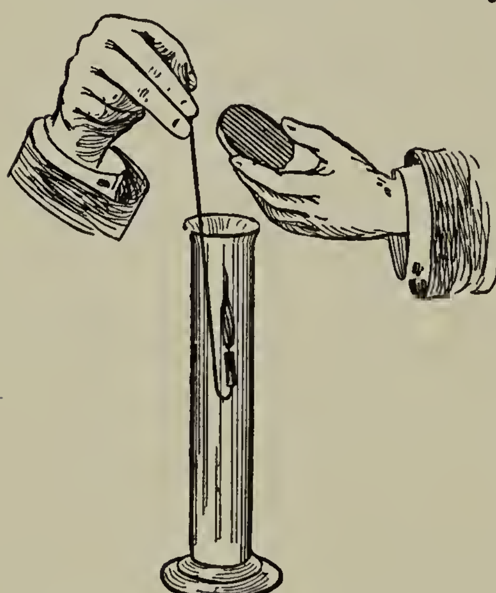
"We have already learned that the air is a mixture of the two gases, oxygen and nitrogen," said Mr. Wilson. "We could make some air for ourselves by preparing one bottle of oxygen and four similar bottles of nitrogen, and mixing them together. The mixture would be pure air.

"But the air all round us is never a perfectly pure mixture of these two gases. I think you know something else which it contains."

"*Air always contains carbonic acid gas*, sir," said Fred. "Every fire, every furnace, and every gas-jet that burns, helps to load the air with carbonic acid, and so do all the animals that live and breathe on the earth."

"Then, too, *there is always water-vapor in the air*, sir," said Willie.

"You are, both of you, quite right," said Mr. Wilson. "Let us deal first with the carbonic acid gas. The other day we burned a piece of carbon in a jar of oxygen. We will now burn this taper in oxygen. The taper burns fiercely for a time and then goes out. It goes out because all the oxygen has been consumed in the burning. There is no oxygen in the jar now; in place of it there is carbonic acid gas.



"How shall I prove that there is carbonic acid gas in the jar?"

"Pour some lime-water into the bottle, sir," said Fred.

"Right. I will do it now, and you see *the* *lime-water at once becomes cloudy or milky-looking.* If we had tested the jar in the same way, after burning the carbon in it, the result would have been the same, for whenever carbon burns, carbonic acid gas is produced.

"Then it is clear that the taper must contain carbon. Indeed all things that burn—wood, coal, coke, fuel of every kind, as well as candles, oil, coal-gas—contain carbon. It is the carbon in them which makes them valuable as substances for burning, and the burning always produces carbonic acid gas.

"Now how shall we prove that carbonic acid gas is given off with our breath?"

"If you breathe into lime-water," said Fred, "the lime-water will prove the presence of carbonic acid gas by turning cloudy."

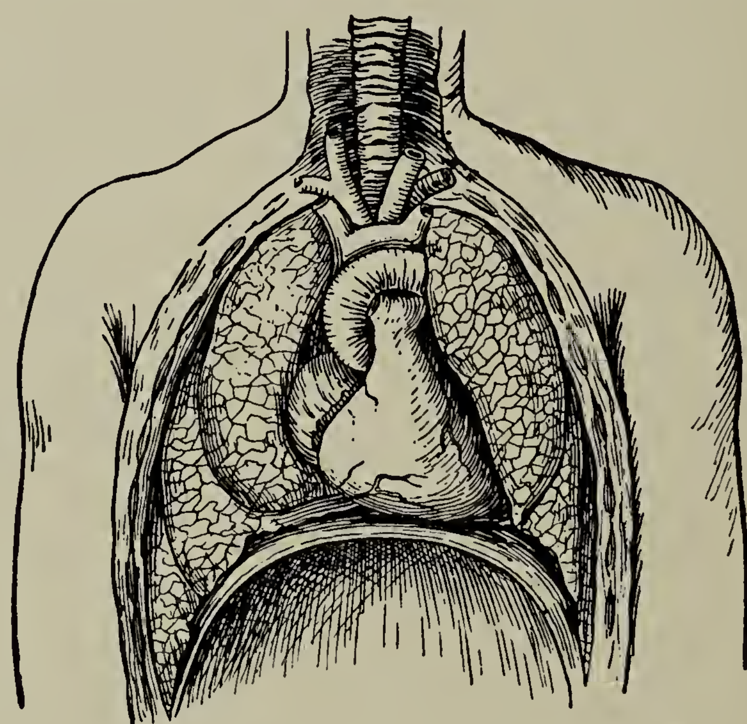
"Quite right, Fred," said Mr. Wilson. "We are now quite clear as to the sources of carbonic acid gas in the air. Yet with all the fires and lights, and all the many millions of breathing animals and people, there is never more than a mere trace of carbonic acid gas in ordinary air—usually about four parts in 1000. How is this?"

"Every plant that grows, sir," said Fred, "requires carbonic acid gas. The plants take carbonic acid from the air, and so a balance is kept between the wants of animals and plants all over the world."

Lesson XXXIX

Respiration

Our lesson on the circulation showed us the blood flowing out from the heart, along the arteries, through the hair-like capillaries, and back again to the heart by the veins. The



blood which the heart pumps out is a bright scarlet color, and fit for its proper work in the body. We call it *arterial blood.* That which is returned to the heart by the veins is of a dark purple color, and loaded with impurities from the worn-out tissues. We call it *venous blood.* This is the blood which enters the right auricle of the heart, and is sent out from the right ventricle to the lungs. When it returns from the lungs it is bright scarlet arterial blood. It has lost its impurities there. We want now to find out what happens to it in the lungs, and to do so we must examine the lungs themselves.

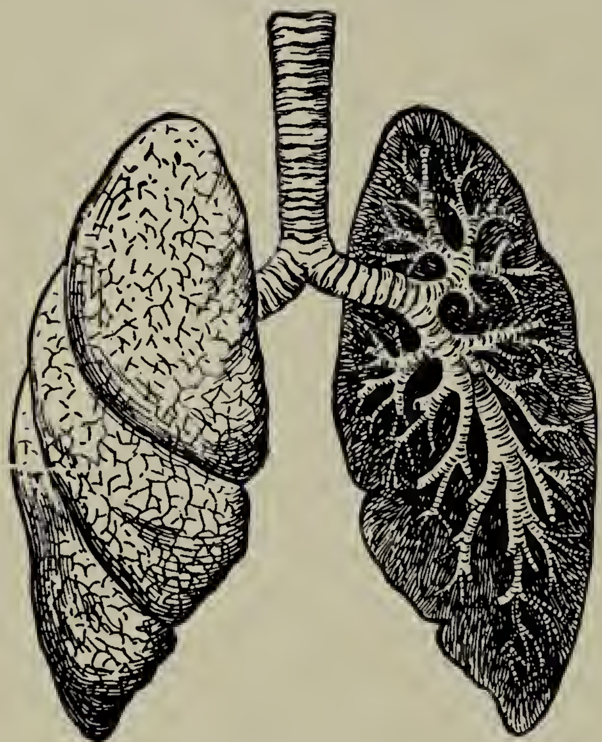
The lungs are two large organs situated in the chest, one on each side of the heart. They occupy the whole of the space in the chest which is not taken up by the heart and its great blood-vessels. They are of a pinkish color, soft and spongy, and very elastic. They are attached to the walls of the chest and the diaphragm by a membrane—the *pleura.*

If you run the finger down the front of the throat, you will feel a hard gristly pipe, which passes down into the chest from the back of the mouth and nasal passages. This is the *windpipe.* On entering the chest it splits into two—one pipe going to each lung. Each of these branching pipes is called a *bronchus.*

In the lung the bronchus splits up again and again into smaller and still smaller pipes—the *bronchial tubes*—the smallest ending in little bags or cells. These are known as *air-cells.*

The whole substance of the lung is simply a mass of these air-cells.

Let us see why they are called air cells. They are in direct communication with the air all round us. When we breathe, the air passes down the wind-pipe, the bronchus, the bronchial tubes, and so into the air-cells.



Now think for a moment of the great blood-vessel, which conveys the dark impure blood from the right ventricle of the heart to the lungs. We call it the pulmonary artery. This artery, like all others, splits up in the lung into smaller and smaller vessels, ending at last in capillaries.

The capillaries spread themselves all round the walls of the little air-cells. The air-cells are full of air, the capillaries all round them are full of this bad blood. Two things then take place. The blood gives up its impurities to the air in the air-cells, and takes something back from the air in exchange. You remember that when we breathe into lime-water, the water becomes cloudy and milky-looking, because carbonic acid has been put into it. Whence did this carbonic acid come? It came from the breath.

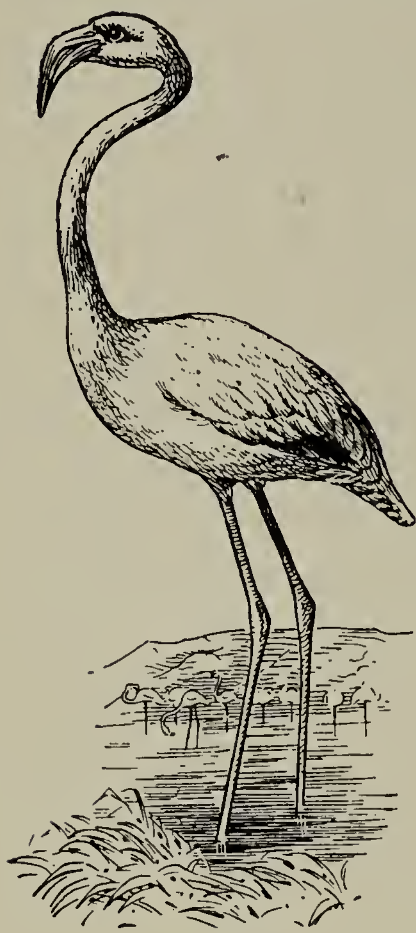
The blood is purified in the lungs by giving up to the air-cells the carbonic acid which it has absorbed from the worn-out tissues. This carbonic acid is sent out every time we breathe. But that is only part of the purifying work that takes place. The air in the air-cells is a mixture of the two gases, oxygen and nitrogen. The blood absorbs this oxygen in exchange for the carbonic acid which it gives up.

Thus the difference between the blood which leaves the lungs and that which enters them is, that it has lost its carbonic acid there, and taken up oxygen in its place.

Lesson XL

More about Birds

We have not yet finished our classification of the birds. The next order for us to consider are the *waders*. These birds have very long legs, for walking in the water. Hence they are sometimes known as stilt-walkers. They live on fishes, frogs, and other water animals. They have long necks to correspond with their long legs, and pointed bills for spearing their prey. They include the snipes, plovers, lapwings, and storks of Europe, and the heron, crane, flamingo, buzzard, and bittern of our country.

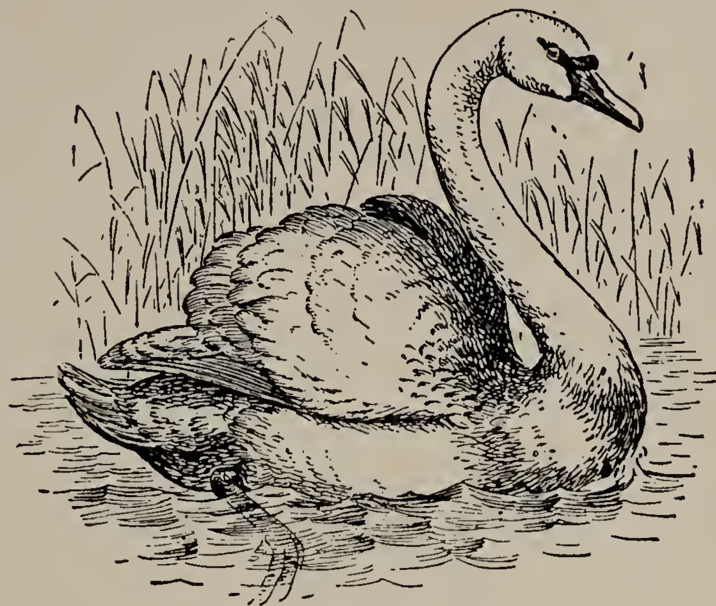


FLAMINGO.

The *swimmers* form the next order. Their distinguishing characteristic is the web between the claws. The webbed feet enable these birds to swim, and so specially fit them for a water life. They live in the water because they get their food out of the water. This is a large and important order; the most familiar members of it are the ducks, geese, and swans. Many of the family are marine birds. Among them are the gull, penguin, petrel, and albatross. The last is an immense bird, the largest of the order. It has marvellous powers of flight, and has been

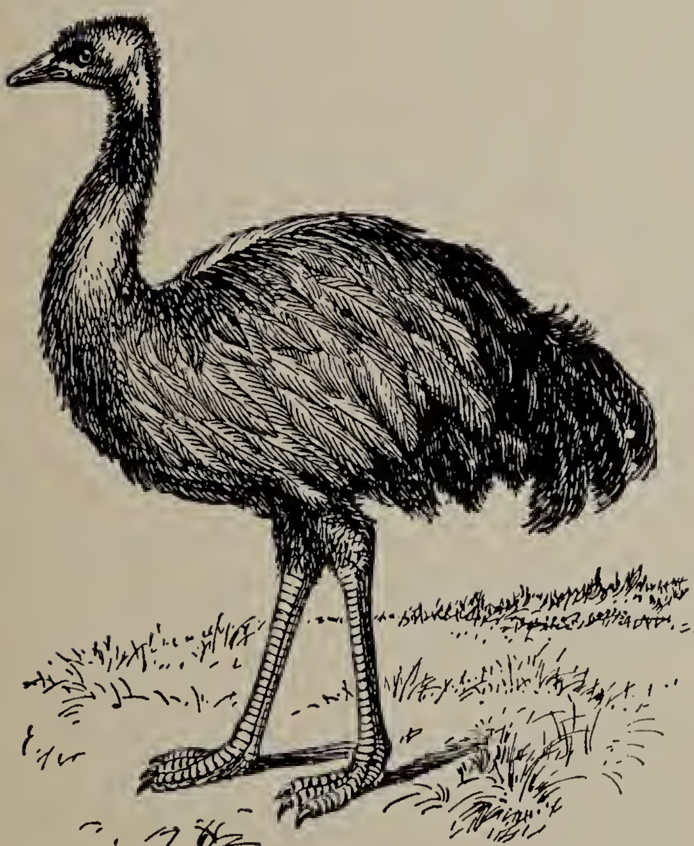
HERON.

seen sailing along for days together without resting, except for a short time on the heaving billows of the sea. It has immense wings, measuring from 14 to 15 feet across.



SWAN.

The order known as *runners* includes a few large and powerful birds, which neither fly nor swim, but are extremely fleet on foot. The legs are exceedingly strong, and the broad thick toes are pointed forwards. As they do not fly, these birds have small wings; and they use the wings merely as balancers while running. The ostrich



EMU.

is the largest and most powerful of the group. It can run at the rate of twenty-six miles an hour. The emu and the cassowary belong to the same order.

Many of our smaller birds, while they differ very slightly in the structure of the claws, are capable of a further useful classification according to the form of the beak or bill. The blackbird, thrush, robin, nightingale, and other well-known birds live mostly on worms, grubs, and insects. These birds have the upper mandible notched near the point, for the purpose of securing their prey. Hence they are known as *tooth-billed birds.* They may be regarded, on the whole, as very good friends to the farmer, in devouring the worst of his destructive enemies, although they do now and then help themselves to a little of his fruit by way of dessert.

If you have ever watched a swallow skimming swiftly over a pool on a summer evening, you must have seen that the bird always flies with its mouth wide open. The mouth is slit some distance beyond the mandibles to admit of this. But

SWALLOW.

what can be the object of such structure and habits? These birds live on insects, which they catch on the wing. The open mouth presents a wide-gaping fly-trap, and the swift, skimming flight through the air is to assist them in catching their prey. The swallow, marten, swift, and whip-poor-will belong to this group, which are known as *wide-gaping bills.*

A glance at the bill of a sparrow, a canary, or a lark will show that it is short and conical in shape. It has the appearance of more strength than you might expect to find in so small a bill. These birds live mostly on seeds. Their short strong beaks are specially fitted for cracking and crushing the husks of the seeds. The group are known as cone-shaped bills.

The humming-birds of our country represent another group. They are all tiny little birds, with remarkably gorgeous plumage, although some of them are scarcely bigger than a bee. They frequent the flowers for the sake of the sweet juice or nectar which they contain, and for the small insects that have been attracted to feed upon the honey. Their bills have no hard work to do, and hence they are soft and slender. The group are known as the slender bills.

Lesson XLI

How Heat affects Bodies

"I am going to amuse you with some new experiments this morning," said Mr. Wilson. "Fred may come to the front to assist me. I have here a short round bar of iron, which fits exactly into this metal groove, and will just pass through the round hole in it. Try it, Fred, and see for yourself. It fits, you see, both ways.

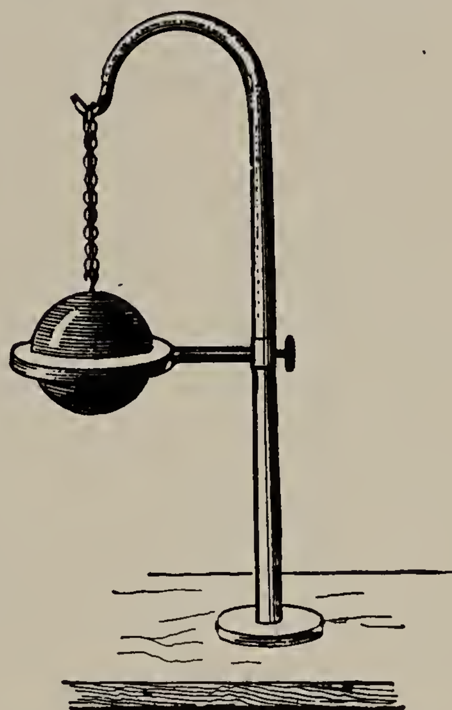
"Now put the iron bar into the fire, and as soon as it is red-hot, try and fit it into the groove again. What, can't you get it in? Then try and push the end through the round hole. It won't go into the hole, you see, with all your trying. Now why is this? The reason is that the bar is longer and thicker than it was. The heat has made the iron expand in every direction.

"Put the bar into this bowl of cold water, and try again, Fred."

"It fits exactly now, sir," said Fred. "I suppose the iron has got smaller again because it is cold."

"Yes, Fred, you are quite right," said Mr. Wilson; "we will try another experiment. I have here a brass ball hanging from a chain. It will just pass through this metal ring. Hold it by the chain and drop it through the ring. That's right. You see it just goes through.

"Now we will lower the ball into this kettle of boiling water for a minute or two. That will do: you may take it out and drop it through the ring as before."



"It will not go through the ring now, sir. The heat of the water must have made it expand. It is too big to pass through the ring now."

"Put it into cold water, Fred, as you did the iron bar, and then, if you try again, you will find that it will pass through the ring easily."

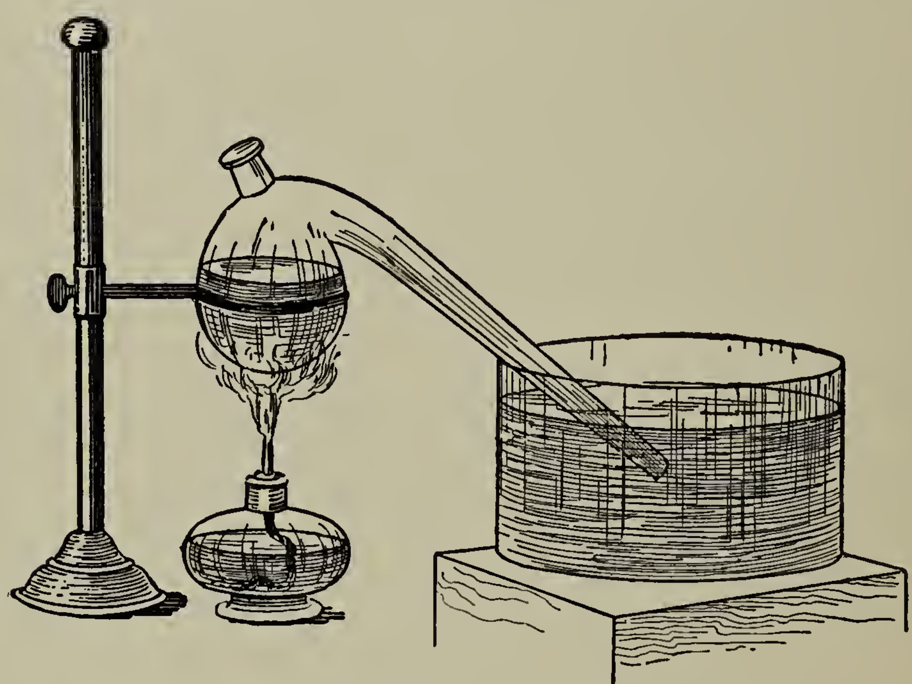
"Yes, sir, it passes through easily enough now," said Fred.

"Remember, then, that *almost all solid bodies expand with heat*, and *contract when the heat is taken away*; for what is true of the iron bar and the brass ball is equally true of nearly all solids.

"Now let us look at liquids. I will fill this test-tube with water, and you shall hold it over the flame of the spirit-lamp. The water, as it gets hot, swells up and overflows. Suppose we now fill another tube with mercury, and heat that. The result is the same. The mercury swells up, and, like the water, would quickly overflow. Both liquids expand, you see, with heat, and require greater space.

"Here is another test-tube, which I filled with boiling water an hour ago. It is not full now. What does this mean? The water has cooled, and as it cooled it contracted into smaller bulk. *Liquids, like solids, expand when heated,* and *contract when the heat is taken away.*

"I have now a very interesting experiment



to show you," continued Mr. Wilson. "I will place this empty glass retort over the spirit-lamp in such a position as to allow its neck to dip down into this bowl of water. When I said the retort was 'empty,' what did I really mean?"

"The retort is full of air, sir," said Fred.

"Just so," said Mr. Wilson. "Now our retort is getting hot. Watch what happens."

"Bubbles of air are rising up and bursting on the surface of the water, sir," said Fred.

"Right; but whence did these bubbles come? The flame heated not the retort only, but the air inside it; and heated air expands or swells, so as to occupy more space. There was not room enough for all the expanded air in the retort, and so some of it passed out into the water, and rose up through it in bubbles.

"Now let us remove the spirit-lamp, and leave the retort to cool. Tell me what you see as the cooling goes on."

"The water is rising in the neck of the retort, sir. There was no water in it before."

"So it is," said Mr. Wilson; "and I think you can easily tell the reason why. Some of the air was driven out in bubbles, when it expanded by the heat. Now that the air is cooling it contracts or shrinks up again; but there is not enough cool air to fill the retort. Hence the water rises in the neck. What is true of air is equally true of all gases. *Gases, like liquids and solids, expand with heat,* and *contract when the heat is taken away.*"

Lesson XLII

The Tube of Mercury

"You remember our long glass tube of mercury, of course," said Mr. Wilson. "The column of mercury filled the tube to the height of about 30 inches, and no shaking of the tube could move the liquid so long as we kept the lower end in the bowl of mercury. I think you are now in a position to explain why this quantity of the metal remains in the tube."

"The column of mercury 30 inches high weighs exactly the same as the long column of air," said Fred; "the two balance each other."

"You are quite right, Fred. We will now take the next step. I will draw a little square on this slate with the help of the ruler. Each side of our square shall measure exactly 1 inch, and we may call it a square inch. We will place the slate on the table, and I want you to imagine a tube 30 inches high, built up on this little square, as its base. Imagine, further, this tube filled with mercury. The quantity of mercury required to fill it would weigh just 15 lbs.

"Now if our tube in the last lesson had been as big as this one (a square inch in section), our column of air pressing down on the surface of the mercury outside must also have been a square inch—that is to say, it must have covered a square inch of mercury in the basin.

"What do we learn, then, from this? It is clear that the pressure of the air on a square inch of surface would be balanced by a column of mercury weighing 15 lbs. In other words, *the air presses downwards with a force of* 15 *lbs. on every square inch of surface.*

"Now let us go a little further," he continued. "We will begin by measuring this slate. It is just 10 inches long and 8 inches across. I will mark the inches on the sides and draw lines across the slate from mark to mark. You see I have marked out the slate into a great number of squares, each of them measuring an inch every way. They are square inches. Count them, Fred, and see how many square inches there are altogether."

"There are 80 square inches, sir."

"Very well; then the surface of the slate must bear a pressure of 80 times 15 lbs., or upwards of half a ton. But a baby could lift the slate. It is not heavy. Why is this? There is not only that enormous pressure on the top of the slate; *there is an equal pressure from below and all around.*

"Think what must be the pressure on this table. But with it all the table is not crushed, because there is an upward pressure of equal force to balance it, and it is not felt.

"Every child goes about with many tons pressing upon his body, but he never feels it, because there is air inside his body too, and that balances the pressure on all sides of him.

"This will help us to understand better why our leather sucker holds fast. Suppose the sucker measured 6 square inches; there would then be a pressure of six times 15 lbs., or 90 lbs. pressing it to the slate. We felt that pressure when we pulled the string, because there was no upward pressure between the slate and the leather to balance it. The pressure of 90 lbs. on the top pressed the sucker and the slate firmly together, and we could not move them.

"When the hole was bored in the leather, and air rushed in, we had the same force of 15 lbs. on every square inch of the under surface, and the sucker let go the stone; the two pressures balanced each other."

Lesson XLIII

Reptiles

The reptiles are the creeping or crawling animals. They produce their young from eggs, and do not nurse them. Although they breathe through lungs they have cold blood, and the heart has three chambers instead of four. The animals belonging to this class, like the mammals and the birds, are divided into different orders. Our

RATTLESNAKE.

earlier lessons have made us familiar with the first of these orders—the *snakes*. It includes huge serpents, that crush and mangle their prey in the folds of their powerful bodies before swallowing them, and venomous snakes, which kill their victims by means of their poison fangs.

LIZARD.

Next to these we have the order *of lizards*. These include a large variety of animals, from the pretty harmless little lizard, a few inches in length, which frequents sunny boulders and banks in our own country, to the enormous and

CROCODILE.

powerful crocodiles and alligators of the tropics, many of which attain the length of 20 feet.

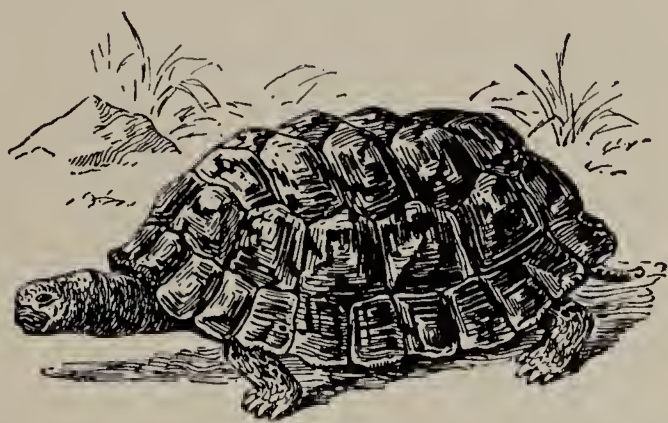
The body, which is long and covered with scales, is supported on four short legs, and there is generally a great length of tapering tail.

They are all armed with teeth. Some of the smaller varieties live on insects, some on vegetable food; but the giant members of the order live mostly in the water, and prey upon fish and other water animals. They also lie in wait for animals that come down to the water to drink.

CHAMELEON.

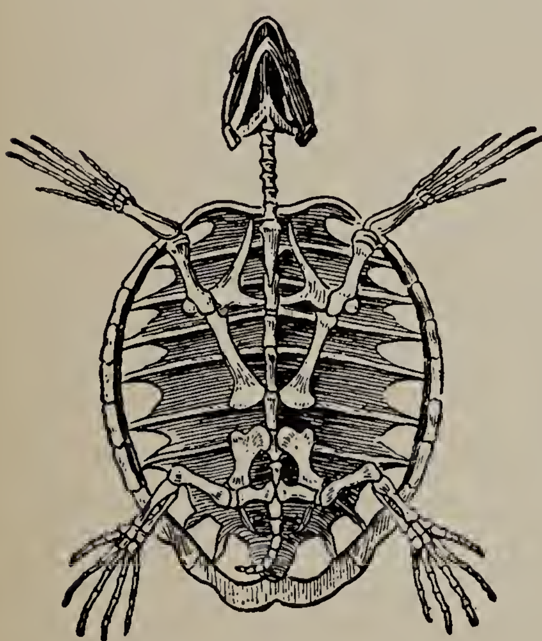
The chameleon is a curious member of the order. It lives mostly in trees, has the singular power of changing its color, and preys upon insects. There are fully twenty different varieties of this peculiar animal.

The *tortoises* form the next order of reptiles. These animals have their bodies enclosed in a sort of double shell. There is a flattened under-shell or breast-plate, upon which the animal rests on the ground. This is made of hard thickened skin, and is known as the



TORTOISE.

plastron. It is joined at its edges by a broad rounded shield, the *carapace*, which covers the animal. This carapace is really part of the bony skeleton of the animal. All the vertebrate animals we have hitherto examined possess an internal bony skeleton, but here we have a creature with its bony skeleton on the outside of its body. The carapace is really nothing but the vertebral bones and the ribs, with the



SKELETON OF TORTOISE.

spaces between them filled up with horny plates, the whole grown together into a hard solid shell. The head, neck, and limbs are not joined immovably to this solid outer skeleton. They are free to move, and they contain all the chief bones found in other animals. The front and hinder parts of both carapace and plastron are left open, for the head and limbs.

The head is very peculiar in form, and in place of teeth these animals are provided with a hard horny mouth. The smaller members of the family feed on vegetables and insects, but there are others, which measure upwards of 3 feet across, and prey upon crocodiles' eggs, fish, and many kinds of water animals.

Lesson XLIV

Water

"Our lessons have taught us many things about water and its properties as a liquid," said Mr. Wilson. "To-day we are going to learn what water really is.

"I have here some bottles filled with a gas, which at present is quite new to you. It is called *hydrogen*. I cannot really show you the gas, because (like oxygen and nitrogen) it is colorless and transparent. You cannot see it in the bottles; you must, for the present, take my word that it is there. I will show it to you by its action before the lesson is over.

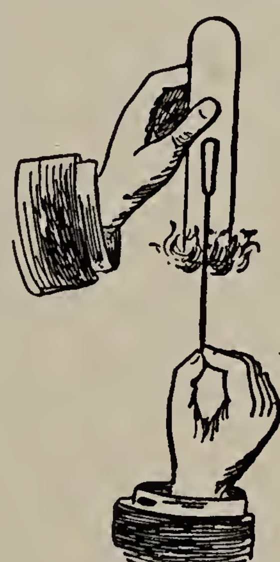
"First, however, I want you to think about the other gas, oxygen. What are the two chief properties of oxygen?"

"It makes other things burn, sir; but it does not take fire itself," said Fred.

"You saw me burn carbon, *i.e.* charcoal, in oxygen. What did we get from the burning?"

"Carbonic acid gas was formed, sir. Carbon unites with oxygen and forms this substance."

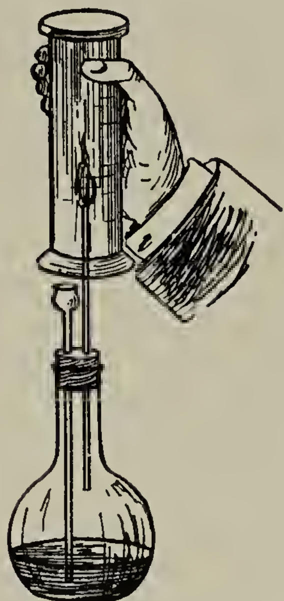
"Now let us return to our new gas, hydrogen. You may have noticed, perhaps, that the jars are all standing mouth downwards. This is because hydrogen is a very light gas—it is, indeed, *the lightest substance in nature.* If I had placed the jars with their mouths upwards, the gas would have escaped. Now watch what happens. I take the jar in my hand, still keeping it mouth downwards, and plunge this lighted taper into it. The hydrogen catches fire and burns with a blue flame in the mouth of the jar, but the flame of the taper itself is no longer burning. It has been extinguished by the gas.



"Can you now tell me any difference between hydrogen and oxygen?"

"*Hydrogen is very inflammable;* it burns with a blue flame. *Oxygen will not take fire.*"

"Hydrogen puts out the taper; it will not allow other things to burn in it; but oxygen



helps all other things to burn. It was the oxygen in the air all round that made the hydrogen burn in the mouth of the jar. If there had been no oxygen present, the hydrogen would not have taken fire, for oxygen makes hydrogen burn as well as other things.

"I am now going to make some more hydrogen in this flask, and as the gas forms and passes up through this little tube, we will burn it. It takes fire instantly, and burns with a pale blue flame. I will next cover the flame with a dry cold glass, and one of you shall come and tell what you see."

"The inside of the glass is covered with little drops of moisture, like dew-drops, sir."

"So it is; but how did they get there? I must tell you. Hydrogen burns and forms a new substance—water; just as carbon burns and forms a new substance—carbonic acid gas.

"Carbonic acid was formed by the union or combining of carbon and oxygen when in a heated state; the new substance—water—has been formed by the union or combining of hydrogen and oxygen when in a heated state.

"You must remember that the water formed by this burning hydrogen is not liquid as we usually see it. It is in the form of steam or water gas. We could not see it until we placed the glass over the flame. It condensed into little drops of actual water when it touched the cold glass.

"So, then, we have seen that out of fire comes water. The fuel we burn in our fires, the candles, oil, and gas we use for lighting purposes, all contain hydrogen. When such things burn, therefore, water must be formed."

Lesson XLV

The Barometer

"I want you to think about our long tube of mercury again," said Mr. Wilson. "Here it is. The mercury stands in the tube, and you know it balances the air which is pressing on the surface of the mercury in the basin. It stands now at about 30 inches; but what would happen if the pressure of the air were to change?"

"The quantity of mercury in the tube would change too, I suppose, sir," said Fred.

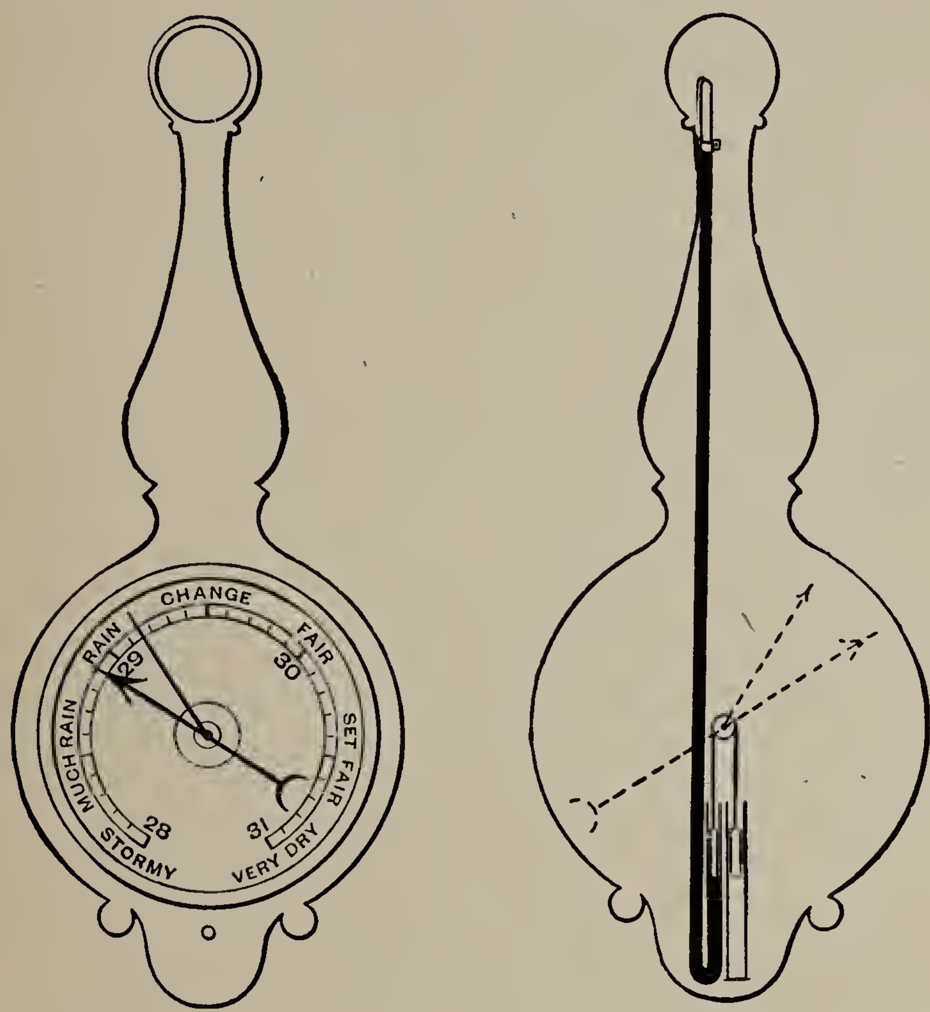
"Quite right, Fred. If the air pressed with greater pressure, more mercury would be forced up the tube. If the air pressure were less than it is now, some of the mercury would flow out into the basin; it would not stand so high.

"Let us in imagination take our mercury tube up with us in a balloon. If we look at it after we have ascended 1000 feet, we shall find that the mercury has fallen 1 inch, and it would continue to fall at the same rate for every 1000 feet of our ascent. On the top of Mont Blanc, 15,000 feet high, the column would measure only 15 inches instead of 30 inches, and would weigh only $7\frac{1}{2}$ lbs. instead of 15 lbs. You know that the air gets thinner and thinner the higher we ascend, and the mercury proves that it also gets lighter, and of course presses with less force.

"On the other hand, if we took our mercury tube down into a coal mine we should find that the lower we went the higher the mercury would rise. It would rise, roughly speaking, at the rate of 1 inch for every 1000 feet we descended. The weight and pressure of the air in the mine increases with the depth.

"Now I want you to think of something else. You know that the air always contains more or less water-vapor, and that this vapor rises in the air. It is very clear then that it must be lighter than the air. Air which contains much moisture is always lighter than dry air. *Dry air is heavy; moist, damp air is light.* Now how would the condition of the air affect our mercury tube? When the air is dry and therefore heavy, it presses with great force on the mercury in the basin, and forces more mercury up into the tube; the column of mercury is high. When the air is full of vapor and therefore light, the pressure is less, and the column of mercury in the tube falls.

"You can see from this that the mercury in the tube measures exactly the pressure or weight



of the atmosphere, and I am now in a position to tell you that we have all this time been studying a very useful and wonderful instrument. That which I have purposely spoken of as a mercury tube has a proper name. We call it a *barometer*. The word means '*the weight-*

measurer.' It measures the weight or pressure of the air.

"Our tube and basin of mercury would be very awkward to carry about from place to place. This is why, for the sake of safety, the tube is fitted into a frame, with a little cistern at the bottom instead of the basin. The height of the column is marked in inches at the side of the tube, and the instrument is complete.

"The barometer is used for measuring the heights of mountains, and you will readily see the reason why.

"It is also used as a weather-glass. If the air contains a large amount of water-vapor, we know that we are likely to get rain and stormy weather. If the air is dry, there is a prospect of fine weather. The barometer, in either case, gives us timely warning of the weather to be expected, by registering the pressure of the air."

Lesson XLVI

Expansion and Contraction

"We have seen that heat causes bodies to expand," said Mr. Wilson, "and that when the heat is removed the bodies contract again to their original bulk. It will be our business now to learn why this happens. Look at this piece of iron. It is so hard that we cannot even scratch it. The smith, by heating it in his forge, would make it soft and plastic, so that he could beat, cut, weld, and pierce it, and work it up into any shape he pleased. Now in the first place, why is the iron such a hard substance?"

"Its molecules are held closely together by a very strong force of cohesion, sir," said Fred. "The stronger the cohesive force, the denser and harder is the substance."

"Very good, Fred. Now can you guess why the iron becomes soft when it is put into the furnace? I think I must tell you. *The heat overcomes the force of cohesion.* Cohesion is not so strong between the molecules as it was before the iron was put into the fire. It is the same with all metals.

"What happens to these metals when they are still further heated?"

"They melt, sir; they change from the solid to the liquid form."

"Quite right, Fred," said Mr. Wilson, "and you can now explain what it all means."

"I suppose the force of cohesion becomes still further weakened by the heat, sir, so that the melted particles are free to move about."

"Just so. *The heat changes the solid to a liquid by overcoming the force of cohesion* between its molecules.

"Now let us take another step. The force of cohesion in liquids is very slight, and is thus easily overcome. What happens when we apply heat to a liquid?"

"The liquid is converted into a gas, sir, and the particles of a gas, having no cohesion, fly from each other in all directions."

"Exactly. The solid ice becomes liquid water; the water becomes vapor or water-gas; and all by the application of heat.

"Workmen often make great use of these expanding and contracting forces in the materials which they use. The wheelwright, for instance, in fitting the tire of a wheel, first makes it red-hot, and while it is in this expanded state, fixes it round the wheel. It is then plunged into cold water, and as it cools it contracts and presses the wheel so closely, that it binds all parts of the wheel together.

"In building a furnace, too, the workman always leaves one end of the iron bars free. If both ends were built fast into the bricks or masonry, their expansion by reason of the heat would tear away the brickwork.

"In laying down a railway line, the iron or steel rails are not placed with their ends close together. There is a little space left between them. The rails expand with the heat in the summer, and if they were close together the expansion would cause them to bulge and curve.

"In riveting the iron and steel plates of ships and boilers, the rivets are always fastened and fitted red-hot, and thus as they cool, they draw the plates together with great force by their own contraction. Heated iron bars are often used to draw bulging walls upright. The bars are secured and screwed up while heated, and as they cool they contract, and so draw the wall into the proper shape."

Lesson XLVII

Fishes

The fishes form the last class of vertebrate animals. Their most marked feature of distinction from the other vertebrates is their special adaptation for the element in which they live, and their consequent unfitness to live out of it.

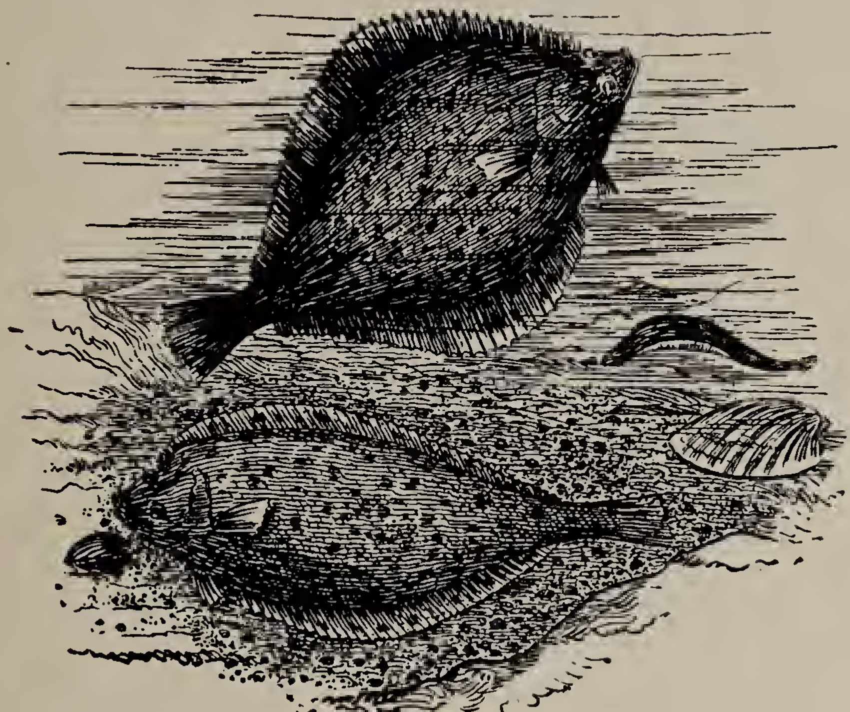
This might be also said with a large amount of truth of the whale family of mammals. They are all formed for a water life, and would soon die if they were left stranded on the dry land. But they would die only through their inability to obtain food, and from no other cause whatever. They would be starved out of the water. They live in the water because their food is in the water; but they breathe through lungs, and must come to the surface of the waves to do it. The fish, taken out of the water, dies from its inability to breathe in the atmosphere. It is suffocated in the new element, as the whale would be if it were immersed for any considerable time beneath the waves.

The amount of oxygen taken in by their gill-breathing is not sufficient to warm the blood, consequently fishes are all cold-blooded animals. *The heart has only two chambers*—an auricle and a ventricle.

Most fishes possess a curious air-bladder, which enables them, at will, to descend to the bottom, or rise to the surface of the water. The bladder itself is provided with strong muscles. When these muscles contract, the bag is made smaller, the air in it is compressed, and the fish becomes heavier than the water, so that it sinks with ease. In order to rise to the surface again, the fish has only to swell out the bag to its original size. This makes the body lighter, and

FISH, SHOWING AIR-BLADDER.

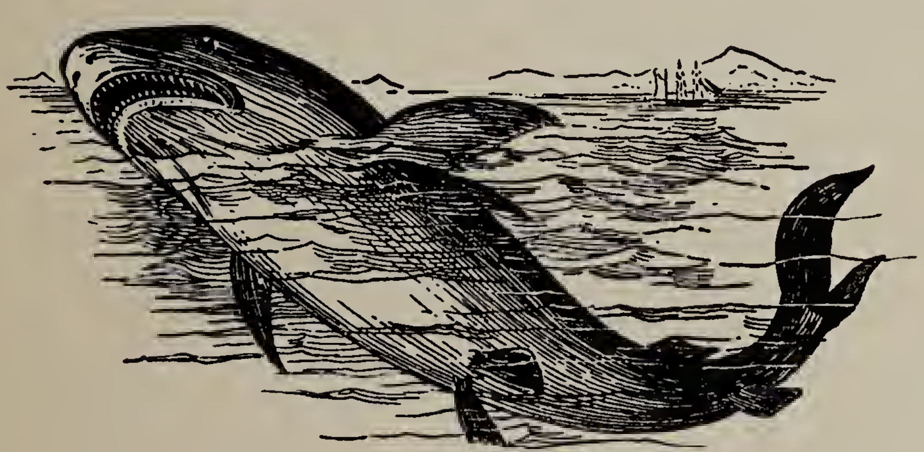
it ascends as easily as it sank. Without this wonderful piece of mechanism, such movements would be impossible. Certain fish, such as the turbot, sole, and plaice, invariably live at or near the bottom of the water, and never move far from



PLAICE.

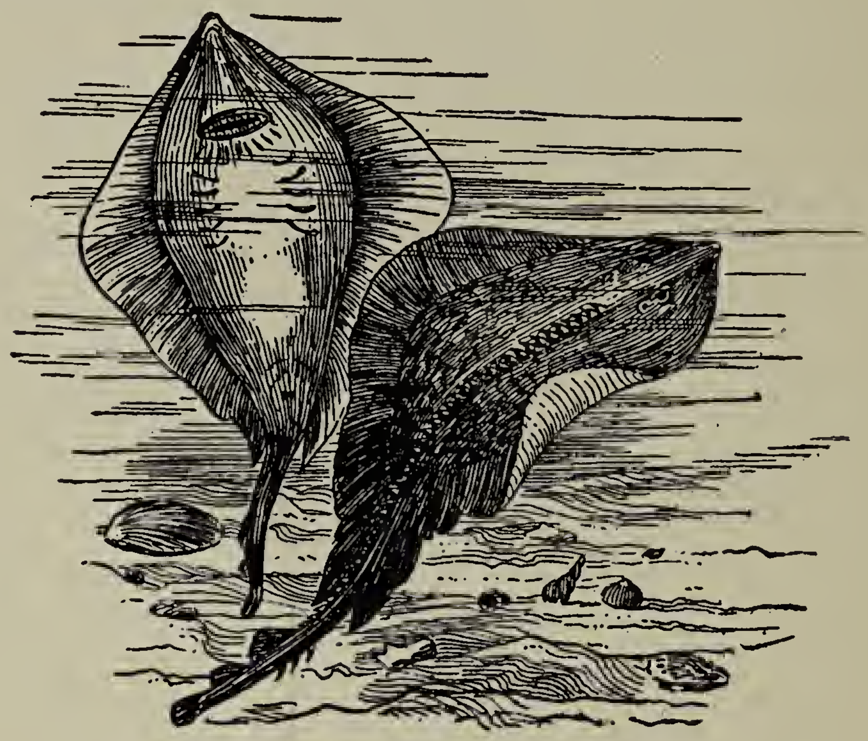
it. These have no air-bladder. It is not required.

Fishes are classified according to the nature of



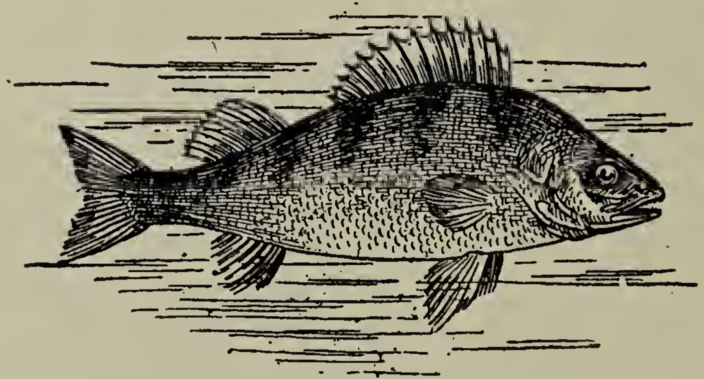
WHITE SHARK.

the skeleton. In most fishes the skeleton is made of a hard bony substance, as is the case with the other vertebrate animals. These are called in scientific language *osseous fishes.* The word *osseous* means *bony.*



SKATE.

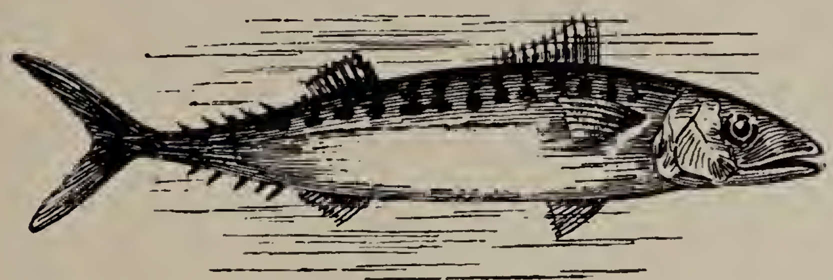
Others have no actual bones, but only gristle or cartilage to form their skeleton. These are



PERCH.

known as *cartilaginous fishes.* The order is a very small one, and includes the shark, dog-fish, saw-fish, skate, and sturgeon.

The osseous fishes are placed in two groups, according to the nature of their fins. If you examine a fresh herring, sole, plaice, turbot, salmon, or eel, you will find that all of them have



MACKEREL.

soft flexible fins. We call them *soft-finned fishes.* You would have no difficulty in realising the distinction if you placed side by side with them a mackerel, a perch, or a little stickleback. The fins of these are anything but soft and flexible. They are sharp, bony spines. These spines give the name to the fishes of this group. We call them *spine-finned fishes.* They form a much smaller group than the soft-finned fishes.

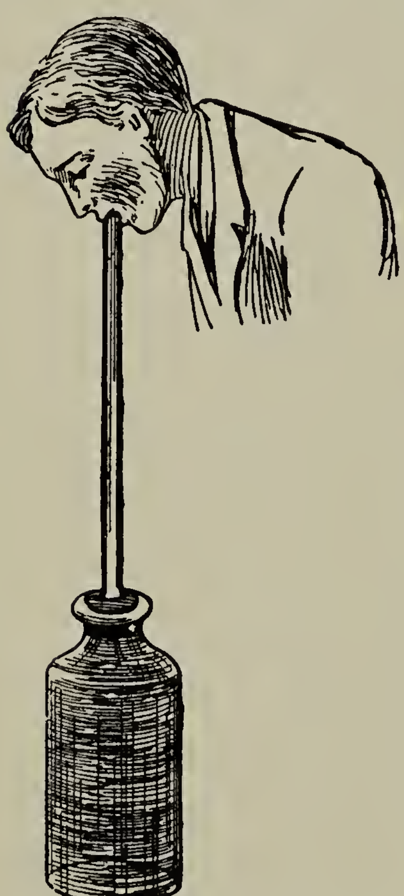
Lesson XLVIII

The Syringe

"We have learned a great many things in connection with the pressure of the atmosphere," said Mr. Wilson. "Suppose we try to go a little further this morning. I have here a piece of glass tube open at both ends. If I close one end firmly with my finger, fill the tube under water, and invert it, you know the water will stand in the tube. Tell me why."

"The pressure of the air on the surface of the water in the basin forces back the water into the tube, so that it cannot run out," said Fred.

"Right. Now I remove my finger, and the water runs out at once. Why does it run out? There is air now pressing on the water in the tube with the same force as that which presses on the water in the basin. One pressure balances the other and the water runs out of the tube, and rests level with that in the basin.



"Come to the front, Fred, and suck the upper end of the tube. What do you find? Oh, you have a mouthful of water. How did that come about? Let us see. I have here a bottle filled with water. The cork fits very close, and I have passed a glass tube through a hole in the cork. Now I will press the cork tightly into the neck of the bottle, and you shall try again to suck up the water as before. What, can't you do it? Try again. No, you can't get any water this time, try as you will. The bottle is quite full of water, and the cork touches the top of it. There is no air in the bottle to press down on the water, as there was just now in the basin.

"This is enough to prove that you do not suck up the water. Now try again with the open tube, and you get a mouthful of water at once.

"The truth is that by sucking you merely remove the air from the tube. In the one case the pressure of the air on the water in the basin forced some of it up the tube when you removed the air. But in the other, there was no air in the bottle outside the tube, and, although you again drew away the air from the tube itself, the water did not rise. In both experiments, then, the water is not sucked up; *it rises in the tube by the pressure of the air all round.*

"Here is a glass squirt or syringe. I am going to show you how we can raise water with this instrument, and to make it clear I will use colored water for the experiment.

"But first of all let us take the instrument to pieces and examine it. It is simply a glass tube, with a rod, which we call the piston, fitting it closely all round, so that no air can pass between them. We say it fits air-tight.

"Now I will dip the end of the tube into the water, and raise the piston rod. As I draw up the piston the water rises in the tube. Why does it rise? That air-tight piston sucks up, and so removes the air from the tube, and an empty space or vacuum is formed above the water. The pressure of the air outside forces the water into the tube to fill up this vacuum.

"The water rises, then, in the piece of glass tube, and in the syringe, from the same cause. The air is first removed, and then the air-pressure all round forces the water up the tube.

"If we press the piston down again, the water is driven out in a stream."

Lesson XLIX

The Thermometer

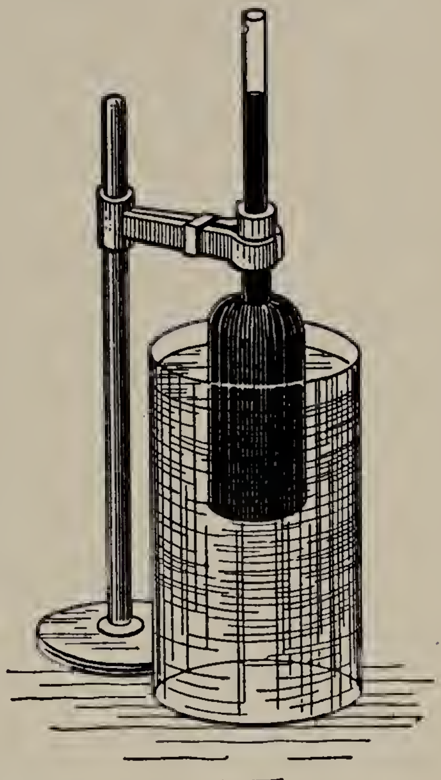
"I think you can all tell me how bodies—solids, liquids, and gases—are affected by heat," said Mr. Wilson.

"Bodies expand with heat, sir, and contract when the heat is taken away," said Fred.

"Right," said Mr. Wilson. "I think too you can give me the reason for this."

"Heat overcomes the force of cohesion, sir. The particles when heated are not held so firmly together, and therefore the body expands."

"Very good," said Mr. Wilson. "Now I want you to pay close attention to a little experiment. I have here a small glass phial, filled with colored water, and fitted with a cork and a piece of glass tubing. The water reaches some little distance above the cork. Here is a basin of hot water. Fred shall come to the front and hold the phial in it. What do you see now?"



"The colored water is rising higher in the tube, sir."

"Quite right," said Mr. Wilson. "But what does this prove?"

"It proves that the colored water in the phial is expanding; it wants more room, and so it rises in the tube."

"But why does it expand?"

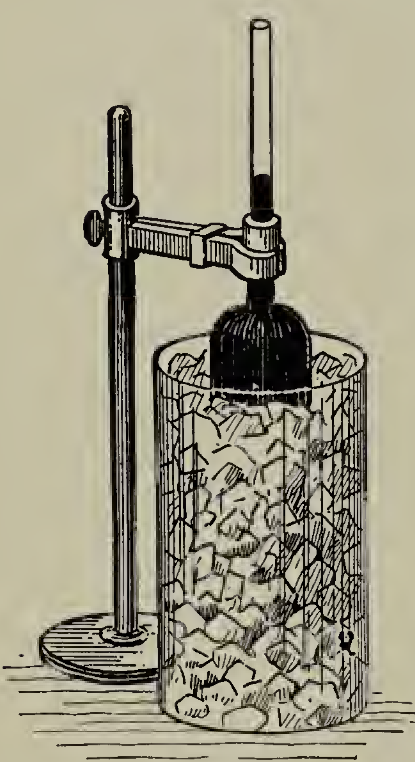
"The heat of the water in the basin makes it expand, sir."

"Exactly," said Mr. Wilson. "Now let us make the water still hotter by pouring into it some boiling water out of the kettle. As soon as that is done you see the colored water in the tube rise higher and higher. The hotter the liquid into which it is plunged, the higher the water rises in the tube.

"Now we will put the phial into this basin of cold water, and watch again. The colored water is now shrinking or contracting; it is falling in the tube. Hence, you see, that by carefully marking the height of the colored water in the tube each time, we could use our phial and tube as an instrument for measuring the temperature of the water. The phial and tube give us a rough-and-ready but true measurement. They make a simple sort of *thermometer*. *Thermometer* means *heat-measurer*, from two Greek words—*therme* = heat, and *metron* = a measure. But what is it that makes the phial and tube a heat-measurer?"

"The expansion and contraction of the water inside does the actual measuring, sir."

"Just so," said Mr. Wilson. "But other substances besides water expand with heat, and contract when the heat is taken away. Why would not a bar of iron, for instance, make a good thermometer?"



"Solids do not expand sufficiently to be seen and marked," said Fred.

"Quite right, Fred; and so of course they would not be suitable for thermometers. Then again, air and other gases expand and contract too rapidly to be of any use in this way. We find liquids are the only bodies fitted for the purpose.

"We said just now that the phial of water made a rough-and-rude sort of thermometer. It is rough and rude because it would not suit all purposes. Suppose, for example, I had stood the phial in ice. What would have happened? The water inside the tube would have become ice too in a short time, and as ice it would have been of no further use for measuring.

"Or suppose I put it over the spirit-lamp. It would boil and become changed into steam, or water-gas, and therefore be useless again. The best liquid for a thermometer is *mercury*.

"It expands and contracts sufficiently to be seen and marked.

"It does not change into the vapor state, till an exceedingly high temperature is reached.

"It does not freeze, except at a very low temperature."

Lesson L

Structure and Habits compared

In studying the build of the various classes of vertebrate animals, and comparing them with man, one must be forcibly struck with the remarkable resemblance they all bear to each other. These animals, man included, are all built upon one general plan. The bony skeleton is simply modified in form to suit the requirements of the different animals. The essential part of the skeleton in all is the spine. It supports the head, carries the ribs and limbs, and contains the spinal cord—the great central nerve.

Our lessons have shown us how this column of vertebræ is modified in the various animals, especially as regards the manner in which the bones are jointed. In man and the mammals generally, the body of each vertebra rests upon *a smooth elastic pad of gristle,* to provide for easy springy movement and to avoid friction.

In the snakes these elastic pads give place to *ball-and-socket joints.* Such joints are essential to these creatures, both for their peculiar locomotion, and for their mode of feeding, by swallowing their prey whole.

The vertebræ of the fish are joined by a *double cup-joint,* the little hollows thus formed between the bones being filled with a thin fluid, to enable them to play freely, and so add to their flexibility as a whole.

Let us next consider the special development of the head. The head, you know, consists of two parts, the skull and the face. The skull contains the *brain;* and in man it is this part of the head which is most highly developed.

We have only to compare the head of a man with the head of any of the lower animals, and we shall see that in them it is the face and not the skull, which is specially developed.

From the brain, *nerves* pass out through special holes in the skull to the organs of sight, smell, hearing, and taste. Most of the lower animals are dependent entirely upon their sense organs, some for their daily existence, others for safety against their enemies. Hence it is that nature specially develops these organs to suit the life and habits of the individual.

The night-prowling flesh-eaters, which stalk their prey after dusk, develop *large, powerful, piercing eyes* for seeing in the dark. Timid and defenceless animals such as the deer and antelope, the ox and horse, the rabbit and hare, always on the alert against their blood-thirsty enemies, have *large, erect, wide-open ears* to give them timely notice of danger.

Some animals, again, rely to a large extent on their sense of smell. These are distinguished by their *length of face*, the nasal passages being specially developed to give greater scope for the nerves of smell.

We have already had occasion to notice the variety of development in the limbs of animals to suit their special style of locomotion.

Man has two pairs of limbs, but although the general plan of structure is the same as in other mammals, he is the one animal that uses only the lower limbs for the purposes of locomotion.

All the land mammals use both pairs of limbs, and even the apes and monkeys depend upon their fore limbs in their movements on the ground.

In birds and in the flying mammals the fore-limbs are built upon the same general plan as in the land mammals, except that the hand portion of the limb is lengthened out to form a wing for the purpose of locomotion through the air.

Among the reptiles, snakes have no limbs, but lizards and tortoises have the usual four limbs. In the latter the bones of the limbs are not immovably fixed like the rest of the skeleton, but are jointed and free to move.

The frog moves by successive leaps, and to provide for this peculiar mode of locomotion the hind limbs are lengthened very considerably. The feet of these limbs, too, are webbed to enable the creature to swim in the water.

Fishes require no limbs for their water locomotion. They propel themselves by the tail, and the fins serve to balance the body.

Lesson LI

The Suction-Pump

"We are going to talk about the common suction-pump this morning," said Mr. Wilson, "and I think we shall find that our lesson on the syringe has made this next step very easy.

"Let us commence by learning the construction of the pump, and we will then find out how it raises the water. The water, you know, comes from a well deep down in the

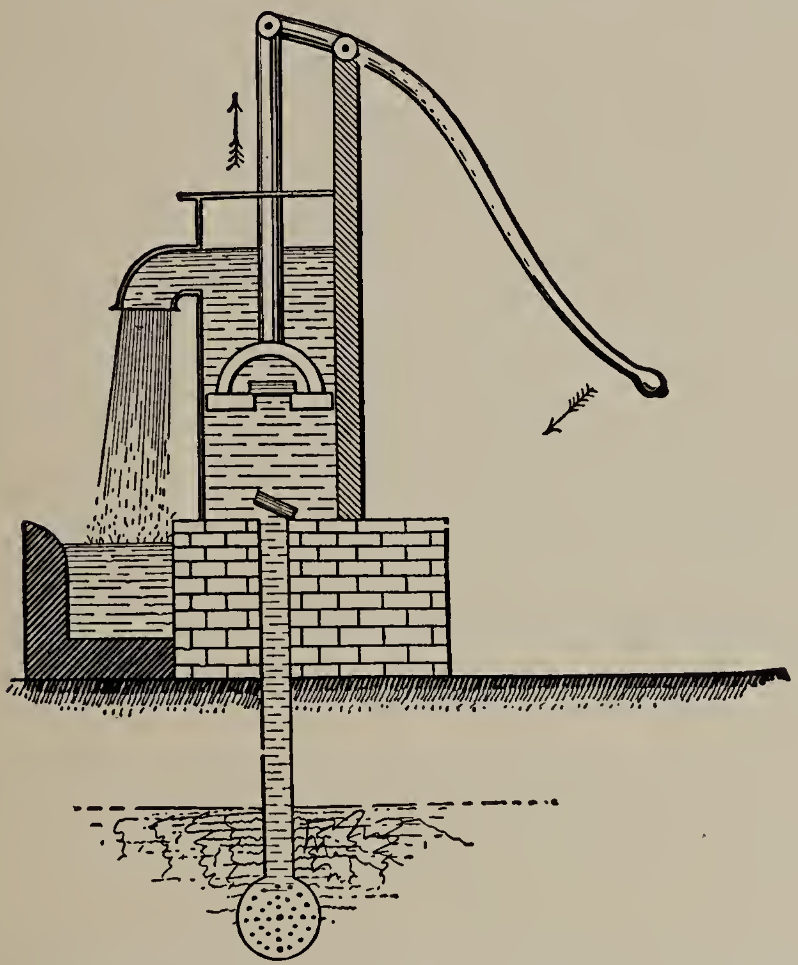
ground. The first essential, therefore, of a pump must be a long pipe to dip down into the water. This is known as the *suction-pipe.* Our open glass tube standing in the water would represent such a pipe. You remember that the water rested at the same level inside and outside the pipe, because the pressure of the air on both was equal. But we managed to raise the water in the tube. How did we do it?"

"We removed the air from the tube, sir," said Fred, "and then the water rose in it, because of the pressure of the air all round."

"Quite right, Fred; and this is exactly what we must do with the pump, or the water can never rise. Let us now go back to the suction-pipe. Fitted closely on the upper end of it is a larger tube—the *barrel.* The entrance to the barrel is guarded by a little door, which works on a hinge, and opens upwards only. Such a door is called a *valve;* it allows the water to pass upward, but prevents it from returning. This one is known as the *suction-valve.*

"In the barrel is fitted an *air-tight piston,* capable of being moved up and down by a piston rod, which is worked by a handle. In the centre of the piston is another valve similar to the suction-valve, and, like it, opening upwards only. This is called the *piston-valve.*

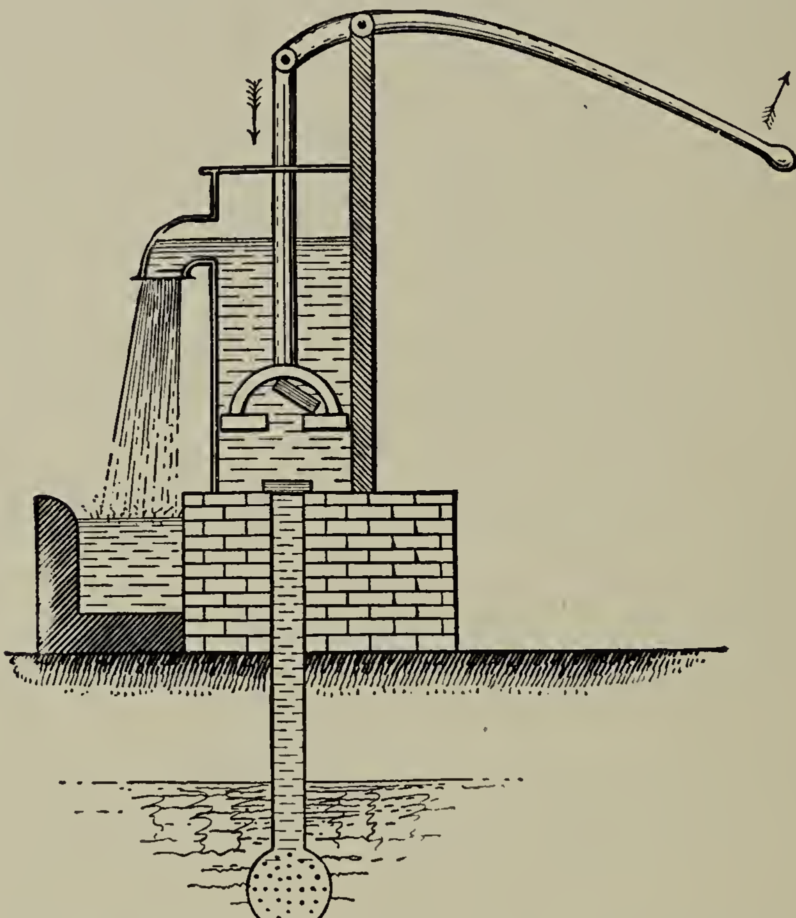
"Now I think we are clear as to the construction of the pump. Let us see next how it works. I told you that the whole object of this contrivance is to remove the air from the barrel and suction-pipe. When this is done the water will rise by the pressure of the air all round, "Imagine that the piston has been forced down, and made to rest upon the suction-valve in the bottom of the barrel. Both valves are closed. There is no space, and consequently no air between them. The pumping will begin by



SUCTION-PUMP, SHOWING PISTON IN THE ACT OF RISING.

raising the piston. There is air, of course, above the piston, and, as the piston rises, this air forces down its valve and closes it.

"But what has been happening at the suction-valve meanwhile? The raising of the piston, with its valve closed, has made *an empty space or vacuum* in the barrel, and the air in the pipe below has forced open the suction-valve, and rushed through to fill up the space. There is, therefore, less air in the suction-pipe than there was; there is not the same pressure on the water within the pipe. But the air outside is pressing



SUCTION-PUMP, SHOWING PISTON IN THE ACT OF DESCENDING.

on the water in the well with the same force as ever, and this outer pressure forces the water to rise some distance in the pipe.

"The next step in the pumping operation is to lower the piston. As it descends it presses upon the air below it in the barrel, and this air forces up the piston-valve, and escapes. But why does the air not return down the suction-pipe again? It cannot. The first result of lowering the piston, and pressing it down upon the air, is to close fast the suction-valve.

"The piston and suction-valve are now close together as they were at first, and the work proceeds by raising the piston as before. This time more air, probably the whole of it, is exhausted from the suction-pipe. If so, the water rushes up through the suction-valve and fills the barrel.

"When we lower the piston again, it is water which forces its way through the piston-valve, and by the time the piston has reached the bottom of the barrel again, we have a continuous column of water from the pipe upwards.

"The next raising of the piston closes its valve by the weight of the water above, and that water is carried up to the spout, whence it runs out in a stream."

Lesson LII

How to make a Thermometer

"The other day I led you," said Mr. Wilson, "by first considering the phial and tube of colored water, to find out for yourselves the nature and use of a thermometer. We began our simple experiment with colored water, but we know now that mercury is a much better liquid for the purpose.

"I have here an actual thermometer," he continued. "Let us examine it. It consists of a long glass tube with a hollow bulb or ball at one end. The tube is so very fine that we may call it a *capillary tube.* The ball and part of the tube are filled with mercury, and both tube and ball are quite sealed and closed.

"Now look at the top of the tube. What do you see?"

"There is no mercury there, sir," said Fred. "I suppose it is an empty space or vacuum."

"Yes, Fred, you are quite right. It is a vacuum," said Mr. Wilson.

"We will now place the bulb or reservoir of the instrument in some hot water and watch it. The mercury, you see, expands with the heat, and rises in the tube.

"Suppose I tell you now how this curious and useful instrument is made and filled with mercury. I think it will interest you.

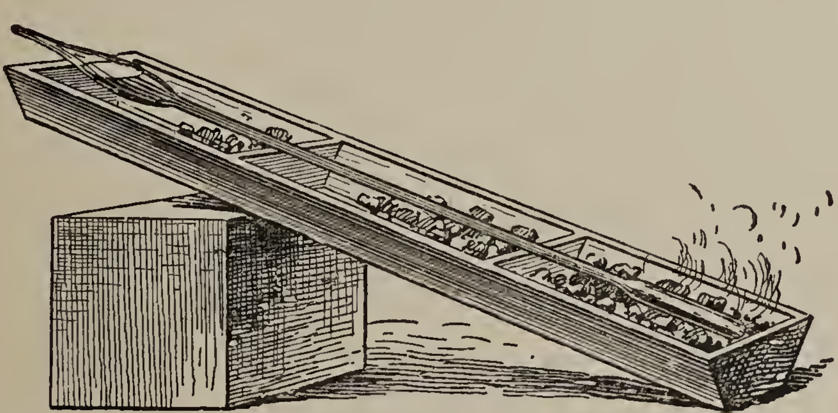
"The first point for us to notice will be the nature of the tube itself. Of course you will readily understand that if the instrument is to measure correctly, the rise and fall of the mercury must be equal in all parts of it. The greatest care has to be used in making the tubes. They must be of uniform bore throughout.

"As each tube is made, it is tested by introducing a small quantity of mercury. The mercury is moved about into different parts of the tube, and if it always measures the same, the tube must be of *uniform bore.*

"When a suitable tube has been obtained, one end is blown out into a hollow ball, and the tube is then ready to be filled with mercury.

"This filling of the tube, however, is perhaps even a more delicate task than making it. It would be absolutely impossible to pour the mercury in, because of the fineness of the bore.

"The upper end of the glass tube is first made soft and plastic by heating it, and while in that state it is blown out into a long pointed funnel, and a small hole is made in the point. The bulb at the other end is then heated over the spirit-lamp, the result of the heating being to expand the air in it, and so force some of it out at the hole in the pointed end.



"The point is then immediately plunged into a vessel of mercury. As the tube cools, the air in it contracts, and requires less room. The *pressure of the air on the surface of the mercury* then forces some of that liquid into the tube.

"The tube is next placed in an inclined position in a charcoal furnace, so as to allow the bulb at its lower end to get hot. The heating, of course, expands the air in bulb and tube, and some of the expanded air escapes by the funnel at the top. It is then set upright to cool.

"The little air left contracts as it cools, and the mercury passes down into the bulb. The same process is repeated again and again till the bulb and part of the tube are filled with mercury.

"The rest is easy. The bulb is heated till the mercury boils, and begins to evaporate. The vapor carries off with it all moisture and air that may still remain in the tube, and the moment the boiling mercury reaches the top, the glass tube is again softened with heat, and then pinched together, so as securely to close it.

"When the tube is closed we have a thermometer, capable of showing changes of temperature, by the rise and fall of the mercury."

Lesson LIII

The Skin and Its Covering

You know that the whole of the external surfaces of your body are covered with a thin coat or covering—the *skin*. You know, too, what a protection this thin covering is, because you have sometimes fallen down and grazed it, and the bare exposed place has been very sore.

Thin as this skin is, it may be separated into two distinct layers. You have all seen the skin of the hand or the foot raised up in a blister. The raised blister is the upper layer of the skin separated from the lower one. This outer layer is so *hard, tough, and horny* that it may be cut or pricked without causing the least pain. You may run a needle through it without feeling it, and without drawing blood. That being so, we know there can be *neither nerves nor blood-vessels* of any kind in this part of the skin.

Beneath the tough, outer layer is another —*the true skin.* The proper name for this is the *dermis.* The outer layer is called the *epi-dermis* because it lies on the dermis.

The under part of the dermis—that next the flesh—consists of fibres closely interwoven together. The rest of the layer consists of soft little bags or cells, too small to be seen without the aid of the microscope. The cells are closely packed together, and surrounded on all sides with nerves and blood-vessels. We could not prick the dermis anywhere with the finest needle without drawing blood and causing pain.

Fresh dermic cells are being constantly formed, and as these form, they push the old ones up to the surface, where they become flattened into tough horny scales—like the scales of a fish. These scales form the outer layer—the epi-dermis. They are really dead flattened cells. They are being constantly rubbed off the surface of the body, and constantly renewed from below.

But the skin is not merely a protecting coat for the body. It is an important organ for cleansing the blood of its impurities. Our earlier lessons have shown us the *perspiration or sweat*, oozing out through the pores of the skin after work or exercise. This perspiration is really waste matter, which has been drained out of the blood, by little coiled-up tubes—called *sweat glands*, in the under layer of the skin.

The bodies of all animals which have an internal skeleton are covered with a double skin, similar in structure to that of man.

Fishes, frogs, and reptiles, being cold-blooded animals, have *naked skins*. They have no outer clothing, or protection, other than the skin itself, for the simple reason that there is no need to preserve the bodily heat—there is, in fact, no bodily heat to preserve.

In mammals and birds, whose blood is warm, we find the skin clothed with a more or less thick and warm covering. In birds this outer coat takes the form of *feathers*, in most mammals the covering is *hair*. We have already had occasion to notice the special fitness of feathers as a clothing for birds, both as regards warmth and lightness, and as an aid to locomotion through the element in which they live.

Most mammals, as we said, are clothed with hair, although there are various modifications of this kind of covering. The cat, rabbit, squirrel, and mole, for instance, have a very smooth, soft coat, which we call *fur*. But what is fur? It is in reality fine, soft, silky hair, growing very close and thick on the skin. Then, too, the sheep has a coat of *wool*. But wool is only fine, long, curly hair set very close and thick on the skin.

The hog has a covering of *bristles;* and bristles are merely thick, strong, stiff hairs. Some animals, such as the hedgehog and porcupine, have these same stiff, strong hairs, only much stiffer and stronger still. We then call them *spines*.

These outer coverings of feathers, or hair in its various forms, are all modifications of the horny matter of which the *epidermis of the skin* consists. It becomes in certain parts very hard and horny indeed. It forms *nails* on our hands and feet, and *claws* on the toes of various animals. The *hoofs* and *horns* of other animals are all formed of the same hard, horny development of the epidermis of the skin.

We tan the skins of many of our large

mammals into leather, but it is only the under layer, or dermis, which is used; the epidermis is all scraped away.

It is worth noticing that the *Cetacea* (or whale-like animals) have *smooth, naked skins* to assist in their water locomotion; but, being warm-blooded mammals, their bodily heat must be kept in. This is accomplished by a thick under-coat of fat or *blubber* beneath the skin. Wool, fur, or feathers would be out of the question.

Lesson LIV

The Lifting Pump

"You remember our long tube of mercury, of course," said Mr. Wilson. "I want you to think about it now. What was the height of the mercury in the tube?"

"The column of mercury is usually about 30 inches high, sir."

"What causes it to rise in the tube?"

"The pressure of the air all round forces the mercury up the tube, sir."

"And what is it that causes the water to rise in a pump?"

"The water also rises in the pump because it is forced up the pipe by the pressure of the air all round, sir."

"Those are three very good answers," said Mr. Wilson. "Now if we used the pump to raise mercury instead of water, how high do you think we could pump it? You must remember that the mercury, like the water, would rise only by reason of the pressure of the air."

"I suppose, sir," said Fred, "it would be impossible to raise the mercury beyond 30 inches."

"You are quite right, Fred. You know that a column of mercury 30 inches high, and a square inch in section, weighs just 15 lbs., and this exactly balances the pressure of the atmosphere on the square inch.

"We might have used water in the tube instead of mercury; but as water is $13\frac{1}{2}$ times as light as mercury, our tube must have been $13\frac{1}{2}$ times as long, because we should have required $13\frac{1}{2}$ times as much water to balance the weight of the air. Our tube must then have been 30 inches $\times$ $13\frac{1}{2} = 34$ feet (nearly).

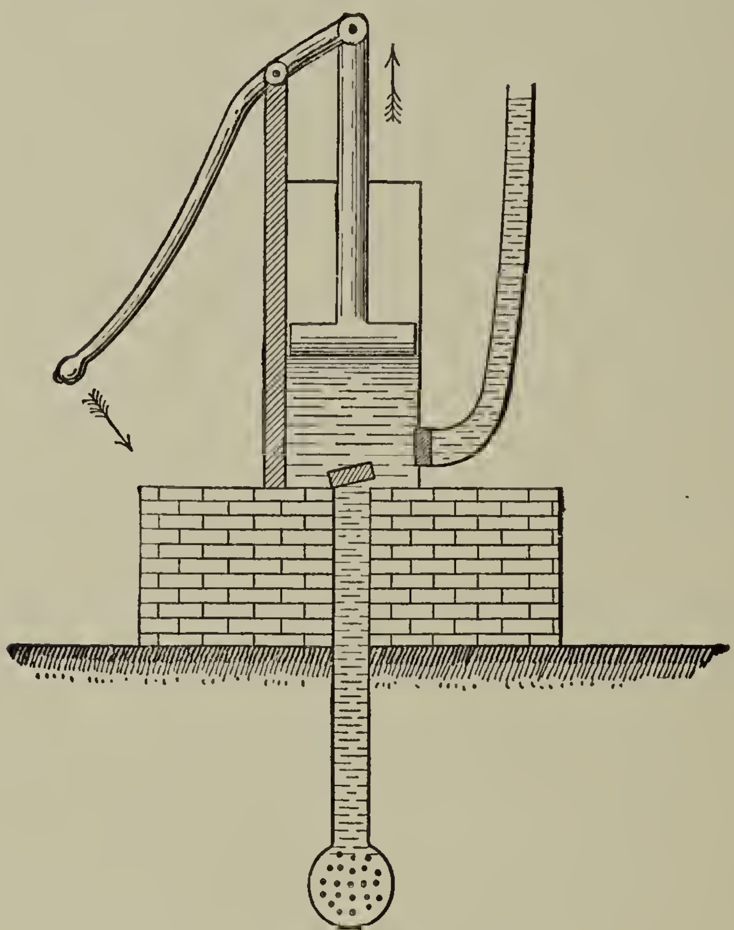
"Now, of course, you see clearly why we use mercury instead of water. It requires 34 feet of water to balance 30 inches of mercury—that is, to balance the pressure of the air.

"I wonder whether you can tell me now how high we can raise water by means of a pump?"

"I should think the water would rise about 34 feet, sir," said Fred.

"Well, it ought to rise to that height, Fred, but it does not, because we cannot get a perfect vacuum, unless the pump is constructed with the utmost care. The greatest height we can raise water with a common pump is from 26 to 28 feet.

"Now although we cannot raise water higher



THE LIFTING PUMP, PISTON RISING.

than this with an ordinary pump, it is often found necessary to carry water to many times this height. Let me explain how it is done.

"For this purpose a pump, called *the Lifting Pump*, is used. The main difference between it and the common pump is that *the piston of this one has no valve.* Near the bottom of the barrel is a *discharge-pipe* which bends upwards, and may be carried to any height. At the entrance to this pipe is *a valve, opening outwards.* It allows the water to pass out of the barrel, but prevents it from returning.

"The working is very simple. As soon as the water reaches the barrel in the ordinary way, the next downward move of the solid piston must force it somewhere. The water itself, you know, will not be squeezed into smaller bulk. It cannot go back into the suction-pipe, because its valve is closed firmly. The other valve, however, leading into the discharge-pipe is open, and, at the first pressure of the piston, the water takes that course. A pump of this kind will lift water to almost any height."

Lesson LV

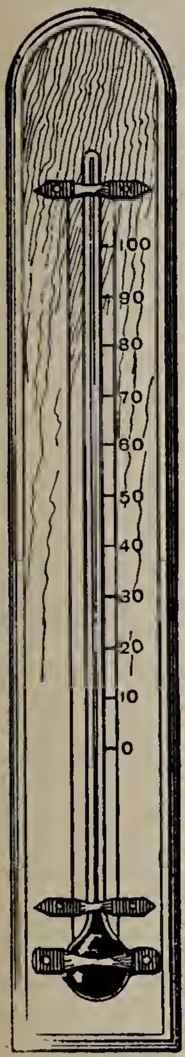
Thermometers

"I want you to think of our lesson on the thermometer," said Mr. Wilson. "We followed the various steps of making, testing, filling, and sealing the tubes. Now let us see what we have got. We have an instrument which will tell us that one body is hotter than another. That is all. We want something more than this. We want to say how much hotter it is. We want to show the steps or degrees of heat.

"To do this the bulb is first placed in a vessel of melting ice. After it has stood there for a short time, the mercury contracts and sinks to a certain point; but it will not sink lower. This point is marked in some way on the tube, and it shows *the melting-point of ice*, or, as we more frequently call it, *the freezing-point of water*. Both mean the same thing.

"The instrument is next suspended in a vessel, in which water is being boiled, so that it is surrounded on all sides by the steam of the boiling water. The mercury expands with the heat, and rises in the tube to a certain point, but after reaching that point, it will not rise higher, however long it is kept there. This point is marked on the tube as *the boiling-point of water*. We have now found two very important points—one, that at which water freezes; the other, that at which water boils. Between these two points we may make any steps we please.

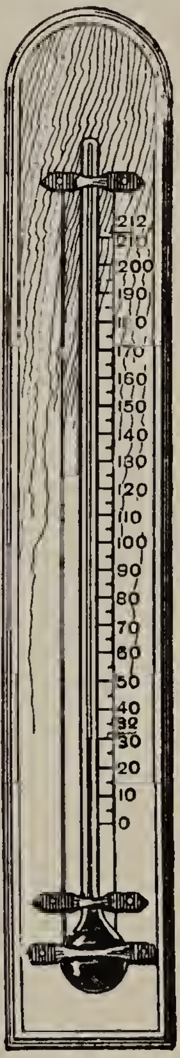
"All thermometers are made in one way up to this stage of the process, but there are different methods of dividing the space between the freezing and boiling points. In one thermometer the space is divided into 100 equal steps; the freezing-point is marked 0, and the boiling-point 100. This is a very simple arrangement, and the instrument is known as the *centigrade thermometer*—from the Latin *centum*, 'a hundred,' and *gradus*, 'a step.'



CENTIGRADE.

There are 100 steps or grades between the freezing-point and the boiling-point. This thermometer is not commonly used in our country.

"The one mostly in use places the freezing-point at 32 degrees, and the boiling-point at 212 degrees, thus making 180 steps or degrees between the two points. We call this instrument *the Fahrenheit thermometer*, from the name of the man who invented it; and we write the steps 32° or 212° (32 degrees or 212 degrees).



FAHRENHEIT.

"This freezing-point of water is not the lowest temperature that can be reached. Fahrenheit found, by making a mixture of snow and salt, a temperature 32° lower than the freezing-point, and he thought he had actually reached the extreme limit. He called this point 0° or *zero*, and worked upwards from it. Lower temperatures, however, have been found since his time.

"Ten degrees below zero on the Fahrenheit thermometer means $32° + 10° = 42°$ below the freezing-point.

"In the centigrade thermometer 10 grades below zero signifies 10 grades below the actual freezing-point, because the freezing-point in that instrument is zero."

Lesson LVI

The Mouths of Animals

Just as the limbs of animals are specially adapted to their mode of locomotion, so are the teeth, the form of the mouth, and even the movements of the jaw adapted to the kind of food the creatures eat. It will be very advantageous at this stage to compare the various classes of vertebrate animals in these respects.

Taking first the *Insectivora*—bats, hedgehogs, and moles—we find the teeth bristling with sharp points, for crushing the hard horny cases of beetles and other insects, which form their natural food. They feed on insects, not by accident, but because their teeth are formed to crush such food. Some of the bats live on fruit. Their teeth have no sharp cutting points, but are broad and rounded for grinding purposes.

Passing next to the *Carnivora*, we notice in all of them the enormous development of the four canine teeth, and the sharp cutting edges of the others. The great canine teeth are meant for seizing the prey; the sharp jagged edges of the other teeth are for cutting through the flesh; and this work is still further assisted by the peculiar up-and-down movement of the jaw.

In the cat and dog families the tongue is long, fleshy, and very flexible. These animals *drink by lapping with the tongue.* In the cats the tongue is furnished with sharp horny spikes on its upper surface, and is used for rasping the flesh from the bones. The dog's tongue is smooth. He perspires through his tongue.

The seal feeds mostly on fish. Its teeth are furnished with *sharp saw-like edges,* to serve the double purpose of seizing and holding such slippery prey.

In the *Rodents* (gnawing animals) the four incisor teeth become the chief peculiarity. These teeth are of more rapid growth than the teeth of most animals; they develop into sharp-edged chisels; their very work of gnawing tends to sharpen them for further use. The cleft in the upper lip is designed to assist in the work of gnawing. There are no canines. Between the last of the incisors and the first of the molars, in each jaw, there is a space where the canine teeth of other animals are set. The molars are meant for grinding, not cutting, and the movements of the jaw, from side to side, as well as up and down, are designed to assist in the work.

The mouths of the *Ruminants* (cud-chewers) present their peculiarity, and it is in the entire absence of incisors in the upper jaw. The place of these teeth is occupied by a hard gristly pad, which the animals use in collecting and tearing off the tufts of grass, preparatory to the act of swallowing them. The molars are all largely developed, but they have broad crowns for grinding; and the jaw has the usual double movement designed for the same purpose.

The so-called *Toothless* animals differ considerably among themselves, according to the nature of their food. In none of the family do we find canine teeth; in some the incisors are wanting; and others, again, are entirely without teeth. In most of them the lips are hard and sufficiently horny to crush the insects and soft-bodied animals on which they live.

It is worthy of notice here that many of the insect-feeding animals—mammals, batrachia, and reptiles—have tongues specially fitted to assist in securing their prey. The tongue is not only long and flexible, but is capable of being *thrust for a considerable distance out of the mouth.* As a further aid in capturing their insect prey, the tongue is generally covered with a slimy, gummy fluid, which holds the victims fast while they are being conveyed to the mouth.

Among the *Cetacea* (whale-like animals) the great Greenland whale presents a remarkable peculiarity. Its mouth is entirely destitute of teeth; but hanging from the roof of the mouth, downwards, are a number of transverse horny *plates of whalebone.* These plates act the part of a trap, in which to entangle the small creatures that form the natural food of this sea monster. Birds, as we know, are without teeth. Their bills serve instead of teeth. Fishes and reptiles have usually a large number of small pointed teeth, all directed backwards, for the purpose of seizing and holding their prey, which they swallow whole.

Lesson LVII

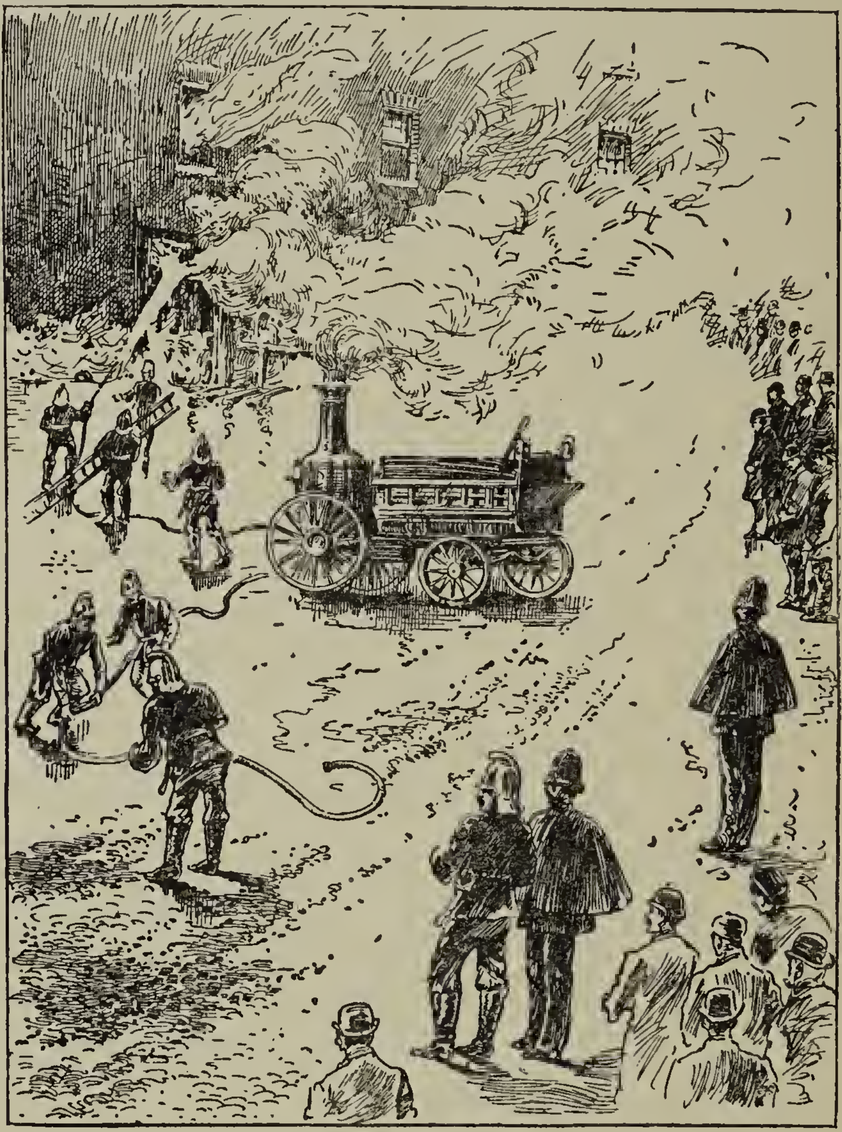
The Force-Pump

"Did any of you see that great fire last week?" asked Mr. Wilson. "Ah! I thought so; several of you saw it, and a very grand and awful sight it was. Did you ever feel curious to know how the firemen send out the water from their hose in that one continuous stream?"

"Oh yes, sir," said Fred; "do tell us, please. It has often puzzled me."

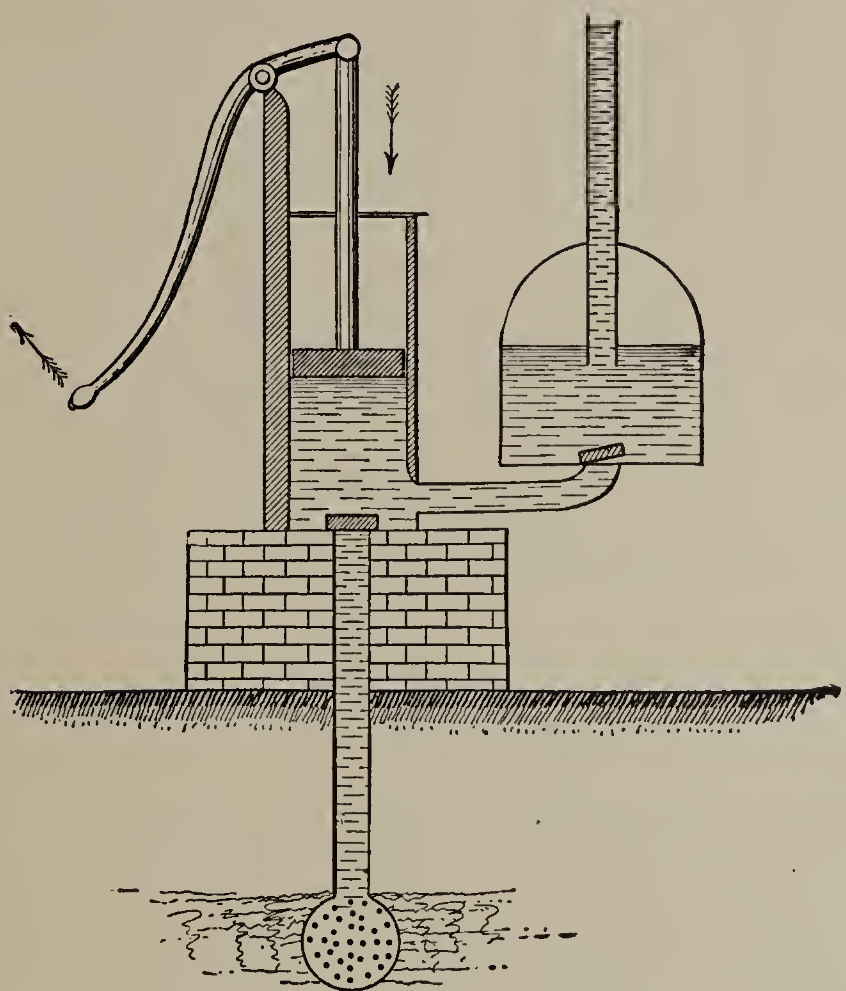
"Well," said Mr. Wilson, "it is the work of a pump; but this pump is like neither the suction-pump nor the lifting pump. It is called a *force-pump.* I will describe it to you.

"In this contrivance, the suction-pipe and



barrel are exactly the same as in the lifting pump, and the piston too is solid—that is, it has no valve. The great difference is that in the force-pump the pipe leading from the barrel opens into an *air-tight chamber* of great strength

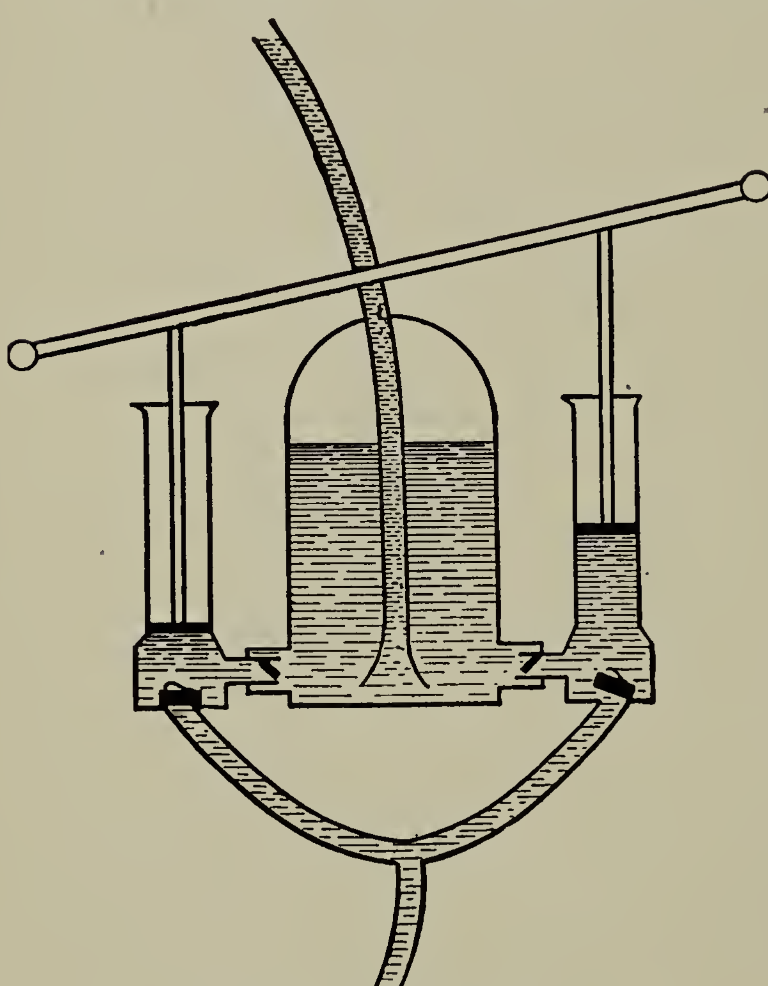
—*the condensing chamber*. The entrance into it is guarded by a strong valve opening upwards —that is, away from the barrel. The discharge-pipe dips down into this chamber, and passes upwards into the air, but there is no valve in it.



FORCE-PUMP, PISTON DESCENDING.

" As in the case of the lifting pump, the piston, in descending, presses down on the water in the barrel and closes the suction-valve. At the same time it drives the water through the pipe into the condensing chamber; and this is repeated with each downward stroke of the piston.

"You must remember that this condensing chamber is not only air-tight, but is full of air. As the water rushes in, this air is very much compressed, and then commences a struggle between the compressed air and the water which is still being forced in. The air presses down on the water, but the water is incompressible; it cannot be compressed into smaller bulk. It cannot return by the way it came, partly because of the valve, and partly because of the body of water rushing up behind it. There is one way of escape — up the discharge-pipe; and up that pipe it rushes in a continuous stream.



SECTION OF FIRE-ENGINE.

"I have been describing to you an ordinary force-pump. The fire-engine is really a *double force-pump*; that is all. There is a central condensing chamber with a force-pump on each side. The pipes from both pumps open into the one condensing chamber, and the delivery-hose passes out from it. A strong hose from the bottom of each pump is attached to the water supply in the road, and, as the pumping goes on, the water is raised through these pipes into the barrels of both pumps, and passed from them into the common condensing chamber, whence it is sent out in a continuous stream through the delivery hose."

Lesson LVIII

Ice

"We are going to have one or two further experiments with our phial of colored water to-day," said Mr. Wilson. "You remember I called it our water-thermometer.

"I will begin by heating some water over the spirit-lamp to about 60° or 70°, and we will test it with an actual thermometer. When the thermometer tells us that this temperature is reached, we will stand the phial in the water, and in a short time the colored water inside the phial will show the same temperature.

"Now we have been taught that bodies expand with heat, and contract when the heat is taken away. We should expect that, in all bodies, there would be a regular step-by-step expansion, with every degree of heat added, and a corresponding, regular, step-by-step contraction, with every degree of heat taken away. If we raised the present temperature of the water in our phial by degrees we should find this to be actually the case. But we are not going to raise it this time. We will lower it.

"How shall I lower it?"

"By adding some cold water, sir."

"Very well: I will add cold water, and at the same time stand the thermometer in it. You in the meanwhile shall watch the result. As the water in the phial feels the diminution of heat, it gradually contracts, and the column in the tube falls lower and lower. This will go on till the thermometer shows us that 39° or 40° is reached. From this point, as the cooling proceeds, the colored water will be seen to rise in the tube again.

"What does this show?"

"It shows that *the water is actually expanding again,* sir. It rises in the tube because it requires more room."

"Quite right," said Mr. Wilson. "Now I will put some pieces of ice in the water to cool it still more. As it cools, the expansion in the tube will go on.

"We will put in some more ice, and wait till the thermometer stands at 32° (the freezing-point). The expansion of the colored water inside the phial and tube still goes on, for it continues to rise, and at last, when it reaches the same temperature as the surrounding water, it assumes the solid form and becomes ice.

"But what has happened now?"

"The phial has burst, sir."

"Yes, *the expansion of the water at the moment when it changed into ice* was so sudden, and so violent, that the glass was not able to yield equally, and it burst. I think you will now readily see why water would not be a suitable liquid for filling thermometers.

"Water is unlike most other bodies in this respect, but its peculiar action, as it changes into the solid state, is of immense importance in nature.

"You know that as bodies contract, their molecules are drawn more closely together; they become denser, and of course heavier. When they expand the opposite happens; their molecules are driven apart; they are less dense, and consequently lighter than they were.

"Water, we have seen, contracts step by step, as it cools, *till it reaches about* 40°, but lower than that it expands. *Water, then, is heaviest* when it stands *at a temperature of* 40°.

"Imagine a pond of water in winter. The surface water cools first, and when it has cooled to about 40° it has so far contracted, that its particles are densely packed, and it is heavier, bulk for bulk, than the other water in the pond.

"What must happen then?"

"This heavy surface water must sink to the bottom, sir."

"Quite right," said Mr. Wilson, "and it does sink, and drives up to the surface that which is not so dense and heavy. This, however, soon cools and sinks in its turn, and so it goes on till the whole body of the water is cooled to that temperature. But suppose this went on till the freezing-point was reached. The coldest and heaviest water would be at the bottom, and the ice would be formed from below upwards, till the whole pond became one solid mass, killing all plant and animal life.

"Instead of this, the water in cooling from 40° to 32° *gradually expands,* so that when the actual freezing takes place, the coldest water—that which forms the sheet of ice—is floating on the surface, *because it is so much lighter than the rest.* The ice which thus forms on the surface of the pond becomes a protecting coat for the still unfrozen water beneath it."

Lesson LIX

The Internal Organs

The main distinction between vertebrate and invertebrate animals lies in the fact that the former always possess a skull and a vertebral column, and with them a brain and spinal cord.

The brain and nervous system are constructed on a very similar plan in all vertebrate animals, although they reach their highest perfection in man. The weight of the human brain averages from 3 lbs. to 3½ lbs.; *it weighs absolutely more than that of any other animal except the elephant and the whale.* The elephant's brain weighs from 8 to 10 lbs.; that of the whale about 5 lbs.; and that of the horse only about 19 ounces. When we compare the relative sizes of these creatures, we see at once the immense superiority of man over them all. Birds have smaller brains than mammals, and reptiles smaller still, while *fishes take the lowest place* in this respect among the vertebrate animals.

The general plan of structure, as to the trunk and the organs lodged in it, is very similar in all mammals and birds. There is an upper chamber (*the thorax*), and a lower one (*the abdomen*), the two being separated by a partition known as *the diaphragm.* The heart and lungs are lodged in the upper chamber, or thorax. The heart is the centre of the circulatory system; the lungs do the work of carrying off carbonic acid, and supplying the blood with fresh oxygen from the air which is breathed in. The mouth and nostrils do the double work of taking in fresh air and breathing out carbonic acid gas.

In mammals and birds *the heart always contains four chambers:* the auricle and ventricle on the right side contain impure venous blood; the corresponding chambers on the left side contain the purified blood which has been sent back from the lungs.

The lung-breathing in all these animals supplies the blood with abundance of oxygen, and their bodies are warm because of the burning which this large amount of oxygen produces.

In birds the lungs themselves are smaller than in mammals, but breathing goes on not only through these organs, but through all parts of the body, so that air penetrates everywhere. Even the hollow bones are filled with air, and there are air cells in the cavity of the chest.

In reptiles *the heart has only three chambers* instead of four, and the lungs are small. Very little oxygen is taken in by these lungs; consequently there is not sufficient burning to keep up a warm temperature, and *the body is cold.*

The two auricles of the heart open into a common ventricle. The ventricle has to receive the venous blood from all parts of the body, as well as the purified blood sent back from the lungs. Instead, therefore, of sending out through the arteries pure blood, well supplied with oxygen, it sends out this mixture of the two.

Fishes differ from all other vertebrate animals in having *gills instead of lungs*. *The heart has only two chambers*, a single auricle and ventricle. The veins bring the blood to the auricle, and, after passing through the ventricle, it is sent out to the gills, and thence into all parts of the body. A very small amount of oxygen is taken in from the water in this way; consequently the oxidation is not sufficient to warm the body. *Fishes*, like reptiles, are *cold-blooded animals.*

Lesson LX

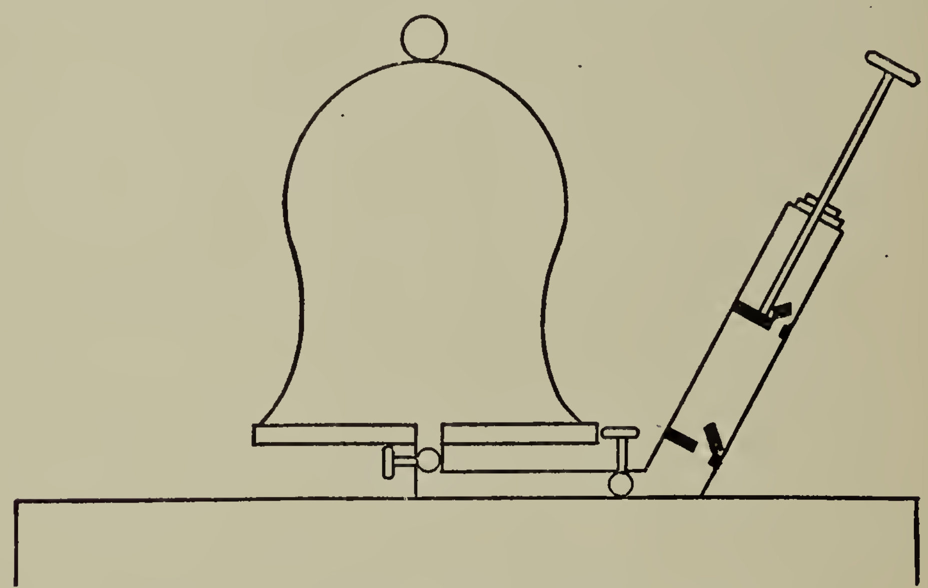
The Air-Pump

"We have had occasion to refer to the air-pump in some of our lessons," said Mr. Wilson. "This morning we will have a look at the pump itself, to find out how it is made and how it acts.

"It consists, as you may see, of two parts—a pump, and a large glass bell, commonly called the *receiver*. The pump is very similar in construction to the common suction-pump. It consists of a *barrel*, and an *air-tight piston* capable of moving up and down in it. It is made of brass, and every part is most carefully fitted.

"As in the suction-pump, the piston is furnished with a valve opening outwards, and there is also at the bottom of the barrel another valve, which opens in the same direction. You know that the whole purpose of a valve is to allow the easy and ready flow of a fluid in one direction, and to prevent it from flowing back again. The first attempt the fluid makes to flow back simply shuts the valve, and the passage is closed.

"Below the barrel is a brass pipe leading from the pump to the second part of the instrument—the *receiver.* This pipe is furnished with a *stop-cock.* When the cock is turned on, the way along the pipe is open ; but when it is turned



SECTION OF AIR-PUMP.

off, and so closed, not a particle of air can find its way through.

"The receiver is simply a large glass bell, which fits closely on a brass plate. In the brass plate is a hole into which fits, perfectly air-tight the pipe leading from the barrel of the pump.

"The whole object of the contrivance is to remove the air from the receiver, so as to leave an empty space, or vacuum.

"Let us turn the cocks on, and commence pumping with the piston close down on the suction-valve at the bottom of the barrel. That valve is quite closed, and so is the piston-valve above. Now, as we raise the piston, the pressure of the air in the barrel closes its valve, and all that air is forced out at the top.

"But what has been going on below the piston? The raising of the piston has made (or tried to make) a vacuum above the suction-valve.

"So far you have noticed, no doubt, that the construction and working of the air-pump and the common suction-pump are exactly the same.

"Now I want you to consider the nature of the two fluids. Water is a liquid, and rises in a body into the barrel, as soon as the air-pressure is removed. The air to be removed from the receiver of the air-pump is a gas. *It has no cohesion between its particles.* They spread out from each other, so as to fill the greatest possible space.

"Keeping this in mind, let us return now to the vacuum which the pumping makes in the barrel of the air-pump. As this is being done, the air in the receiver and the pipe leading from it expands, forces open the suction-valve, fills the barrel again, and prevents a vacuum. There is air still in the receiver, the pipe, and the barrel, but it is not so dense as it was before the pumping.

Some of it has been removed, and *the rest has been made to expand*, so as to fill a greater space.

"Now we will force the piston down again. This downward movement of the piston compresses the air in the barrel and closes the suction-valve; while at the same time this compressed air forces open the piston-valve and escapes through the top of the barrel as before.

"The next upward movement of the piston tends to create a vacuum again, and the air in the receiver expands once more to fill it.

"This is the whole secret. The next downward movement drives out all the air between the suction-valve and piston-valve; the following upward movement causes further expansion of the air that still remains; and so it goes on, each action of the pump removing some of the air, the rest expanding to fill the space, until that which remains *becomes thinner and thinner*—so thin and feeble, indeed, that it has not power to force open the suction-valve. We then say that the receiver has been exhausted."

THE END

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