JUNIOR SCIENCE

HESSLER

BOOK TWO

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BY

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BOOK TWO

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PREFACE

It is almost a truism to say that science is the foundation of modern civilization, yet, curiously enough, educators have largely postponed the study of science to the later years of the school course. This is especially true of the fundamental sciences: Physics and Chemistry. As a result, few of the young people who go to school ever study the physical sciences at all and these few only at the end of their student careers.

To say that most students have not studied science is not, of course, to say that they have not had any practical experience with the *facts* of science. Merely to state such a proposition is to disprove it. From their earliest years children are obliged to adapt themselves to conditions caused by gravitation, inertia, heat, air pressure, convection, and the like; they soon learn to use all sorts of mechanical and electrical devices: but they experience these phenomena and use these devices empirically, without the clarifying influence of scientific explanation and without the inspiration and enlargement of vision that would come from the scientific way of looking at them.

With so little opportunity for science in school, is it any wonder that the child comes to feel that he must pursue the quest of the great natural "whys" of his life outside of the school, or that he must not have so many troublesome questions surging through his mind? A host of school children, it is to be feared, find the latter way the easier and drop out of the ranks of those who wonder. Then, all too late, educators realize that they cannot get such children interested in science. It is well known that normal children, if given the opportunity to seek scientific answers to their problems at an early age, do not need to be "interested" in science; they have the interest as a native endowment. A child's natural eagerness to understand the phenomena he meets in life is so great that it is scarcely true that he needs to BE TAUGHT science; it is more nearly true that he needs an opportunity to LEARN science and to put it to use. Science teaching, moreover, does not consist in getting a pupil to answer the teacher's questions, nor yet in getting the teacher to answer the pupil's questions, but in training pupils to ask and to answer their own questions. Upon the ability to see quickly what is taking place, to understand the reason for it, and to know how to deal with it, not only the progress of the individual, but also the life of the nation depends. Science, which demands observation and reasoning, therefore yields to no branch of knowledge the position of first importance in our modern life; it should have a similar place in our educational system. It is not an elective appendix to the course of study, but the *sine qua non* of an efficient curriculum. The proper pursuit of science will give the child the opportunity not only to know the world of which he is a part, but to know also his relation and responsibility to that world. Right knowledge is the only sure foundation for right action.

It is to meet the science needs of the students and teachers of the Junior High School and of the corresponding grades elsewhere that *Junior Science* is written. Nature Study may be pursued in the earlier grades, but grades seven to nine, inclusive, are ideal for the beginning of a definite study of science. In the writing of the text the age of the pupils of these grades and their degree of attainment have been kept constantly in mind. This statement applies both to the quantity of material selected and to its kind. The style of the book is simple.

The section titles are nearly all queries; many questions are also asked throughout the text, as well as in the exercises at the end of the chapters, in order that the student may be kept open-minded and alert. The author is confident that, by using the desire of boys and girls to know the reasons for many things they are now doing, the teacher can arouse them to know the "why" and the "how" of the duties that await them hereafter.

The text consists of two divisions: Books I and II. Book I contains four Parts, distributed into twenty-two chapters: —

Part I: Introduction.
Part II: The Atmosphere and Its Relation to Man.
Part III: Matter and Energy in Earth and Sky.
Part IV: Science in the Household.

Book II consists of three Parts: —

Part V: How We Use Nature's Forces.
Part VI: Living Things and Their Relation to Us.
Part VII: Our Bodies and How to Care for Them.

In the preparation of this textbook the writer has been greatly assisted by his wife, Maud C. Hessler. He is also much indebted to his daughter, Miss Margaret C. Hessler, of the University of Texas, and to Mrs. Margaret Honeywell Miller, recently of the Harlem Hospital, New York City, for the preparation of necessary material. Most of the drawings for the illustrations were made by Professor Robert W. Lahr, of the James Millikin University, and by Mrs. Lahr. Several were made by Mr. W. F. Henderson, Fellow in The Mellon Institute. Photographs for the half tones were obtained from the McIntosh Stereopticon Company, Chicago, the International Stereograph Company, Decatur, Ill., the Old Colony Insurance Company, the Judd Laundry Machine Company, Professor

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Several illustrations are reproduced from Hopkins' Physical Geography, by the courtesy of Professor Hopkins.

To all those who have assisted him, as well as to the many writers on science whose work has made this book possible, the author wishes to express his thanks and obligation.

J. C. H.

PITTSBURGH, PENNSYLVANIA,
April, 1921.

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CHAPTER XXIII

THE MARINER'S COMPASS

215. What is a Magnet? — Did you ever have a knife with a magnetized blade? If you did, you will remember how the blade attracted and picked up needles, tacks, and other small objects made of iron or steel. Perhaps you have owned a **horseshoe** magnet (Fig. 124); this could pick up a great deal more than the knife blade. Beside these you may have had a pocket **compass**, and enjoyed finding where true north was, even when the sun was behind clouds, or when you were in the woods after dark (Fig. 125). The compass is a magnet, like the magnetized knife blade and the horseshoe magnet; but it is suspended or supported so that it can swing around in the *plane* of our horizon. What does this mean? See § 84.

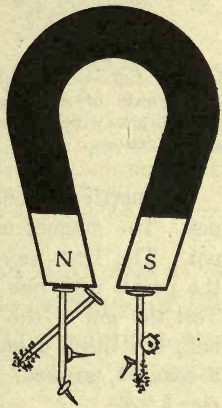


FIG. 124. — Both poles of the magnet can pick up particles of iron or steel.

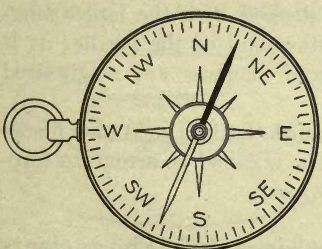


FIG. 125. — A pocket compass. When the needle of the compass is free to move, it points toward the north.

The compass used on ships (**mariner's compass**; Fig. 126) is supported so that it will remain level, no matter how much the ship tosses about in the sea.

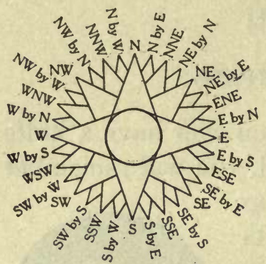


FIG. 126. — The thirty-two points of a compass, according to which ships are steered at sea.

Experiment. — Examine a bar magnet and a horseshoe magnet, and pick up nails and tacks with them. Note that a nail which is being held by a magnet is itself a magnet and will pick up other nails.

Try picking up a brass key with a magnet. Do you succeed? Try also the following: a gold ring or pin; a silver coin; a copper coin; a nickel; an ordinary pin; a needle. Which are attracted by the magnet?

Magnetize a needle by bringing it near, or touching, a large magnet. The magnet may be either a bar magnet or a horseshoe magnet. The best way is to stroke the needle, from the middle to the point, with one end of the magnet. Repeat this several times. Test the end of the needle which you stroked with the larger magnet; is it itself a magnet? Test the other end of the needle; is it a magnet, or not? Find out how large magnets are magnetized (see § 226).

The bar of soft iron which is laid against the two ends of a horseshoe magnet when the magnet is not in use is called an **armature** (pronounced är′mă-tiūr). Find out why it is used.

How did people ever learn about magnets? The ancients were acquainted with them, and magnets received their name from certain pieces of iron ore which were found in Magnesia, in Asia Minor. These pieces had the peculiar property of drawing small pieces of iron and steel to themselves. Later, in England, such natural magnets were named **lodestones**, from the word "lode," meaning a way or path, that which *leads*.

We can magnetize a piece of steel, such as a knife blade or a needle, by stroking it against one of these lodestones, just as well as against a bar or horseshoe magnet.

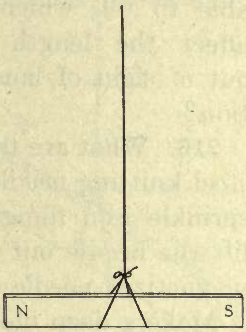


FIG. 127. — If a bar magnet is suspended by a hair or by untwisted silk, it will be free to turn to the *N–S* position.

Who do you suppose it was that first suspended a magnet or lodestone (Fig. 127), so that it could swing around to take any position it chose? Perhaps he placed it upon a floating chip or plank, and was astonished to see the floating body turn about until the magnet was lying in a general north and south direction. Whoever he was, this man (or was it a woman?) of long ago had discovered the principle of the compass. The compass was in use long before the time of Columbus.

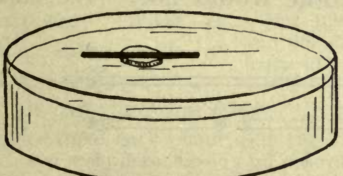


FIG. 128. — If a needle is floated upon water in a glass or porcelain dish, and is then magnetized, it turns until it has a *N–S* position.

You can make a compass for yourself. Push a sewing or darning needle through a slice of a small cork (Fig. 128), and float the cork and needle upon water in a glass or porcelain dish (not an iron one). Does the floating body seem to prefer to lie in any particular direction? Now magnetize the needle, and float it upon the water; what happens?

When you face north, which of your hands points east? Which west? What gain was it for sailors to be able to tell which direction was north? How did it affect the length of their voyages and their going out of sight of land? How, then, did it affect civilization?

216. What are the Poles of a Magnet? — Magnetize a steel knitting needle, then lay it on a sheet of paper and sprinkle iron filings over it. What happens when you lift the needle out of the filings? To what parts of the magnetized needle do the filings cling?

Make a deep file mark at the middle of your knitting-needle magnet and break the needle into two pieces; now put each of the pieces into the iron filings. What happens? Do not the two ends of each half pick up the bits of iron? See Fig. 129. If the steel needle were broken into four, or six, or any number of pieces, each piece would be a magnet. In each case the ends would attract the filings, but the middle would not. We call

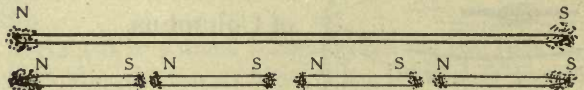


FIG. 129. — If a magnetized needle is broken into pieces, each piece is a magnet.

the two ends of a magnet its **poles**. The pole that would point to the north if the magnet were suspended, as in the compass, is called the *north-seeking*, or simply, the north pole, of the magnet; the other is called the *south-seeking*, or simply, the south pole, of the magnet.

Bring an unmagnetized knitting needle or knife blade near the north pole of the floating compass which you have made (Fig. 128). Is one pole attracted as much as the other? Is either pole repelled? Then find (how?) which is the north pole of one of your knitting-needle magnets, and bring this pole carefully near the north pole of your floating compass. What happens? Bring the south pole of your knitting-needle magnet near the south pole of your floating compass. What is the result? Finally hold the north pole of one near the south pole of the other and see what happens. What is the story told by Fig. 130?

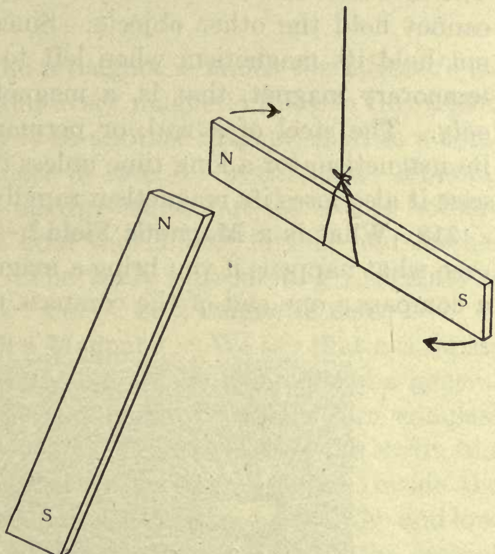


Fig. 130. — One of the bar magnets is suspended, and the other bar magnet is brought near it. What happens?

Is this statement true: "In the case of two magnets, the two like poles repel each other, but the two unlike poles attract each other"?

217. What is a Temporary Magnet? — Is it true that "once a magnet always a magnet"? With a bar magnet or horseshoe magnet hold a soft-iron bolt or wire, and then let the bar or wire touch a heap of tacks or brads. See how many tacks or brads your magnet will hold. (Look back at Fig. 124.) Here the soft-iron bar or wire acts as a magnet and holds the other iron objects. Remove the magnet from the bar or wire; what happens? The soft iron does not retain its magnetic power, and so cannot hold the other objects. Since the soft iron will not hold its magnetism when left to itself, we call it a **temporary magnet**, that is, a magnet *for the time being only*. The steel of a real, or permanent, magnet keeps its magnetism for a long time unless it is heated; in that case it also loses its magnetism rapidly.

218. What is a Magnetic Field? — You have already seen what happens if you bring a magnet up to the side of a compass: one end of the compass needle turns toward

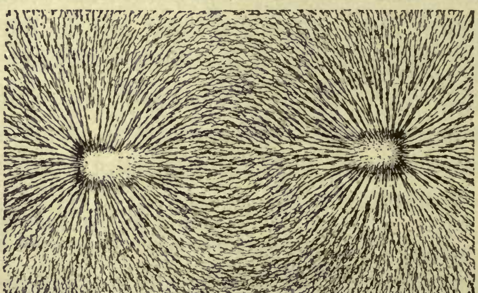


Fig. 131. — If a magnet is placed under a pane of glass, or a sheet of paper, the magnet's influence passes through, and each of the bits of iron on top of the pane or paper becomes a magnet.

the magnet, although the two do not touch each other. Try it again. Also try holding the magnet just above the compass; then below it. The results are the same: wherever you place the magnet, it will affect the compass needle, if the two are not too far apart.

Also carry out this **experiment**: Put a **magnet** under a plate of glass (Fig. 131); then sprinkle iron filings upon the glass, and tap it gently. The filings arrange themselves end to end in distinct curves. Why do they do this?

The region around a magnet is under the magnet's influence, or power, and every magnetic thing in this region is affected, whether it be another magnet, such as a compass needle, or a piece of steel, or iron filings. This influence extends in all directions, but its effects become less and less as we hold the objects farther and farther from the magnet. The space surrounding a magnet is called the magnet's "field," or a **magnetic field.**

219. Is the Earth a Magnet? — We say that a compass points north and south, but this is true only in a general way. The place in the north to which our compass points is not the geographical north pole of the earth, but a **magnetic pole** located in Northern Canada, inside the Arctic Circle. In 1905 it was in latitude 70° 5′ N. and longitude 96° 46′ W. Find it on a map. Even in the days of Columbus, men in Europe knew that the compass did not point exactly north. As Columbus sailed westward, he discovered another thing: the direction of the needle changes as we go from one place to another. This greatly frightened his sailors, for they thought they were going into regions from which they could never find their way back to their home.

Fig. 132 shows in a general way how far the compass direction is from the true north for different parts of America. In regions in which there are deposits of iron ore, as in Alabama and Michigan, the compass needle is drawn aside in an irregular way. The lines in the figure do not show this. So we see that the compass cannot tell us true north at any place, unless we know how far it points east or west of true north at that place. This difference is called the **declination** of the compass.

If you were in Greenland, in what direction would the compass point? If you were in Alaska? At the north pole?

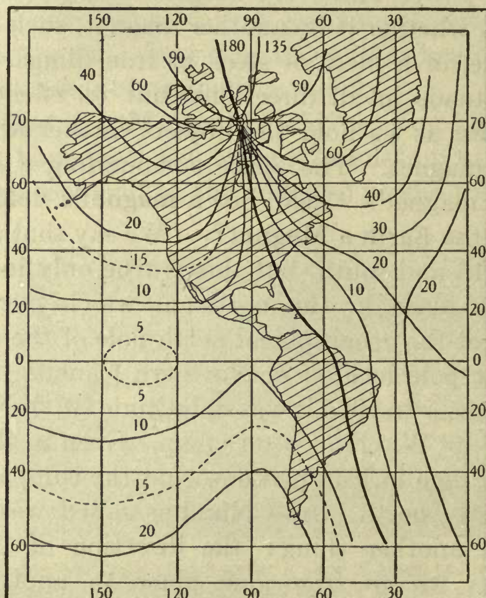


Fig. 132. — The lines show the direction in which a compass needle points in the Western Hemisphere and in the oceans that wash its shores. Thus, at any point of the line cutting off the eastern corner of Brazil and marked 10, the compass will point 10° west of true north.

220. How Can We Find the Earth's Magnetic Poles?

— How do you suppose men found where the magnetic pole north of us is located? If we balance a knitting needle nicely and support it (Fig. 133) so that it can swing in an up and down, or **vertical**, circle instead of in a horizontal circle, and if we then magnetize the needle, we shall find that its north pole **dips** more and more as we take it farther north, until a place is reached at which it stands **vertical**; the needle is then **over** the earth's north magnetic pole. In the Southern Hemisphere there is also a place where the needle becomes vertical, but here the south pole of the needle points downward. Such a needle is called a **dipping needle.**

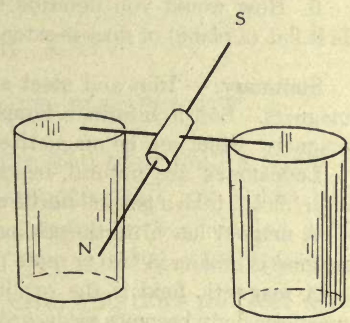


FIG. 133. — The dipping needle points downward toward the earth's magnetic pole. The nearer it is to the pole, the more nearly vertical its position is. How does it behave when brought over a large magnet? Try it.

Does it seem strange that our earth is a great magnet? Do you suppose it is the magnetic force of the earth that has magnetized the natural "lodestones"?

221. Exercises. — 1. Pass a magnet through some dry sand; do you get any evidence that the sand contains iron particles?

2. In what ways could a ship which was out of sight of land be steered in the right direction on a bright day? On a bright night? On a cloudy night?

3. How does a compass needle behave if brought near a large body of iron, such as a stove? How would a dipping needle behave if brought over such a body of iron?

4. If you hold the north-seeking pole of a bar magnet near the north-seeking pole of a compass, is that end of the compass needle

attracted, or repelled? Tell, then, how you can find out, without suspending the bar magnet, which of its ends is north-seeking. Try it.

5. Can a compass be depended upon absolutely to give the correct directions?

6. How would you describe the magnetic field about a magnet? Is it flat (a plane) or does it extend in all directions?

Summary. — **Iron** and **steel** are **magnetic**: they are attracted by magnets. Soft iron forms a **temporary** magnet, while it is *near* another magnet. **Steel** can be magnetized **permanently.**

Lodestones are natural magnets. All magnets, whether natural or artificial, take a general **north-and-south** position when free to move.

A **magnet** has a north-seeking and a south-seeking **pole.** When a magnet is broken in two or more pieces, **each piece** is a magnet.

A **magnetic field** is the region surrounding a magnet, in which a magnetic body becomes *magnetized.*

The **earth** is a great magnet, with a north-magnetic and a south-magnetic pole. **Compass** needles point toward these poles, except as they are interfered with by other magnetic fields.

A **dipping needle** is a magnet that can move in a **vertical** direction.

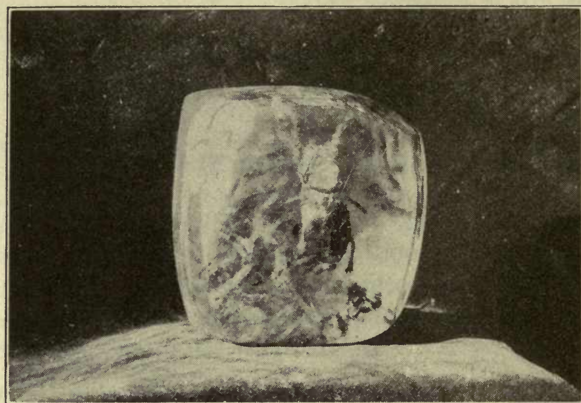
CHAPTER XXIV

FIRST THINGS ABOUT ELECTRICITY

222. Electric Magic. — Have you ever held a sheet of writing paper up against a smooth wall, on some cold winter's night, and rubbed the paper with a woolen cloth or with a silk handkerchief? Try it. You will find that the paper is attracted by the wall, and does not fall when you let go of it. If you pull the paper away, it will be drawn back. Why is the paper attracted after being rubbed?

Comb your hair rapidly with a rubber comb, or rub the comb briskly with a woolen cloth or with fur; then bring the comb near bits of paper, cloth, or cork. What happens? Can you tell why?

Have you ever seen **amber** beads? Amber was once a gum that was produced by trees, but ages ago it hardened and so was preserved for us. It is a **fossil** gum (see § 147). Sometimes the amber contains the remains of insects that were caught in the gum while it was yet soft and sticky (Fig. 134). The ancient Greeks were observing enough to know that after amber had been rubbed with a cloth it would attract small bodies, such as bits of wood, paper, and cloth. They called amber " electron " (ē-lĕk′trŏn); so this power of rubbed amber to attract bodies came to be called **electricity**. We say the amber becomes "charged with," that is, *loaded with*, electricity.



(Courtesy of the Field Museum of Natural History.)

FIG. 134. — Amber is a fossil gum that is easily charged with electricity, when rubbed. For what is it used?

If a **glass rod** is rubbed with **silk** cloth, both the rod and the silk will attract light bodies, such as paper, cork, and cloth (Fig. 135). This experiment succeeds best in dry, cold weather, as during a "cold

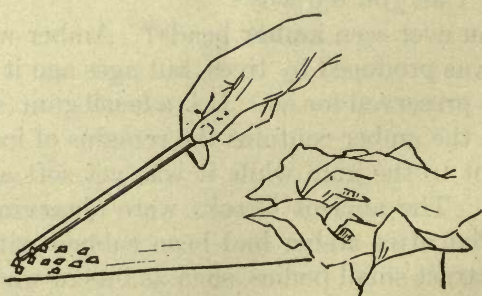


FIG. 135. — A glass rod or slender bottle will be charged with electricity when rubbed, and will pick up objects of paper, cloth, and the like.

wave." Instead of the rod of glass you can use a long, slender, glass bottle.

You can also use a **pane** of glass instead of the glass rod. Raise the pane of glass up from the table by placing it over two books, as in Fig. 136, and rub the glass with a silk cloth. Bits of cork or paper placed under the glass are set in motion by the charged glass.

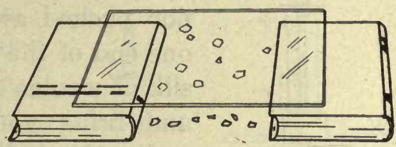


FIG. 136. — When the upper surface of the pane of glass is rubbed, it becomes charged, and objects under it are affected by the charge.

Rub a stick of **sealing wax**, or a rubber comb, with some flannel, wool, or fur. Electricity will be produced. It has been found that any two unlike substances, when rubbed together, become charged; part of the **muscular energy** you use up in the rubbing is changed into electricity.

You can charge your own body by dragging your feet across a heavy carpet. Try it, and then bring a finger tip near a gas or electric light fixture. What happens?

223. Are All Electric Charges Alike? — Have you asked yourself whether the electric charges produced on glass, rubber, silk, paper, sealing wax, wool, and amber are all **alike**? In the case of magnets we learned that one pole is north-seeking and the other is south-seeking, and that either pole will attract bodies of iron or steel. We also learned that while the north pole of one magnet will attract the south pole of another magnet, the north poles of two magnets will **repel** each other, and the south poles of two magnets will also repel each other. Can we find out whether there is some such difference between electric charges as between the two poles of a magnet? How shall we go about finding the answer?

In Fig. 137 we have a picture of a glass rod that is supported in a paper **stirrup** hung by a double silk thread.

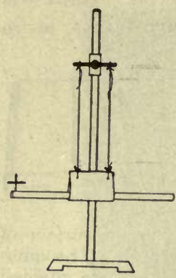


FIG. 137. — If you bring your finger, or a ruler, or any uncharged object, near the charged suspended rod, the rod will turn toward the object.

If you bring your finger near the rod, the rod is neither drawn toward your finger nor pushed away from it. Now charge one end of the glass rod by rubbing it with silk or woolen cloth, hang it in the stirrup, and bring your finger near the charged end. You will find that the rod now turns **toward** your finger.

If you use a charged stick of sealing wax or rubber instead of the glass, it will behave in the same way. It seems that a **charged** body is attracted by one that is not charged. When you bring a compass near an iron stove, does not the stove attract one pole as well as the other? Try it.

Observe the **rubbed** rods of glass and sealing wax carefully, as they swing in their stirrups; do they seem to choose a north and south position as a magnet does?

NOTE. — When you wish to get a charged body into an uncharged condition, that is, to **discharge** it, you need only pass it through your hand.

Prepare **two stirrups** and threads as in Fig. 138, hang a rubbed glass rod in each stirrup, and bring the rubbed ends near each other. Do they attract, or repel, each other? Try the same thing with two rubbed rods of sealing wax or rubber. What happens? Do the experiment with one rubbed glass rod and one rubbed rod of sealing wax or rubber. Do these two attract, or repel, each other?

Do you think that the charge produced on the glass is the same as that on the sealing wax or rubber? We call the charge formed on the glass a **positive** charge, and mark it with a **plus** sign (+); the charge formed on sealing wax or rubber we call **negative**, and mark it with a **minus** sign (−). When we test the charges produced on other bodies that are rubbed together, we find that they are like either the **one** or the **other** of these two.

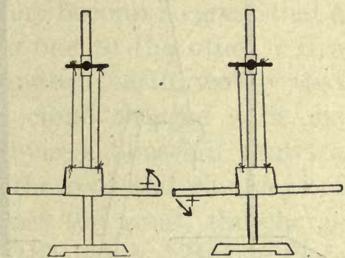


FIG. 138. — When the charged ends of the two glass rods, having the same kind of electric charge, are brought near each other, they repel each other.

Is this statement true: "Two bodies having **unlike** electric charges **attract** each other; two with **like** charges **repel** each other"?

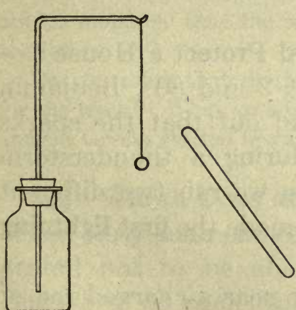


FIG. 139. — An electric pendulum, consisting of a ball of cork, pith, or dry paper, suspended by a dry silk thread.

In Fig. 139 we have a picture of a stand that may be used to hold a tiny ball of some such material as **cork, pith** from a dry stem of burdock or cornstalk, or simply wadded, dry **paper**. The ball is tied to the stand by means of a dry silk thread. We call such an apparatus an "electric pendulum"; why? You can work just as well with a gas — or electric — light fixture for the support.

Rub a glass rod (or slender bottle) with a pad made of silk, and bring the rubbed part of the rod near the hanging ball. What happens? At first the ball is **attracted** by the rod; then it flies off and is repelled, as shown in the left portion of Fig. 140. The right-hand portion of the figure shows a stick of sealing wax that has been rubbed with wool. At first the ball was attracted; then it was repelled, just as in the case of the glass rod.

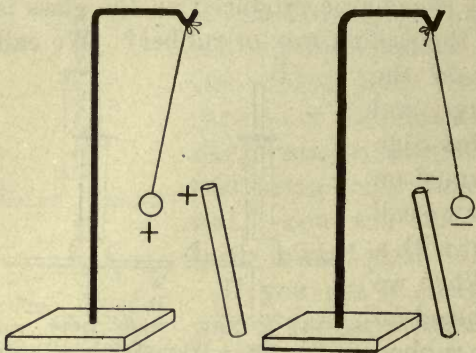


FIG. 140. — Each pith ball is first attracted by the rod, and then repelled, as it becomes charged by the rod. Like charges on objects that are free to move cause them to repel each other.

Hang two pith balls near each other, as in Fig. 140. Be sure to discharge each by holding it for an instant in your hand, and then charge each ball from the rubbed glass rod. Do the balls now attract, or repel, each other? Why?

224. How Does a Lightning Rod Protect a House? — As we have learned before (see §§ 2 and 80), Benjamin Franklin was the first man to find out that the sparks obtained from the atmosphere during a thunderstorm are exactly like those we get when we rub two different materials together. Franklin also made the first **lightning rods** to protect houses.

In a dark room hold your finger near a charged rod of glass or sealing wax, or a charged rubber comb, and see if sparks do not pass between your finger and the rod. Men have studied the passage of sparks from objects of different shapes and have found that the charge of electricity flies off from the **points** of an object far more easily than from parts which are blunt or rounded.

When two charged **clouds** come near each other, the *strain* in the air between them may become so great that a powerful spark passes from the one to the other. If a charge passes between a cloud and the earth, we say that the lightning "strikes." As a cloud charged with **one** kind of electric charge passes over a house, it draws a charge of the **opposite** kind to the roof and chimneys of the house. If the strain becomes too great, the charge passes between the cloud and the house. But if there are metal rods on the housetop, the electricity **streams off** from the rods to the cloud above, instead of leaving all at once in a large spark. As a result the house is not struck.

All the metal points on a housetop should be connected to the rod that goes to the ground, and this rod should go, not merely to the surface of the ground, but down to a depth at which the ground is always **moist**, so that the charge can pass freely from the ground to the rod.

Do you think that the leaves of trees might act as lightning rods for the trees? What an amount of thinking and experimenting those ancient Greeks started when they rubbed amber with cloth!

225. Where Does an Electric Current Come From? — When early man came into his dark den or house, he expected not to be able to see until daylight returned. But when we come home in the dark, we press a button and fill our house with a flood of light.

What do we pass into an electric lamp to get **light** from it? "Electricity," you say. Yet it is not the form of electricity produced by rubbing or friction that we use, but an **electric current.** This current does not just "happen" to be in the house, but comes to us from some distance, perhaps from many miles away. If you trace the wires far enough, you will come to a **power house**

FIG. 141. — Westinghouse electric generators in the 74th Street Station of the Interborough Rapid Transit Co., New York City.

(Fig. 141), in which powerful engines run by steam, or by rushing water, or by gasoline, are turning a machine we call a **dynamo** (dī′nă-mō). In the dynamo the rapid motion of the engine is changed into an electric current. With this current, as you know, we not only light our houses and streets, but we run electric washing machines, sewing machines, trolley cars, motor cars, vacuum cleaners, and do a multitude of other things besides.

How did men first learn about electric currents?

While men have known about magnets for centuries, and have also known about the effect of rubbing amber, glass, and other materials with cloth or fur, they did not learn about electric currents at all until a little over one hundred years ago. It was not until 1786 that Galvani, an Italian, accidentally discovered some effects of electric currents; and not until 1800 that Volta, also an Italian, invented a simple electric cell for producing currents of electricity. The words "galvanic" and "galvanize" come from Galvani's name; the words "voltaic" and "volt" come from Volta. Have you ever heard these words used?

You can make a **simple cell**, like the one made by Volta (see Fig. 142).

Cut two strips of sheet metal, one of **zinc** and one of **copper**, each about one inch wide and 4 inches long. With a sharp nail make a hole near the end of each strip, and put through the hole one end of a piece of bare copper wire about 6 inches long. Bend the part of the wire that is through the hole, and with a hammer flatten the wire tightly against the strip. Then tack the strips of zinc and copper on opposite sides of the block, as shown in the figure. The block should be long enough to reach across the top of the glass, so that the metal strips can hang in the glass.

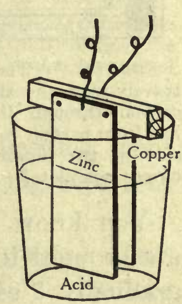


FIG. 142. — The simple voltaic cell consists of two metals, a solution containing an acid, and wires by which the metals may be joined.

Now lay the metal strips aside while you put into the glass some **dilute sulphuric acid**. If you have the **concentrated** acid, slowly pour about two tablespoons of it into a glass which is about three fourths full of water. When we dilute sulphuric acid, we always pour the concentrated **acid into the water, never** the water into the acid. This is to avoid the danger of spattering the acid into our eyes.

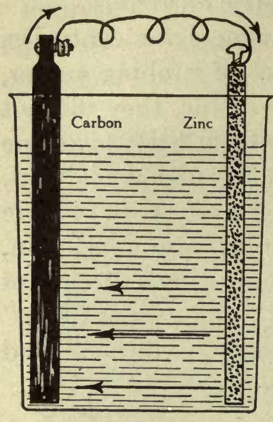


FIG. 143. — The current travels from the zinc to the carbon **through** the liquid, but from carbon to zinc outside of the liquid. Is the circuit complete?

Finally put the block across the top of the glass, so that the strips of metal hang in the dilute acid. Join the two wires, and look carefully for any change. This arrangement of two strips of metal, the wires, and the dilute acid make up a **simple cell.** Fig. 143 shows a **carbon cell,** with carbon in place of copper. After the simple cell has been used for a minute or two, its current may become weak. If you need the cell for a longer time, remove the metal sheets and wash them with water; then put them back into the dilute acid.

If your simple cell is too weak to give good results, put into the dilute sulphuric acid about two teaspoonfuls of a saturated solution of **potassium dichromate**, and perform the experiments again.

You know that when zinc and dilute sulphuric acid are brought together, **hydrogen** is formed, and the zinc is gradually " eaten up " by the acid. See § 114. Some **heat** is also produced in the action. In the simple cell the zinc is used up as before, and will disappear in time. But while the action is going on we get a **current of electricity.** Fig. 143 shows the **direction** of the current in the cell; it passes through the solution from the zinc to the copper, or carbon, plate; then through the connecting wire from the copper (or carbon) back to the zinc.

Do you wish to " **taste** " the current? You can do so by separating the two connecting wires, and holding the ends to your tongue. There is a sharp, prickly sensation as the current passes through your tongue.

226. Can We Make a Magnet from a Current? — Do you suppose that an electric current has any effect upon a **magnet?** Fasten the two wires of your simple cell together, and hold them so that the current passes **parallel** with a compass needle (see Fig. 144). Does the needle remain in a north-south position?

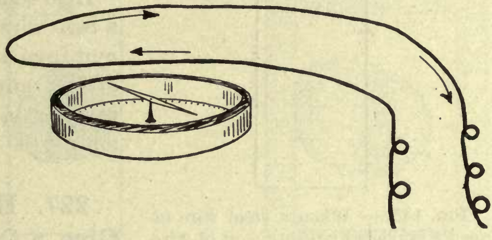


FIG. 144. — When wire carrying a current is brought near a compass or a suspended magnet the needle is turned from its *N–S* position because of the magnetic field around the wire.

Hold the wire in several positions over the needle; what happens? Does this show that a wire carrying a current is surrounded by a magnetic field?

What do you think would happen if you passed a current **around** an unmagnetized knitting needle? Do you think it would become **magnetized**, as it was when it was brought near another magnet? Try to answer your question in some such way as this (see Fig. 145):

Take a piece of covered (**insulated**) copper wire about a yard long, and remove about half an inch of the covering at each end. Wind as many turns as possible of the wire about a piece of glass tubing, or a pencil, about 6 inches long. When you remove the tubing or pencil, you will have a coil of wire. Inside the coil place an unmagnetized knitting needle, and connect the **bare** ends of the wire coil with the ends of the wires of your simple cell. After a few minutes take the needle out, and **test** it to find out if it is a magnet. If your current is not strong enough, use a **dry cell,** such as is used in ringing a doorbell.

Hold some fine **iron filings** against a bare wire that is carrying a current from a dry cell; does the wire attract any of them? Is a wire carrying a current a magnet, or not?

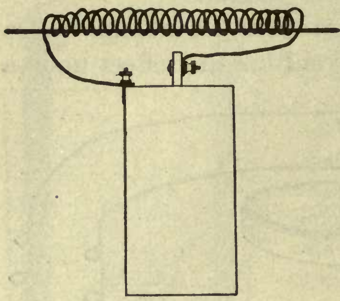


FIG. 145. — When a steel wire or needle is placed within a coil of wire carrying a current, the steel is magnetized.

227. How Does a Dry Cell Give a Current? — Examine a pocket **flashlight** and see what produces the current. You will find it is a small cell in a zinc case. It is a **dry cell**, like those used to ring doorbells.

You can see that the simple cell made by Volta would be very inconvenient to carry about; it also wears out very soon. A cell which contains a substance called **sal ammoniac** (săl ă-mōn′ĭ-ăk) is in common use (Fig. 146). The zinc acts with the sal ammoniac, and part of the energy of the action appears as an electric current. In one form of cell the sal ammoniac is **in solution**; another form is the so-called "dry cell." Sal ammoniac is the old name for a white solid which the chemist calls **ammonium chloride.** If we put into the sal ammoniac solution a stick of **zinc**, and a plate made of a mixture of **carbon** and manganese dioxide, and connect the two plates with **wire,** we get a current. Set up such a cell, if possible, and test its current. The stick of zinc wears out after a while, and a new one must be put into its place. This cell is used in ringing **telephones** and doorbells, as it gives a strong current for a short time. Is it a good plan to push the button of a doorbell for a long time?

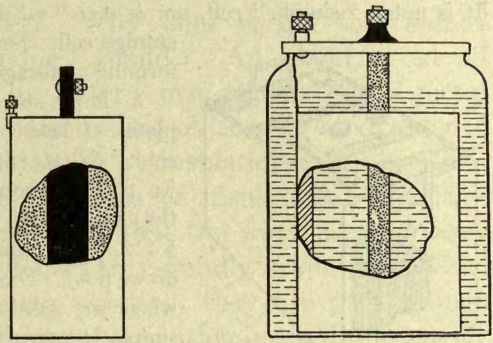


FIG. 146. — The larger cell has a solution of sal ammoniac, a stick of zinc, and a hollow cylinder of carbon. The smaller cell is a "dry" cell.

The **liquid** form of sal ammoniac cell is kept in a glass jar, but a dry cell has a jar of **zinc**, the inside of which acts as the zinc plate. A stick of carbon is put in the middle of the jar, and the space between the carbon and zinc is filled with a paste made of sal ammoniac, manganese dioxide, charcoal, and water (Fig. 146). The top of this cell is tightly closed, so that the water cannot evaporate. Is it really a " dry " cell?

What is a Battery? — It is **several cells** connected together. Examine a battery of two or more cells. You will see that there are two ways in which you can connect them. One way is to join all the zinc plates to one wire and all the carbon (or copper) plates to another wire. The cells are then connected " in parallel." By connecting these wires together we **make, or close, the circuit.** Another way is to connect the zinc of one cell with the carbon of the next cell. The cells are then said to be connected " in series."

What is a Storage Battery? — What kind of cell is used to propel an electric automobile, or to produce the spark that is needed to explode the mixture of gasoline vapor and air in an ordinary automobile? It is not a "simple" cell, nor is it a "sal ammoniac" cell; it is a **storage** cell. Several are generally used, forming a **storage battery** (Fig. 147).

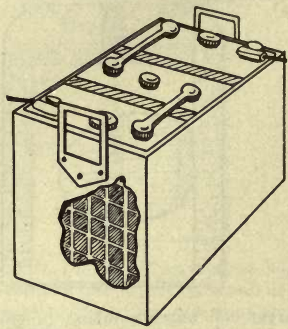


Fig. 147. — A storage cell is charged by a current. When the charging current is removed, the storage cell may itself be used to give a current.

A simple storage cell consists of two plates of lead hung in dilute sulphuric acid. What change takes place when we pass a current of sufficient strength through dilute sulphuric acid? Read § 112. We obtain hydrogen and oxygen, do we not? The same change takes place when we pass a current through the simple storage cell, or the storage battery; but only the hydrogen is set free, while the oxygen **combines with the lead** to form a dark substance called **lead peroxide** (see § 32). This is what happens when we "charge" the battery. After the battery has been charged, we can use it as a **source of electricity**, as we can any other form of battery. We have only to **complete the circuit**. The lead peroxide then loses some of its oxygen. As the change takes place, **energy** is set free, and appears as an electric current. So we do not really store the electricity at all, but we change it to chemical energy and store that. Then, when we wish to use electricity, we change the stored chemical energy back into electricity (see §§ 104 and 237).

228. Why are Electric Wires Covered? — Do you suppose that if we use a cord of cotton, linen, or silk, instead of a copper wire, the current will pass through the cord? No, it will not; neither will a piece of wood, of rubber, or of glass carry the current. We may thus divide substances into two classes. Those which conduct the current easily are called **conductors**; those which will not carry it, or will carry it with great difficulty, are called **nonconductors**. A nonconductor is also called an **insulator** (ĭn′sū-lā′tẽr). Why does it get this name? *Insula* is the Latin for "island." An island is cut off from the mainland by water; in a similar way a metal wire is cut off from surrounding objects by a covering of nonconducting materials, or by **insulation**. Rubber, silk, linen, and wax are examples of insulators. The laws compel builders to see to it that the wires used to carry the current into our houses are carefully insulated. When the wires pass through a board, they are put through **porcelain** tubes, or thick tubes of other insulating material. In most modern buildings the wires are not only insulated, but they are carried in **metal** tubes, or **conduits** (cŏn′dĭts), throughout the building. Such tubes make the wiring of a house safe; because they prevent the insulation from being worn off by handling, or eaten by mice. Why is it dangerous to leave a "live wire" in contact with wood? How is it dangerous to life? Read §§ 234 and 258.

229. Exercises. — 1. Did you ever experience a shock when stroking a cat's fur in cold weather? What caused it?

2. When you brush your hair vigorously in cold weather, it often "fluffs out," showing that the hairs are repelling one another. Why?

3. Is it safe to stand under a tree in a thunderstorm? Why?

4. Can you think of some way of finding out whether, or not, a charge is produced on the silk pad with which we rub a glass rod to electrify it?

5. Hold a smooth wooden ruler in your hand, using a woolen mitten, and rub it with another mitten. Can you prove that a charge is formed on the ruler?

6. Get some pith from the thick part of the stem of a dry burdock or cornstalk, and make an electric pendulum. Why is the pith ball first attracted by a rubbed glass rod, and then repelled?

7. What kind of battery is there in a gasoline automobile? What is it used for? What charged it in the first place? What keeps it charged?

8. Examine a " dry cell " that has been used up, take it apart, and tell how it is made.

9. How are the cells that ring your doorbell connected, in series, or in parallel? See § 227.

Summary. — The name **electricity** comes from **electron**, meaning "amber."

Electric charges can be developed upon dry wood, glass, rubber, sealing wax, and even upon metals, by rubbing them with silk, wool, or fur; but the charges will not remain unless the bodies rubbed together are all **insulated**, or electrically separated, **from the earth.**

Electric charges are of **two kinds**: positive, and negative.

A **charged** body attracts one that is **not charged**, also one charged with electricity of the **opposite sign**.

When a charged body gives enough of its own charge to an uncharged body, the two **repel** one another.

Charges of the same kind **repel** each other.

You can **discharge** a body having a small charge by holding it in your **hand.**

Lightning is an electric charge collected on a cloud or on the earth under the cloud. A **metal rod** carries off the charge from a house in a fine **stream**, and protects the house from a violent **discharge**.

Electric currents are usually produced by **cells** or by **dynamos**. A cell consists of two **different** materials, such as zinc and copper, and a **solution** that acts upon one more than upon the other.

The **region** near a wire carrying a current is a **magnetic field.**

A **dry cell** has the needed materials in a closed zinc can, to prevent spilling and evaporation.

A **battery** is a group of connected cells.

A **storage battery** consists of cells into which an electric current can be passed to produce a **chemical change**, and from which the current can be obtained when the change is allowed to **undo** itself.

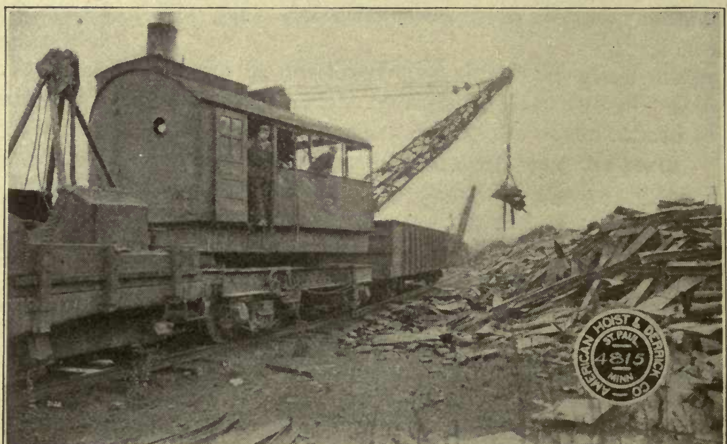
Electric wires are covered to **insulate** them, or separate them from other conductors. Insulators are nonconductors.

In our **houses** electric wires should not only be insulated, but kept in metal **conduits.**

CHAPTER XXV

HOW MAN USES ELECTRICITY

230. What is an Electromagnet? — Have you ever seen men handle a great heap or carload of **scrap iron?** Such iron is valuable because it can be used in making **steel**;



(*Courtesy of the American Hoist & Derrick Co.*)

FIG. 148. — The magnetic crane has a huge, powerful electromagnet that picks up scrap iron, pig iron, and other iron and steel objects, and drops them wherever they are wanted.

but it is made up of pieces of all shapes and sizes, and is very hard to handle. Do you know the modern way of loading or unloading scrap iron? Instead of picking it up, piece by piece, men use a great **steel arm**, called a

crane, at the end of which there is a powerful **magnet**. The pieces of iron, big and little, are attracted by the magnet and lifted out of the heap. All sorts of iron and steel objects, if not too large, can be handled in the same way (Fig. 148).

You can see readily that we might get a horseshoe or bar magnet large enough to pick up the iron or steel object; but how can we make the magnet **drop** its load at the right time and place? We must have some way of causing the magnet to lose its magnetism **instantly**. We can do this if we use an **electromagnet** (Fig. 149).

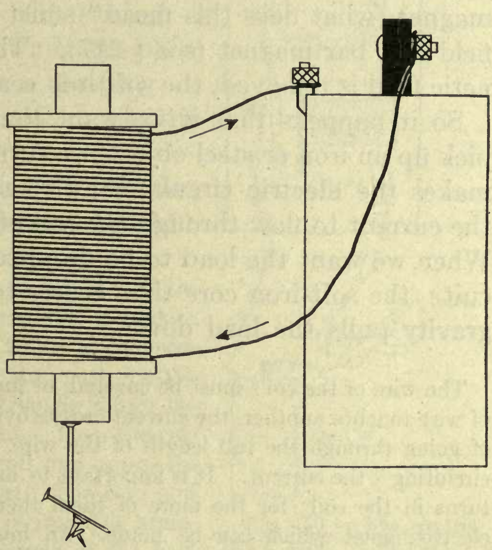


FIG. 149. — An electromagnet made of a bar of soft iron surrounded by a coil of insulated wire carrying a current.

You will remember that when a **metal wire** is carrying a current of electricity, and it is held over a compass, it causes the compass needle to **change** its position. If the wire is carrying a strong enough current, it will pick up iron or steel filings just like a magnet. The reason for this behavior is that a wire carrying a current is surrounded by a **magnetic field.** What happened when you put an unmagnetized needle inside a coil of wire and passed a current through the wire? The needle became **magnetized.** What do you think would happen if you were to put a piece of soft **iron,** such as a thick wire, or an iron bolt, inside a coil of wire through which a current is passing? Try it. The soft iron becomes a **temporary magnet** (what does this mean?), just as if it were in the field of a bar magnet (see § 217). The instant the magnetic field is removed, the soft iron ceases to be a magnet.

So it happens that if we want the magnetic crane to pick up an iron or steel object, we turn on the switch that makes the **electric circuit** (sŭr′kĭt) complete and allows the current to flow through the coil of the electromagnet. When we want the load to be dropped, we **break** the circuit; the soft-iron core then ceases to be a magnet, and **gravity** pulls the load down.

The wire of the coils must be covered, or **insulated**; for if one turn of wire touches another, the current crosses over by a short cut instead of going through the full length of the wire. This is called "short circuiting" the current. It is important to have a **large number** of turns in the coil; for the more of them there are, the stronger the electromagnet which can be made. An interesting fact has been found to be true of the soft-iron core; a **bundle** of small wires makes a much stronger magnet than a single piece of iron having the size of the bundle.

Could we use an electromagnet to **sweep up** the iron chips and turnings of a factory?

231. How Do We Ring an Electric Bell? — Have you ever seen one of the old-fashioned house bells which you rang by pulling a **knob**? There was a wire attached to the knob, and there was a spring attached to the other end of the wire. When you pulled the knob, you set the spring in motion, and the moving spring jingled the bell. The **modern** doorbell can be put in almost any out-of-the-way place, and its wire can go around corners and through walls. One thing it must have, however, which the older bell did not need: a **battery**, or some other source of an electric current.

Examine an electric bell, and compare it with the diagram in Fig. 150.

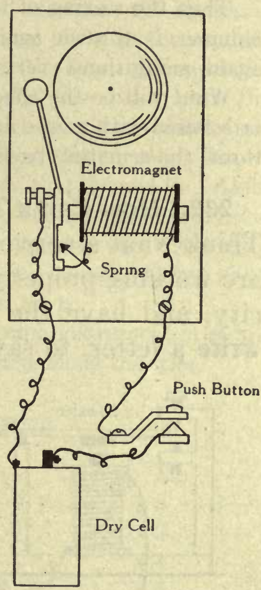


Fig. 150. — The electric bell is rung by an electromagnet which draws the hammer to the bell when the circuit is complete. The spring throws the hammer back as soon as the circuit is broken.

Trace the **circuit** from the battery to the **push button**. Here the circuit is broken, and no current can pass to the electromagnet. But if we **press** the push button against the little metal triangle shown below it, we **close** the circuit. Then the current passes through the coil, and causes the core to become a **magnet**. The core now draws to itself the piece of iron (the **armature**) attached to the hammer of the bell. The hammer is drawn in that way also, and strikes the bell. As a result we hear a sound.

At this point another interesting thing happens. When the armature is drawn forward, what becomes of the circuit? You will see that it must be broken at the place at which the armature touched the metal **stop**. If the circuit is broken, what must happen to the electromagnet?

Of course it will lose its power to attract the armature. The metal below the armature is a **spring**; as soon as the magnet ceases to pull the armature, the spring throws the armature back against the stop. If you are still pressing the push button, the circuit will be closed once more, and the whole performance will be repeated.

Thus the ringing of the doorbell is a **series** of rapid sounds: the hammer is thrown against the bell, withdrawn, and thrown back again, many times every second of time.

What will be the effect if the armature or the core becomes rusty or covered with grease and dust? If the spring becomes too weak to throw the armature back against its stop?

232. How Can a Telegraph Wire Carry a Message? — Think what a convenience the telegraph is. If the wires are working properly, we can get a message to a distant city, and have the answer back again before we could **write** a letter, to say nothing of getting it delivered.

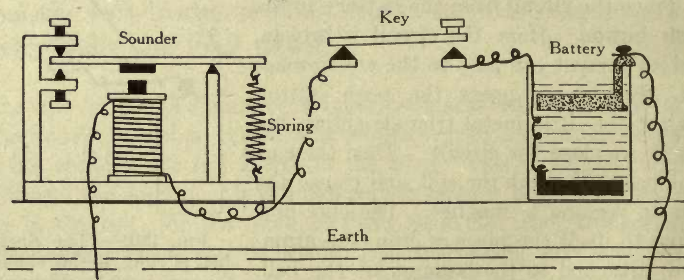


Fig. 151. — The electric telegraph is an electromagnet which pulls down the sounder when the key is pressed. When the key is released, the spring pulls the sounder up.

If possible, examine a **key** and **sounder** instrument, and compare it with the diagram of Fig. 151, so as to learn how the telegraph works. In the doorbell we have a wire connection both ways, but in the telegraph the "return circuit" is through the **earth** itself. What effect does this have upon the cost of the wire?

When the operator **presses** upon the telegraph key, he **closes** an electric circuit. The electromagnet under the sounder then pulls down the iron **armature** of the sounder, and stretches the **spring** at the end of the sounder. We then hear a sharp **click**, as the sounder strikes its stop. When the operator releases the key, he breaks the circuit, so that the magnet has no power, and the spring pulls the sounder up against the upper stop. If there is a very **short** time between the two clicks, the operator receiving the message knows that a **dot** is meant; if a longer time, he knows that it must be a **dash**. The telegraphic alphabet, or **code**, is made up of short and long clicks, which stand for dots and dashes. Thus by pressing and releasing a key, an operator in a far-away city can cause a sounder to be raised and lowered in the telegraph office of our own town.

Have you ever heard the click of the telegraph instrument in a railway station, telling you that a current has come along the wire?

THE MORSE ALPHABET

a - —	k — - —	u - - —	1 - — — -
b — - - -	l ——	v - - - —	2 - - — - -
c - - -	m — —	w - — —	3 - - - — -
d — - -	n — -	x - — - -	4 - - - - —
e -	o - -	y - - - -	5 — — —
f - — -	p - - - - -	z - - - -	6 - - - - - -
g — — -	q - - — -	& - - - -	7 — — - -
h - - - -	r - - -	, - — - —	8 — - - - -
i - -	s - - -	? — - - — -	9 — - - —
j — - — -	t —	. - - — — - -	0 ———

Who was Morse? Was it easy for him to get people to use his invention? When did he succeed? What was the first message sent?

233. Can a Current Silverplate a Spoon? — Why do we not use knives, forks, and spoons made of copper, iron, or lead, instead of silver? Of course, you know that some of the reasons are that these other metals rust, or have a bad taste, or form poisonous substances with our foods. But most of us cannot afford to have all of such utensils of **solid** silver; we use a **plating**, or covering of silver instead. We can also plate objects with copper, nickel, or other metals.

Experiment. — Dip a knife blade or a wire nail into a solution of **blue vitriol** (copper sulphate); then take it out and see the bright deposit of **copper**. This is easily rubbed off. To make a deposit, or plating, which will adhere firmly, we must **electroplate** it.

You remember the operation we called the **electrolysis** of water (see § 112). We passed a current through water to which we had added a little sulphuric acid. **Hydrogen** collected at one wire, or pole, and **oxygen** at the other. Suppose we pass a current through a copper sulphate solution, what will happen? See Fig. 152. **Copper** will be formed at one pole. Suppose we hang an **iron** dish at that pole, and continue passing the current. The copper sulphate solution would soon be used up, because all of its copper would be deposited on the dish. But if we

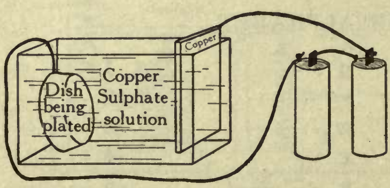


FIG. 152. — To plate an iron dish with copper, we hang it at the pole by which the current leaves the copper sulphate solution. We attach a copper plate to the pole by which the current enters the solution.

hang a sheet of copper at the **opposite** pole, then the copper sulphate will be re-formed as fast as it is used up. So the copper sheet will waste away, but an equal amount of copper will be deposited on the iron dish. We have *electroplated* the dish.

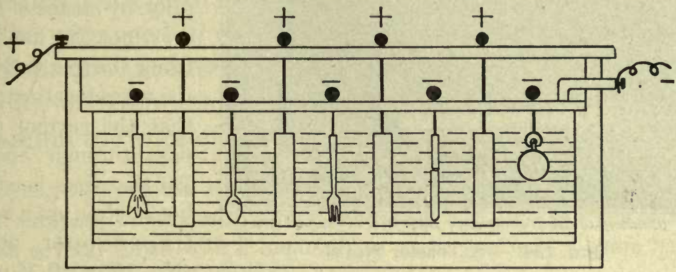


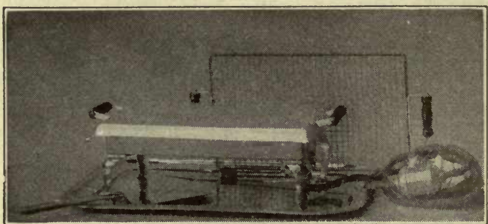
FIG. 153. — Objects that are to be silverplated are hung upon one pole in a solution of a silver salt, while a piece of silver is hung upon the other pole.

Silverplating (Fig. 153) of spoons and other objects is carried on in the same way. The solution contains a silver compound, instead of a copper one. A bar of silver hung at one pole wastes away, but an equal amount of silver is deposited upon the object at the opposite pole.

Name some objects that are silverplated. Some that are copperplated. Some that are nickelplated.

234. How Does Electricity Produce Heat? — Do you know how **trolley cars** are heated? If you examine one, you will find the heater at the side of the car, or under the seat. Have you ever used an electric **flatiron**, or an electric toaster (Fig. 154), or an electric stove? In all of these you will find that the heating device is a long piece of **metal** wound in coils, or bent into many turns. When you turn the current on, the metal becomes hot and serves to heat the car, flatiron, toaster, or stove. How can this be done?

Experiment. — To the two **binding posts** of a good dry cell attach two pieces of ordinary copper wire (No. 16 or 18) about 2 inches long (see Fig. 155). Carefully, by means of *forceps* (**not** the hands), bring the free ends of the wires together; so that the current can pass through them. Do the wires become hot? Now use a very fine copper wire (No. 36 or 40, if possible); does it become hot? Finally, in place of the copper wire use a fine iron wire (No. 36 or 40, if possible). Be sure to use the forceps. What is the result? If one dry cell does not give good results, use two or three connected *in series*, that is, with the zinc binding post of one cell connected with the carbon binding post of the next one.



(Courtesy of the Westinghouse Electric & Manufacturing Co.)

FIG. 154. — A Toaster Stove.

We have already learned (see § 228) that some substances allow the current to pass more readily than others. Both copper and iron are **conductors.** There is, however, no conductor that is perfect; that is, in passing through any conductor the current meets with **resistance.** Some of the energy of the current is lost. What becomes

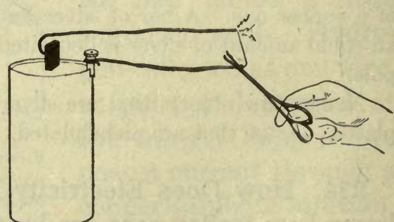


FIG. 155. — The current meets with so much resistance in a fine copper or iron wire that the wire becomes very hot.

of it? It is changed into another form of energy — heat. So by selecting some material which has the right resistance, we can use the current to produce heat. The iron wire of a certain diameter has more resistance than a copper wire of the same diameter; and the small copper wire has more resistance than the large copper wire.

The wire used in electric heating apparatus is generally of **nichrome** (nī'krōm), which is an alloy, or mixture (see § 165), of the metals *nickel* and *chromium* (krōm'ĭ-ŭm). Examine the wire of an electric **toaster** and describe it.

Is any other form of energy readily changed into heat? Think what happens when you rub your hands together, or when you strike a nail several times with a hammer, or when you hold a knife hard against a revolving grindstone.

235. How Does Electricity Produce Light? — In 1879 Thomas Edison gave us the first successful **incandescent bulb** light (what does *incandescent* mean?), and so made it possible for us to use the electric current, instead of some form of fire, for the lighting of our houses. What is needed to change the current into light? You know very well that if the *temperature* of a heated object is sufficiently *high*, the object gives off light as well as heat. What is the difference between a *hot* iron and a *red-hot* iron? If then we use a wire made of a material having a great **resistance** and of sufficiently small diameter, we can turn an electric current into light. We do this every day when we turn on the electric light.

What are the materials of the fine wires we see in electric light bulbs? See Fig. 156. In the **carbon bulb** the wire, or filament, is of charcoal. Why does not the heated charcoal burn up? Read §§ 26 and 37. The answer is that there is no air in the bulb; the air has been pumped out, and the charcoal is really being heated in a **vacuum**. Have you ever heard the loud report made by a bursting bulb? It is due to the rushing of air into the empty space inside the bulb. In more modern forms of electric light bulbs the filament is made of one of the rare elements, **tungsten** (tŭng′stn). Examine one of these bulbs, and see how fine the filament is. Some modern, very bright bulbs are filled with **nitrogen.**

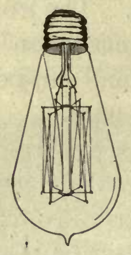


FIG. 156. — The incandescent bulb is a device by which we get light from a wire heated white-hot by an electric current.

Arc Lights. — The large, bright electric lamps which are used for street lighting, and which give a bluish-white light, are **arc** lights. They consist of two carbon rods through which a powerful current is allowed to pass. The rods are a little distance apart: $\frac{1}{4}$ of an inch or so; but the current is conducted by a layer of white-hot carbon vapor that forms between them; this is called the "arc." It has probably the highest temperature man has been able to produce: about 3800° C. The rods have to be renewed from time to time, as they are gradually burned away by being heated to so high a temperature in the air.

236. How Does a Dynamo Produce an Electric Current? — You probably remember that when you studied the geography and early history of our country you learned that many of the rivers which empty into the Atlantic Ocean have falls or rapids at a certain distance from the ocean. Can you find out what is the cause of this? At many of these falls or rapids the settlers built **mills**, and towns grew up around the mills. Can you name any such towns?

Why were the mills built at the waterfalls? It was because the rushing water was a source of **energy**, which could be used to turn the great wheel of the mill and the machinery attached to the wheel. Years afterwards, when **coal** came into general use, men cared less and less for water power, and built their mills and factories at places where coal could be obtained cheaply and in large amounts. Name some such places. But as **electric power** has come into use, **water power** has become of great importance once more; for the energy obtained from a far-away stream can be turned into an electric current, and when it is thus harnessed it can be sent long distances over wires, and made to do a great deal of the world's work. The same power can be obtained at the bottom of a dam, because the water at the bottom is forced out in a powerful stream by the pressure of the water above it (see Fig. 157).

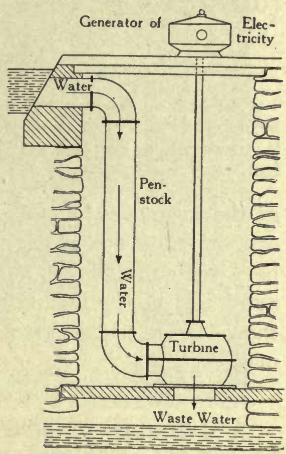


FIG. 157. — The force of falling water, or water pressure, turns the turbine, and this moves the dynamo, or generator, producing a powerful current.

What is the machine that brings to us the energy of **falling water?** Of course there is, first of all, the **water wheel**, which revolves in a circle; then the water wheel turns a **dynamo** (dī′nă-mō), which produces, or **generates**, the current. We cannot learn all about the dynamo now, but we can get an idea of the principle by which it works.

To understand the dynamo we must go back to the study of the **electromagnet** (see § 230). You will remember that in an electromagnet we have a **coil** of insulated wire and a **core** of soft iron inside it. If we pass a current through the coil of wire, the soft iron core becomes a **temporary magnet**, for the reason that the iron is in the magnetic field which surrounds the wire. Suppose we put a magnet into a coil of wire that has no current (see Fig. 158), can we reverse the charge, and actually **produce** a current? This is just what happens, as long as the magnet is **in motion**. Whether we push the magnet into the coil, or pull it out of the coil, as long as we keep it moving, there will be a current in the wire. The current is produced because the magnetic field of the magnet moves past the wires, or, what is the same thing, because the wires move through the magnetic field of the magnet.

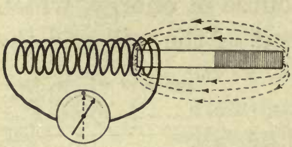
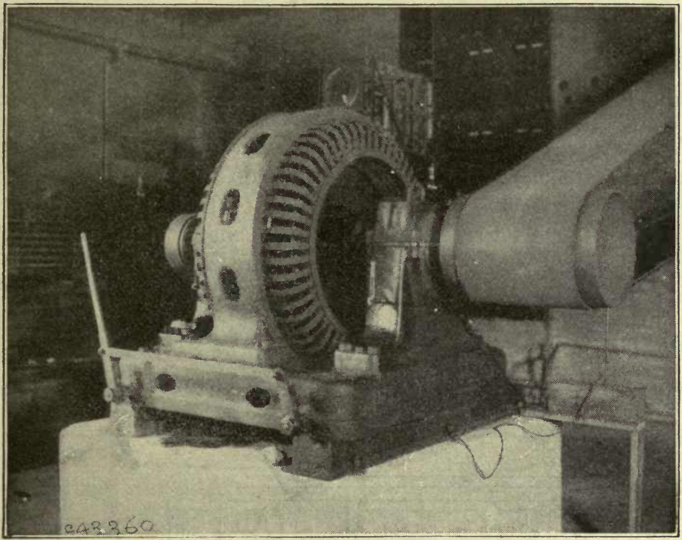


FIG. 158. — When a magnet is moved into, or out of, a coil, it produces a current in the coil.

A **dynamo**, or *generator* (see Fig. 159), is a wonderful machine in which coils of insulated wire are made to revolve rapidly through the fields of powerful electromagnets. The coils are all attached to a single frame called the **armature**. The currents produced in the wire coils of the armature are collected in two large wires which form the **poles** of the dynamo. What is the real use of the water, or steam, or other source of power which runs the dynamo? Is it not to **turn the armature** rapidly in the fields of the electromagnets, so that the energy of motion may be turned into electric energy?

What do you say of the debt we owe to Faraday, who made the first dynamo? What is the importance of the dynamo to modern living? Who was Faraday?



(*Courtesy of the Westinghouse Electric & Manufacturing Co.*)

Fig. 159. — Generator in Municipal Plant, Eau Claire, Wis. The engine is run by steam and in its turn makes the coils of wire revolve in the magnetic fields of powerful electromagnets.

237. How Does Electricity Produce Motion? — How can the water pressing against the dam at Keokuk be made to move street cars in St. Louis? How can the power of falling water at Niagara turn the wheels of a factory in Rochester? The first part of the process is, of course, to change the **water** power into **electricity.** But we do not really want the electricity for itself; we want it for the things we can do with it. Perhaps we want heat and light; perhaps it is motion of a trolley car or a sewing machine or a grindstone. You will see at once that what we need is some way of turning the electric current into motion; that is, it must make some "wheels go 'round," somewhere. The machine for doing this we call an **electric motor.**

The motor is really like a dynamo, but its work is the **reverse** of that of a dynamo. What does a dynamo do? It changes energy of motion into an electric current, does it not? The work of a motor is to **change the electric current back into energy of motion.** In a dynamo we move coils of wire (the armature) rapidly in the fields of great magnets and thus produce currents. In a motor we pass the current from an outside source into the armature and electromagnets, and so cause the armature to **revolve** with great speed. Whatever machine is attached to the armature can thus be made to revolve also.

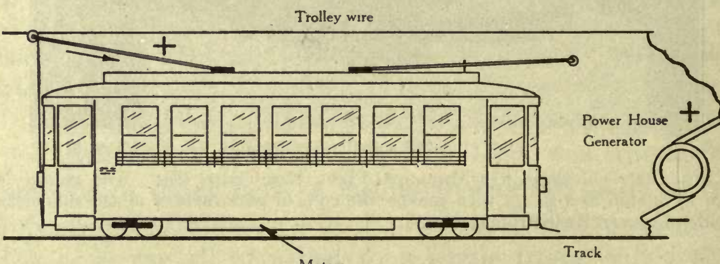


FIG. 160. — The trolley car is driven by motors which get their current from a distant power station, where some generator is changing motion into electricity.

Compare the arrangement shown in Fig. 160 with that of a real trolley car. The motor is on the under side of the car. The current enters through the **trolley** wire and pole. Sometimes a " third rail " carries the current from the power house to the motor of the car. The current returns to the power house through the **car track**, and thus makes the circuit complete.

238. Exercises. — 1. What are several uses of electromagnets? What advantages have they over permanent magnets?

2. Write in the Morse code: "Buy one thousand shares Utah Copper at eighty-one."

3. Why do men use copper for trolley wires instead of iron?

4. What is the use of the telegraph in railroading? In the weather service? In business? In newspaper making?

5. Describe the changes of energy that take place when we use a waterfall on the Feather River to run a sewing machine in San Francisco.

6. Do you suppose there is a magnetic field around a dynamo? Why?

7. Why are glass or porcelain protectors used on telephone poles?

8. Can you suggest how men might distribute the energy of coal without shipping the coal away from the mine?

9. When you disconnect an electric flatiron, you will usually notice that a light which is on the same circuit burns more brightly. Why?

10. Where is the Gatun dam? The Assouan dam? The Keokuk dam? How are they used to generate electric currents?

11. Name all the uses you know of electric motors.

12. How can you light an electric lamp which is on the ceiling, by pushing a button on the wall?

13. Why are we told not to touch a bare electric wire carrying a current, if we are near some metallic fixtures or pipes at the same time?

14. If your electric doorbell will not ring, where will you look for the trouble. Where, if it will not stop ringing?

Summary. — An **electromagnet** is a bar of soft iron placed in the **magnetic field** of a coil carrying a current. When the current is stopped, the iron ceases to be a magnet.

An **electric bell** rings because of the rapid **making** and **breaking** of its circuit by a spring attached to the hammer of the bell.

The **telegraph** is an instrument for making a **sounder** produce **dots and dashes** to correspond with the making and breaking of the circuit by means of the **key**.

In **electroplating** we use a solution containing a compound of the metal to be deposited. The metal wastes away at one pole and is deposited at the other.

When a **current** passes through a **conductor**, it meets with **resistance**. If the resistance is great enough, part of the current is changed into **heat** and **light**.

A **dynamo** is a machine in which energy of **motion** is changed **into** an electric **current**. It consists of **coils** of insulated wire, revolved rapidly in the **fields** of powerful magnets.

A **motor** is a machine for turning a **current into** mechanical **motion**.

CHAPTER XXVI

THE LIGHT OF DAY

239. Why Can We See Objects? — As we look about this universe of ours, what is the most necessary thing in it? Is it not the **light** of the sun? How helpless mankind would be without it; how quickly all life would shrivel and die if it should be removed. No wonder early man worshiped the sun. We do not need to be sun-worshipers to appreciate the power of the sun and its benefits to us. The more we study about light, the more wonderful our great **lamp**, the sun, seems.

Why is it that we see the objects which surround us? Is it not, in the *first* place, because these objects send us **light rays**, and, *second*, because we have an instrument, the **eye**, which is affected by these rays? Think of some bodies besides the sun which produce *within themselves* the light they give off, and so can be called "sources" of light. How about a burning stick, an electric bulb, a firefly, a flash of lightning? Name others. We call such bodies **self-luminous**. On the other hand, many bodies merely **reflect** light. We see them simply because another body shines upon them, and they reflect some of its light to our eyes. Such bodies are **illuminated**, or lighted, by the self-luminous bodies. How do we see a chair in daylight? By reflected sunlight, do we not? What happens when the sun goes down, and the chair has no light to reflect? Why does the chair become visible again when we turn on a light in the room?

The **moon**, like the chair in daylight, reflects light from the sun. Objects which we see by moonlight reflect light that comes from the moon; but the moon, in turn, has reflected the light of the sun. In moonlight, then, we see an object by **twice-reflected** sunlight. How about an object seen by starlight? By the light of the planet Venus? By the light of a "shooting star"?

Can you name a substance through which you may look and see an object on the other side? Glass, you say. How about water and air? Such substances are **transparent** (see § 110). Other substances do not permit light to pass through them, so that an object on the other side of them cannot be seen. Name some of these. They are **opaque** bodies. There is also a third class called **translucent** substances; if objects are seen through them, the objects are *indistinct*. Oiled paper, horn, and thin china are translucent; how about fog? Ground glass is translucent because the light passing through it is scattered, or "diffused," in many directions. How is glass ground? See § 14. Very thin plates of all opaque bodies are probably translucent.

240. How Does Sunlight Travel? — Notice how sunlight comes through a small opening into a dark room (Fig. 161); does it not come in a **straight line**, illuminating only those dust particles which are in that line? When some other force does not change the direction of light, it seems always to travel in *straight lines*, like matter itself (see § 105). But the velocity of light is much greater than the speed of any body of matter we know of. A rate of 186,000 miles a second, which we have learned (see § 91) is that of light, is about 10,000 times that of the earth as it travels around the sun. How slow is the swiftest airplane compared with light, or even with the earth! Scientists have found that light comes to us in the form of **light waves**, which can travel enormous distances through space (see § 88). We call a single line of light a **light ray**; a number of parallel rays makes a **beam**. It is a beam that comes into the room: a "bundle" of light rays.

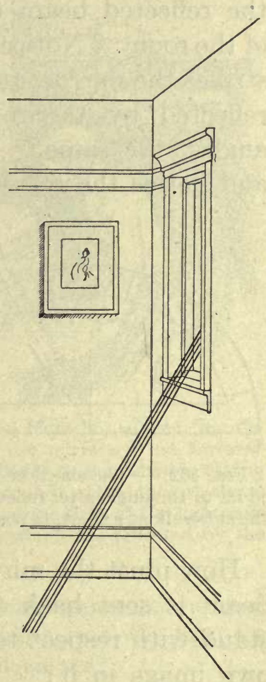


Fig. 161. — The straight beam of sunlight is made visible by the dust particles which reflect its light to our eyes.

When we think of it, we shall see that if it were not for bodies that in some way turn the rays of sunlight from their straight course, we could get sunlight only when we are looking directly toward the sun. Yet we rarely look straight at the sun; its light is too intense and hurts our eyes. The objects around us: trees, grass, water, houses, stones, clouds, dust and water particles in the air, all these reflect sunlight to us, and we do not need to look at the sun itself in order to get its light.

We must remember that sunlight brings us something besides light. Does it not bring us **heat** also (see § 251)? Then, too, sunlight has marvelous **chemical powers**, as when it tans our skin, or takes a photograph, or helps green plants to build up their food out of water and carbon dioxide (see § 43).

241. How Does a Mirror Change Light? — Hold a hand mirror so that it will catch a sunbeam coming into the room, and by changing the position of the mirror direct the reflected beam to the opposite wall, or the ceiling, of the room. Notice the *slant*, or **angle**, at which the beam strikes the mirror, and the slant it makes after it has been reflected by the mirror. Are not the two slants, or angles, the same? Try several positions of the mirror and notice the results.

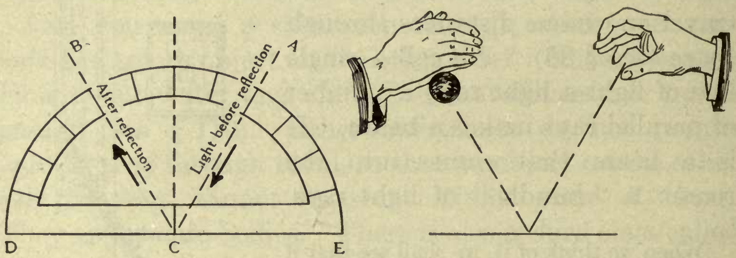


FIG. 162. — The slant, or angle, with which a ray of light strikes a mirror is equal to the angle after reflection by the mirror. If you throw a tennis ball to the sidewalk at a slant, it bounds at the same slant, but in an opposite direction.

How must the mirror be held so that the reflected sunbeam is sent back toward the sun? Where must you stand with respect to a mirror so that you may see your own image in it?

Stand on one side of a mirror, so that you can see the image of another person in the room; ask him if he can also see your image. Find out what the path of the light must have been from you to him and from him to you. Is it true here also that the slant, or angle, with which light **strikes** the mirror equals the slant at which it is **reflected from** the mirror?

If you throw a tennis ball vertically down on a smooth sidewalk, it bounds up again in a vertical line. But if you throw it to the sidewalk at a **slant**, it bounds off at the same slant, but in the **opposite** direction (Fig. 162). Light and sound (see § 267) bound off in the same way.

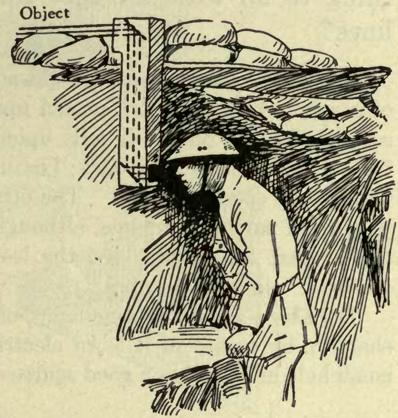


FIG. 163. — How a soldier in the trenches can use mirrors in an inclosed tube (a **periscope**) to see what is taking place above ground. Note the two slanting mirrors and the path of the light rays (dotted lines) which are reflected by the mirrors.

Do you know how a **periscope** works? Study Fig. 163. If rays of light from an ocean liner enter the tube of a submarine's periscope, the light falls upon **mirrors** inside of the tube, and is reflected by them down into the submarine. As a result the "lookout" in the submarine need not put his head above water to see the image of the liner toward which the opening of the periscope is directed. A similar periscope was used in the **trenches** during the World War. Could a man who must see around a railroad curve use a periscope to advantage?

242. Why Does an Object Have a Shadow? — Walk toward a bright light, such as a street lamp, and look behind you at your **shadow**. How does the shadow change as you go toward the lamp? As you pass it? As you walk away from it? Notice the shadows cast by a tree, a house, or any opaque object out of doors. What position has the shadow soon after sunrise, at midday, and just before sunset (see Ex. 14, § 94)? Why do objects have shadows? Does the forming of shadows have anything to do with the fact that light travels in **straight** lines?

In a room otherwise dark, light a candle, and examine the shadow of a spool or small pencil placed upright near the candle. You can see the shadow best if it falls upon white paper. The shadow has **two parts**. One is very dark, because the candle light is cut off by the opaque spool or pencil. The other is not so dark, because it gets light from **part** of the flame, although not from all of it. We call the darker part the **umbra**, and the less dark part the **penumbra** (pĕn-ŭm′bră, " almost an umbra ").

Try also a small kerosene lamp, or an electric light bulb, and study shadows by means of it. An electric bulb, in a covered box with a small hole in it, makes a good source of light from a very small surface.

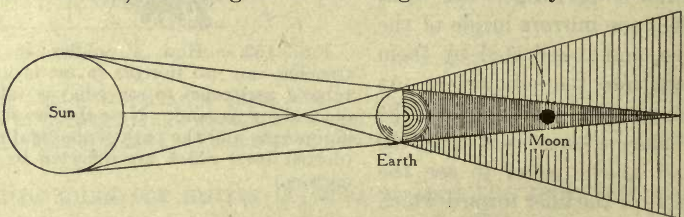


FIG. 164. — Owing to the size of the earth's shadow and its motion, the moon may require two hours to pass through the umbra in an eclipse. To an observer on the moon, the sun's light would be entirely cut off for all this time.

If the source of light is **very small**, that is, almost a **point**, the shadow is very **distinct**, and just as dark in one part as in another; but if the light-giving body has a large surface, so that there are **many** points giving off light, the shadow will have a darker and a lighter portion.

In an **eclipse** of the moon the earth comes between the sun and moon, cutting off sunlight from the moon (see

§ 2 and Fig. 164). What happens when the sun is eclipsed? Study Fig. 165.

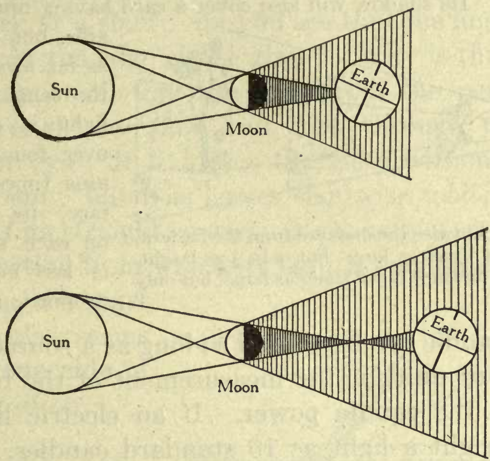


FIG. 165. — Because of the small size of the moon and its distance from the earth, the umbra of its shadow is never more than 168 miles in diameter. At such a time all places within the umbra have a *total eclipse* of the sun. In the lower figure the umbra does not quite reach the earth, hence the moon appears, to an observer directly behind it, to be a great round disk, not quite large enough to cover the sun.

243. How Does Distance Affect the Brightness of Light? — If you sit in the far corner of a room, do you receive as much light as a person who sits beside a reading lamp in the middle of the room? No, of course not. But if you sit **twice** as far away as he does, you receive, not half as much light as he, but only $\frac{1}{4}$ as much. Why is this? Study Fig. 166. A person **three** times as far away as another receives $\frac{1}{9}$ as much light.

The lantern of Fig. 166 represents a **beam** of light with rays spreading out in all directions. If a card one inch on a side (its area is one

square inch) is placed, say, four inches from the light, it will cast a shadow exactly covering a card having **four** times the area, but **twice** as far away. Its shadow will also cover a card having **nine** times the area, but **three** times as far away. But as the same amount of light is spread out over four times, or nine times, the surface, its brightness on each square inch is less in the same proportion.

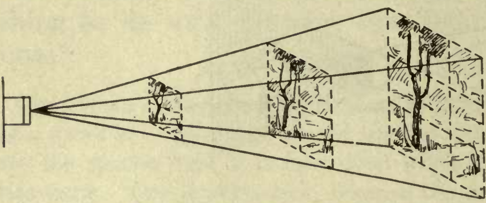


Fig. 166. — At twice the distance from the lantern, the picture is 4 times as large, but only ¼ as bright. At 3 times the distance it is 9 times as large, but only ⅑ as bright.

As the candle has been used so long as a source of light, the **standard unit** for the measurement of the brightness of light is the **candle power.** If an electric light bulb gives as bright a light as 16 standard candles, the bulb is said to be a 16-candle-power light.

244. Can Light Be Turned Out of Its Course? — We have already learned that light rays, which come to us in straight lines, can be turned, or reflected, by the smooth surfaces we call **mirrors.** Do you suppose that they can also be bent by transparent bodies through which they pass. Let us perform a few **experiments.**

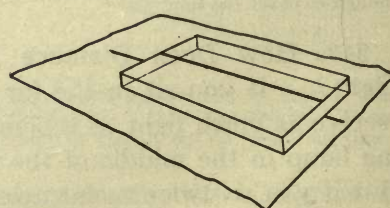


Fig. 167. — As the rays of light pass **at a slant** from the glass into air, they are bent, and the line seems to be broken at the edges of the glass.

On a sheet of paper make a straight pencil mark (Fig. 167), and lay a thick piece of glass over it, so that the mark projects beyond the edges of the glass. If you look straight down (vertically) upon the line, it does not seem broken. But look at the mark at a slant; do you see that the line seems to be broken at the edge of the glass? Why is this true?

What happens is that the light from the pencil mark passes through the glass and then through the air to reach your eye. If it leaves the glass without a slant, it is not bent; but if it leaves slantwise (*obliquely*) it is bent out of its straight course. Now, as you see the mark in the direction from which its light is coming as it enters your eye, the part under the glass seems to be **at one side** of its true position.

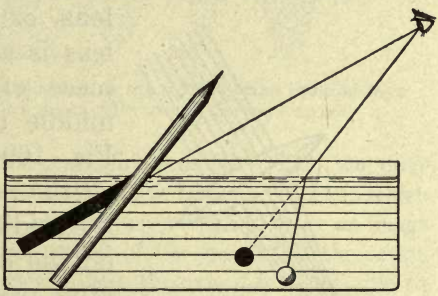


FIG. 168. — If you look **at a slant** at some object which is under water, the light rays are bent as they pass from water into air; hence your eye is deceived as to the true position of the object.

What happens when the light passes from **water** into air? Study Fig. 168. In a cup place a **coin.** Raise the cup, or lower your head, so that the coin just goes out of sight; then pour water slowly into the cup. Does not the coin seem to **rise,** so that you can see it? Has the coin actually risen?

If you see a **fish** at the bottom of a pond, is the fish where it seems to be? See Fig. 168. Will not the light coming from the fish to your eye be bent as it leaves the water, so that the fish will seem to be **farther** from you than it really is? Will not the water also seem to be more **shallow** than it is in fact? Is it safe to step off into water that seems "just up to your neck"? If you were trying to spear a fish, would you aim directly at the place at which the fish seems to be, or nearer to you? Explain why it is that an oar, or a water plant, sticking out of the water, seems bent at the water's surface.

As the light from the sun, or a star, **near** the horizon comes from outer space into our atmosphere, its rays are bent downward toward us, so that the sun, or star, seems higher than it really is. May a star have really set, and we still see it?

245. How Does a Burning Glass Work? — Have you ever used a magnifying glass or a reading glass to gather the rays of sunlight together, so that you could use them to set paper on fire? The glass is then called a **burning lens**, or burning glass. Such a lens is a round, lozenge-shaped piece of glass, thicker in the middle than at the edges (see Fig. 169). The spot at which all the rays are brought together is called the **focus** (fō'kŭs). Why do the light rays come together after passing through the lens?

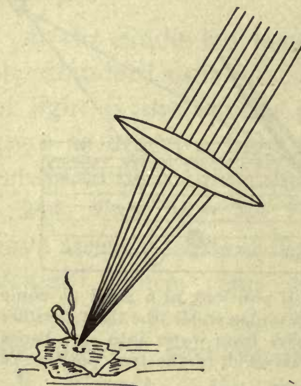


FIG. 169. — The glass lens gathers parallel rays coming from the sun and brings them together at one spot; there they are able to set paper on fire.

To understand the burning lens, let us think again of the bending of the rays of light when they go from glass into air, or from water into air. When the glass surface is flat (a **plane**), and you look through it slantwise, the rays are bent toward you. If you use a lozenge-shaped piece (a **lens**), the light that passes through any part except the middle will all be bent *toward the middle;* that is, toward the **thicker** part of the lens. So, at a certain distance from the lens many separate rays will come together.

Lenses may have several forms (Fig. 170), depending upon whether the faces are bulging (**convex**), hollow (**concave**), or **plane**. The rule is that the light is always bent toward the thicker part of the lens; so some lenses spread out the light rays instead of bringing them together. Which ones do this?

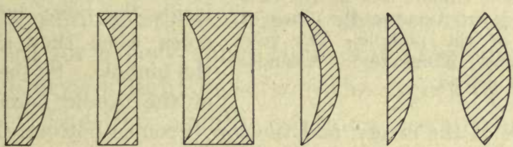


FIG. 170. — The lenses that are thickest at the middle bring parallel rays together; those thinnest at the middle spread the rays apart.

Our eye has a lens, called the **crystalline lens** (see § 252), the duty of which is to bend the light rays coming to us from an object at which we are looking. The light must be bent just enough to make an image of the object upon the sensitive **screen** of the eye, called the **retina** (rĕt′ĭ-nă). **Eyeglasses** are lenses to help the eye, if it is not able to bend the light rays properly.

246. How Does Light Form an Image? — You know what a **camera** is. It is a box in which light rays are allowed to fall upon a prepared plate or **film**. An easy way to study how images are formed is to use a very simple kind of camera, called a "**pinhole**" camera.

Remove the two ends of a box, leaving the two sides and the top and bottom (Fig. 171). Cut an opening in the center of one side, and cover it with tinfoil. Make a **pinhole** in the foil. The inside is made black, except a white spot opposite the tinfoil. If, now, you darken the room, and place a small, lighted candle in front of the pinhole, you can see an image of the candle on the white spot inside the box. The image is **upside down** and **reversed** sidewise too. Why is this true? The answer is that a light ray is sent from every point of the surface of the candle, and that these rays make pictures of the points from which they came, wherever they strike the white spot inside the box; but they all **cross** when they go through the pinhole. So the right side of the candle flame becomes the left side of the image, and the top becomes bottom. How does this show that light travels in straight lines?

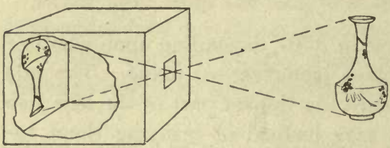


FIG. 171. — The image of the vase inside the pinhole camera will be reversed and upside down, because the lines of light cross at the pinhole. The vase must be brightly illuminated. A candle may be used instead.

Direct the pinhole toward a bright landscape; do you get an image of it? Is it inverted?

247. How Does a Camera Work? — When we examine a beautiful, modern **camera** (Fig. 172), the pinhole camera seems a very crude affair indeed. But when we think of it, we see that the real camera is very much like the pinhole one after all. The real camera has a **lens** in place of the pinhole. The lens gathers many more rays of light and so makes a stronger, more definite image. Instead of a white spot,

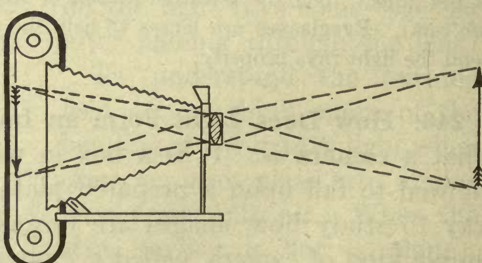


FIG. 172. — In a camera the lens gathers the rays coming from each point of an object and brings them to a focus on the film.

the camera has a *sensitive plate*, or **film**, on which the image of the object can be made permanent. By looking through an opening at the back of his camera, the photographer can see the image on a ground-glass screen, and can make the lens bring the image to a proper **focus** before he allows the image to fall upon the sensitive plate and to "take the picture." When everything is ready, the photographer opens a shutter in the front of the camera for a very short time, but long enough to let the active rays of light pass from the object to the sensitive film. The film usually contains a compound of the metal **silver**. Wherever the light rays touch this compound, they **change** it. Where the light was strongest, the compound will be changed the most.

You cannot tell that a film or plate has been changed until it is "developed." **Developing** is the process by which the silver compound that has not been changed by the light is washed off. The chemical used is usually the one called "hypo." After developing, the outlines of the picture appear. Suppose the photograph is that of a girl having **black** hair and a **white** dress. The black hair does not send many light rays into the camera. Why? See § 250. So the silver compound is not changed much where the hair is pictured. When the film is developed, the hair appears as a **light** spot. The white dress, on the other hand, sends many light rays to the film and these change the silver compound a great deal. In the developed film the dress will appear as a **dark** spot. Because white spots in the photographed object are black in the developed film (see Fig. 173), and black spots in the object are white in the film, the film is called a **negative**. But when the picture is "printed," it makes a **positive** print. We make the positive print by placing the film over sensitized paper and exposing it to the light for a few minutes or seconds, the time depending upon the strength of the light and the clearness of the film. The light changes the substance on the paper wherever there are **light** spots in the film; but that part of the paper under the **dark** spots of the film is left unchanged. Then, when we develop the print, and remove the unchanged compound, the picture has light and dark spots just opposite the way in which they appear in the film or plate. So at last, in the **printed** picture, the light and dark spots are the same as they were in the photographed object.

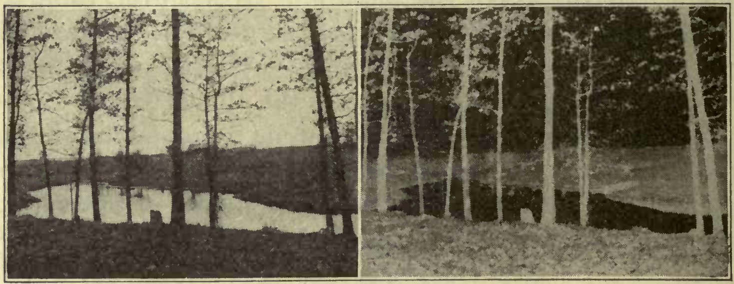


FIG. 173. — A positive and a negative photograph. The negative was taken by the camera; the positive was printed by light that passed through the negative.

In the ordinary **kodak**, the principle is the same as in the camera. Instead of having an opening at the back to look through, you focus a kodak by means of a "finder." This is a tiny box which reflects the image, so that you see in it exactly how the image will be focused upon the film when the shutter is opened.

248. What is the Color of Sunlight? — Think what this world of ours would be if it were not for **color**, and if the sky and water, sunsets and flowers, were all alike to us. What is the color of sunlight? **White**, you say. Then where do all the wonderful colors of the objects we see by sunlight come from?

Let us study sunlight by passing it through a piece of glass (see Fig. 174). This time we will not use a glass plate, nor a lens, but a **prism**, so that the light will be made to go through two glass surfaces which are straight, but **not parallel**. Through a narrow, **horizontal** slit admit a beam of sunlight into a dark room, and let it fall, or reflect it, to a piece of white paper on the opposite wall of the room. Then put the prism of glass in the path of the sunbeam. What happens? Where do the colors come from? This series of colored bands is called the **solar**, that is, the *sun's*, **spectrum**. If you have no prism, you can use a "cut" chandelier pendant, or a "cut" glass bowl, to break up the sunlight into its colors. The **violet** light is bent most, so it forms the upper band of the spectrum. Then come **indigo**, **blue**, **green**, **yellow**, **orange**, and **red**. Their initials form the make-believe word, **vibgyor**. Which rays are bent the least?

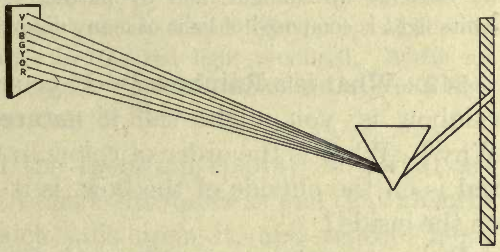


Fig. 174. — The white light coming from the sun is broken up by a prism into the rainbow colors: VIBGYOR.

Fig. 175. — When the spectrum colors are re-united by being passed through a reversing prism, white light is produced.

Do you suppose we can put these colors together again? Study Fig. 175. If we put a second prism in reversed position, so that it catches the colored bands before they reach the wall, the colors are mixed once more, and we have **white** light. So we can prove, both by breaking up sunlight, and by putting the parts together, that white light is composed of light of many different colors.

249. What is a Rainbow?—If you wish to tell what a rainbow is, you might call it **nature's solar spectrum.** Why? What is the order of colors in the rainbow? The **red** is on the outside of the bow, is it not, and the **violet** on the inside?

Did you ever see a rainbow at **noon?** No; to see a rainbow we must be looking at falling rain with a rather low sun behind us. The sun must not be quite half the distance from the horizon to the zenith (see § 84). The rays of sunlight are **bent** as they enter each tiny drop of rain, then they are **reflected** from side to side in the drop, and finally **bent again** when they leave the drop. Did you ever see a rainbow in a waterfall, or in the spray of a lawn sprinkler? Try to make one with the sprinkler.

At sunrise and sunset we get colors from one end of the spectrum only. What are they?

250. Why Does an Object Have Color? — Have you ever seen a woman who was buying colored cloth in a store that was lighted by *artificial* light? Probably she took the cloth to the window to examine the color. Why did she do this? She wished to see what its color was in the **white light** of the sun. What is the matter with gas light or electric light so far as color is concerned? It may not have in it all the colors we find in sunlight, and so may make colored objects look **unnatural.** Did you realize that the color of an object is the color of the light rays it **reflects** to your eyes? So the color the object is to reflect must be in the light by which we see it.

Put some red tissue paper over an electric light bulb, and examine objects of different colors by the red light produced. Which are natural? Which are changed? Produce yellow light and blue light in a similar way, and see what the results are.

We have studied the **spectrum** colors; but what are **white** and **black?** A black substance is one that **absorbs** all of the light which falls upon it, and reflects none. **Soot** is such a substance. A **white** object is one which **reflects** all the light rays that fall upon it. Why do we prefer white outer clothing in summer, and black in winter?

251. How Can We "Trap" Sunlight? — Have you ever seen a "cold frame" in which vegetables can be grown in the early spring, long before the ground outside is ready for use? Examine Fig. 176. It shows a box covered with glass — a **cold frame.** A greenhouse is a much larger structure of the same sort. Have you ever thought that these are really **traps** to catch the light of the sun?

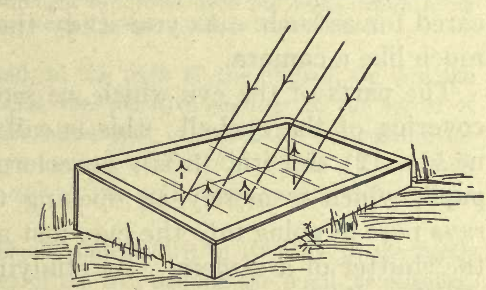


FIG. 176. — The cold frame traps the rays of sunlight, changing them into heat for the growing plant.

Hold a piece of **glass** between you and a hot stove and you will find that the glass cuts off many **heat rays** of the stove. It cannot, however, cut off **light** rays; these pass freely through it. If the light rays could be changed to heat, the sun's energy could go through the glass, but could not get out, and so would furnish a great deal of warmth. This is just what happens in the cold frame. As the light rays are **absorbed** by the dark soil, and not reflected, they are **changed into heat**, and warm the soil under the glass.

The energy of the sun comes to us in the form of waves (see § 240), which we call **heat**, **light**, and **chemical energy**. When, however, the light waves and chemical waves are absorbed, they are changed into heat. The **water vapor** and **clouds** of the atmosphere act as a heat trap for the earth, much as the glass cover does for the cold frame (see §§ 75 and 79).

252. How Does the Eye See? — Have you ever realized how wonderful our eyes are? They are among the most delicate of our organs, and ought to be prized and cared for as such. As you study the eye, see if it is not much like a **camera**.

The **parts** of the eye which we see are: (1) the **outer covering** of the eyeball; this is called the **cornea** (kŏr′-nē-ă); (2) the **iris** (ī′rĭs), or colored curtain; (3) the **pupil**, which is merely an opening through which light rays pass in going into the eye, just as they pass through the shutter of a camera. By studying Fig. 177 you will see that the eye has a great many complicated devices which are not seen from the outside.

The entire ball is covered by a tough, strong membrane called the **sclerotic** (sklē-ŏt′ĭk) coat. In the *front*, this coat is transparent, and is called the **cornea**. Inside this heavy protective covering the eye is divided into **two chambers**, or rooms. The **crystalline lens** (see § 245) acts as a wall of division between them. These chambers are both filled with a liquid which keeps the eyeball full and rounded out. The liquid in front of the lens is called the **aqueous humor**, which means "watery liquid," and that in the large, back chamber is called the **vitreous humor**, or "glassy liquid." The crystalline lens is filled with a denser, jelly-like substance. The light rays pass through these three transparent layers.

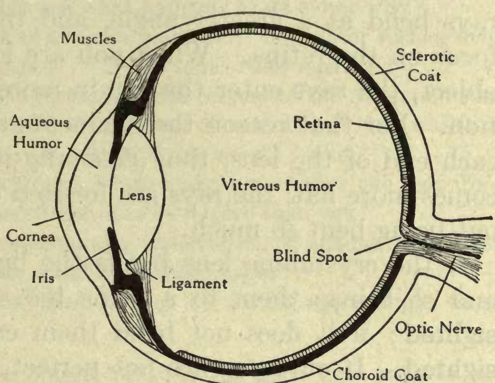


FIG. 177. — The eye consists of a darkened room open to light from the front, through the pupil. The size of the pupil is regulated by the iris. The light is brought to a focus upon the retina, which in its turn sends the sight message to the brain.

In the figure you can trace the **choroid** (kōr′oid) coat, which lines the back room of the eye. In front, this coat appears as the **iris**. Inside the choroid, in the back of the eyeball, we find the **retina**. The retina contains the sensitive endings of the nerve of sight, or **optic nerve**. The **blind spot** is caused by the coming together of nerves from nerve endings all over the retina. There they all unite, and leave the eye as the optic nerve, which carries sight messages to the brain.

Muscles attached to the eyeball hold it in its place in the head. Small muscles, inside, control the iris, making the pupil, or opening, **large** when the object is hard to see, and **small** when you are in the dazzling sunlight. Why is this adjustment needed? Why do you set your camera at "25 seconds" on one day, 50 on another, and sometimes take a "time exposure"?

Strong **ligaments**, or bonds, are found just back of the choroid coat; they control the **shape** of the crystalline lens. When objects are near, these ligaments become loose, and the lens is rounded. This makes the light rays bend at a greater angle, and thus gets them to a focus on the retina. When you are looking at a **distant** object, the rays enter the eye in more of a **parallel** position. For that reason the ligaments are made to **pull** at each end of the lens, thus *flattening* it. As the lens becomes more flat, the rays are focused on the retina without being bent so much.

If the crystalline lens bends the light rays too much, and so brings them to a focus too soon, we are **near-sighted**; if it does not bend them enough, we are **far-sighted.** If our eyes are not perfect, we should consult a skillful oculist, and have him tell us what kind of eye-glasses we need, so that the eyes may be helped to do their work properly.

As your eyes are so very delicate, you should give them the best possible **care.** Never rub the eyeball with your fingers, unless you are sure they are clean; the eye may become **infected.** Never try to read on a moving train, as the eyes are strained by trying to follow the shaking book. Reading while lying down is harmful.

253. Exercises. — 1. Why is the foaming top of a wave white ("whitecap"), while the remainder of the wave is blue or green?

2. If you try to pick up a stone from the bottom of a stream, do you find that it is where it seems to be? Why?

3. What is the rate at which light travels? How long would it take light to go once around the earth at the equator?

4. If we see a rainbow at 7 a.m., in what part of the sky will it be? At 5 p.m.?

5. Look at a mirror in the dark, and suddenly turn on the light. What happens to the pupil of the eye? Bring a cat from a dark room into a very light one, and see what happens to its eyes; why?

6. What is the back of a mirror made of? Is a water surface ever a mirror? A varnished floor? Name some other mirrors.

7. What position has the earth, with respect to the moon and sun, at the time of full moon? At the time of new moon? At which of these times can there be an eclipse of the moon? Why?

8. If you sit 4 feet from a lamp, and your brother one foot from the lamp, how much more light does he receive than you?

9. Is a finger nail transparent, translucent, or opaque? A sugar solution? Milk? Ice? Lead? Greased paper?

10. Do you think that glass bottles left in the woods might cause forest fires? Tell how.

Summary. — We see objects because they send **light rays** to our eyes. **Self-luminous** bodies send us their own light; **illuminated** bodies send us **reflected** light.

Bodies may be **transparent**, **translucent**, or **opaque**.

Light travels in the form of **waves**, at the rate of about 186,000 miles a second.

Light waves from the sun bring us **heat** and **chemical energy** as well as **light**.

Light may be reflected by **mirrors**. The **angle** at which the light leaves the mirror is the same as that at which it strikes the mirror.

Periscopes are tubes containing mirrors which reflect light "around corners," so that men can see without being seen.

A **shadow** is the region from which light is cut off by an opaque object. If the source of light has a considerable **area**, its shadow will have **two parts**: an **umbra** and a **penumbra**. In an **eclipse**, one heavenly body passes through the shadow cast by another.

The **unit** of light brightness is the **candle power**.

When light passes at a **slant** from glass or water or other transparent materials into air, it is bent out of its course, or **refracted**.

Burning glasses are lenses for bringing many light rays together at a point called the **focus**.

A **camera** is a device in which rays of light coming from an object are brought to a focus upon a sensitive **film**, so that a picture of the object may be produced.

The **white** color of sunlight is made up of the colors of the **solar spectrum.** When all these colors are recombined, they produce white light.

A **rainbow** is a solar spectrum produced by the bending and reflecting of sunlight in many raindrops.

We can **trap** sunlight in a greenhouse or a cold frame. The earth's atmosphere acts as a great trap.

The **eye** is a wonderful camera, in which light rays from each part of an object are brought to a focus upon a sensitive " film " — the **retina.** The **optic nerve** then carries the sight message to the brain.

CHAPTER XXVII

LIGHT IN THE HOUSE

254. How Do We Get Sunlight into the House? — The light of the sun is our symbol of health and joy, and the eye is the organ by which we get most of our knowledge and our delight in our surroundings. Why, then, did primitive peoples, and our own ancestors, only a few generations ago, have so little sunlight in their houses? Think a minute; what was the first and most important *use* of the house? It was **shelter**, was it not? Shelter from weather and from powerful animal and human enemies. The castle itself, with its thick walls, often had only *slits* for windows. Why?

Even when civilization came, and man did not greatly fear enemies, except those of the weather, the problem of the window was still a hard one; for what material could he use to fill the hole in the wall? Oiled paper, isinglass, and thin sheets of horn were used at first; they are still used in some less civilized communities. Are these materials as good as glass? What, then, do you think of the debt of gratitude we owe to the man, or the men, who made it possible for us to get cheap window glass? We shall feel that the debt is much greater when we realize that in shutting out his larger enemies early man shut in many powerful but **tiny enemies** he did not know anything about. What were they? How about the **germs** of disease, which are almost sure to flourish in the dark and dirty house that has no sunlight?

How Is Glass Made? — Do you find it easy to believe that so brilliant and clear a substance as glass (see Figs. 178 and 179) can be made out of **sand, limestone,** and **soda?** Yet this is true. The

Fig. 178. — The glass blower blows a large lump of hot, softened glass into a hollow globe. When this is cut open, and then softened by heat, it forms a flat sheet.

Fig. 179. — The lump of soft glass attached to the hollow tube is put into the mold. The workman, or a current of compressed air, blows into the glass lump until the glass has the shape of the mold.

mixture is melted in fire clay pots about 4 feet high and 4 feet in diameter, until a clear, transparent liquid is formed. In some glass factories a larger amount is melted in a tank.

255. How Have Men Lighted Their Houses at Night? — Few stories are more interesting than the story of the many ways in which men have tried to lengthen the day, for work or pleasure, by making a light in the house to take the place of the light of day. As you know, the pioneers of this country gathered around the open fire for light by which to work or read, as well as for the heat by which to keep warm (see §§ 23 and 57).

FIG. 180. — An ancient lamp in which lard or olive oil was burned to give light.

In ancient times men learned to burn grease and oil in **metal vessels**, with pieces of bark, or twisted moss or cloth to serve as **wicks**. Fig. 180 shows a lamp such as was used by the Greeks and Romans. The Eskimos still use a lamp of this sort, with *blubber* as the fuel (see § 57). The flame is often two feet high. Can you imagine yourself doing without a furnace, a range, and electric lights, and having only one greasy, bad-smelling lamp instead?

Candles. — As the old lamps were easily spilled, and were heavy and inconvenient, the *tallow candle* was invented. Tallow is a grease which is very hard when cold. To make a candle, men dipped the wick into melted tallow; then took it out until the tallow cooled; and then dipped it again and again until the candle was of the proper size. Do you think this was a rapid or a slow process?

A *more rapid* way is to fasten the wick in a hollow **mold**, and to pour the melted tallow around the wick. When the tallow hardens, the wick is embedded in it.

Watch a candle burn, and see the little bowl of melted grease that supplies the wick with fuel.

256. How Do Kerosene Lamps Work? — Your grandparents will probably remember the first kerosene lamps, which came into use about 1860. **Petroleum** had just been discovered, and when it was distilled it gave *kerosene*, *gasoline*, and other combustible liquids. So men turned back from the solid candle to the oil lamp. But kerosene took fire so easily that they had to invent a lamp in which to burn it. This consisted of a bowl and a wick, like the older lamps, but there was a **burner** to hold the *wick*, as well as to hold the *chimney*, and to allow an even *current of air* to flow constantly past the burning kerosene of the wick. The chimney protected the flame from other drafts, and carried away the gases formed in the burning. What were they, probably? Thus a strong, bright, even flame was produced.

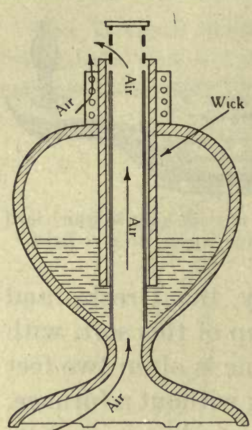


FIG. 181. — In the center-draft kerosene lamp, air passes up through the center of the lamp, so that the kerosene on the wick can be supplied with a large amount of air.

Some lamps have a **center** draft (see Fig. 181); this allows more air to enter, and a larger wick to be used. As a result the flame is very bright.

Examine a "blue flame" kerosene stove, and find out what kind of burner it has.

257. How Do We Get Light from Gas? — Have you ever seen, in the city, the large gas tanks that rise out of the ground like giant toadstools? In them the gas for the city is stored. How do you suppose this gas is made? Some of it is **natural gas**, which is found in the rocks of the earth in certain places; but most of it men make by **heating soft coal**, or by passing *steam over red-hot coke* or coal. Gas is carried to our houses in iron pipes. The joints must be made carefully, because the gas is under pressure; and any leak must be attended to at once. Most gas is poisonous, and a person in a closed room may continue to breathe it until death results. Then, too, there is danger of fire, if a flame is brought near a pipe in which there is a leak.

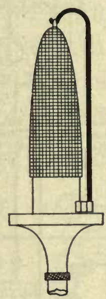


FIG. 182. — In the mantle light a Bunsen flame heats the film of oxides of certain rare metals. These become incandescent, and give off a brilliant light.

The **old way** of burning illuminating gas was to pass it through a **slit** that gave the flame a "fish-tail" form. The modern way is to use a gas burner of the form known as a **Bunsen burner**, which mixes so much air with the gas that it burns with a **colorless** flame; this flame is very hot. How can a colorless flame be made to give us light? It is allowed to heat a "mantle," and this in turn gives off a brilliant, white light (Fig. 182).

Examine a **gas stove** and its burners. Gas stoves are really Bunsen burners, like those of the mantle light. There are openings in the side of each burner through which air is drawn in by the rushing gas. The mixture of gas and air burns with a colorless flame, without soot, but very hot.

258. How Does a Fuse Box Protect a House? — Is there any danger from the electric light in our houses? Read § 228. There we learned that electric light wires must be **insulated** carefully, and that builders take special care to keep the wires away from wood and from one another, using porcelain, or rubber, tubes, and metal pipes, or **conduits**, for the purpose. The danger is that a spark may pass from one wire to another, or that the current intended for several wires may all be loaded upon one of them, and this may become hot enough to set wood on fire. If the wires were very thick, a great deal of this danger might be avoided; but as copper is expensive, the smallest possible wires are generally used.

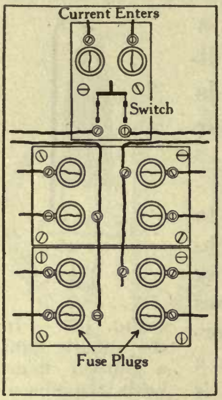


FIG. 183. — A fuse box consists of a set of "fuse plugs" each containing a short piece of easily melted wire. The wire melts, and breaks its circuit, before the circuit is hot enough to set the house on fire.

To take care of the danger from heated wires men provide each circuit with a **fuse** through which the current of that circuit must pass. These fuses are generally placed in a **metal box** (see Fig. 183), or a box lined with asbestos board. The "**switch**," through which the current from the outside, "service" line enters the house, is usually in the same box. Find the fuse box and switch in your house and examine them carefully. When we open the switch, we cut off the current from the house. We ought always to do this when any work is being done upon the electric system of the house.

Examine a "fuse plug"; it contains a short piece of wire made of an alloy of metals that will melt at a rather low temperature. When any circuit becomes too hot, because of the extra load it is carrying, the fuse on that circuit melts, and the current will not flow until a new fuse is put in.

259. How are Gas and Electricity Measured? — Do you know how the amount you owe for electricity and gas is calculated? Possibly you do, for you may have seen your **meters** read. A man comes once a month for this purpose. You pay for the amount of electricity or gas which has run through the meter since the last reading was made. This is the record of all that has left the gas main or electric service line and entered the house where it was used. Thus, the difference between the reading of the meter on March 1st and on April 1st is the amount of gas or electricity you have used during the month of March. People often complain because their gas and electricity bills are so high. Don't you think you ought to be able to read your own meters, so as to save trouble and argument as to whether or not the bills are fair? Gas and electric meters, while alike in general, are read in different units.

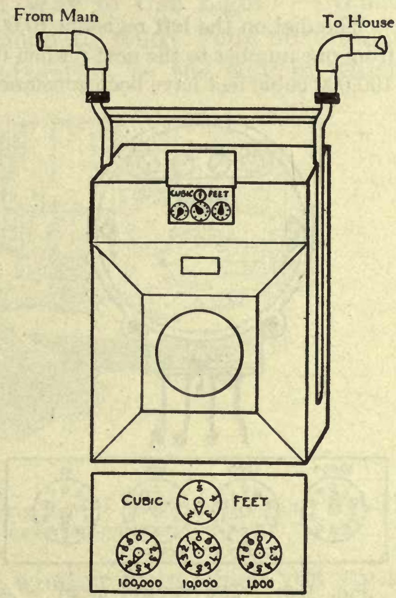


FIG. 184. — The gas meter measures the amount of gas that enters the house from the gas company's "mains."

260. How is a Gas Meter Read? — Gas is measured in **cubic feet** and paid for at so much a cubic foot. The meter (Fig. 184) is a metal box having four dials on its face. The top dial registers every foot of gas which goes through the meter. When this dial moves around once, **5** cubic feet of gas have gone through the meter. When it has gone around 20 times, **100** cubic feet of gas have been used, and the hand on the lower **right-hand** dial will have moved from **0** to **1.**

When this hand has registered 100 for 10 times, and the pointer is at **0** again, the dial to the left of it will have moved from **0** to **1** and **1,000** feet of gas will have been used. When the top dial and the 1,000 dial have moved enough to bring the pointer on the 10,000 dial back to **0**, 10,000 cubic feet have gone through. How many times would the top dial revolve to make the one under it revolve once?

The dial on the **left** registers 10,000 cubic feet every time it moves from one number to the next; when its point has gone entirely around, 100,000 cubic feet have been consumed, and the meter must be started over again.

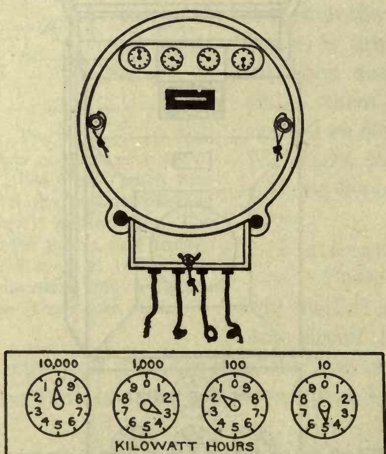


FIG. 185. — The electric meter is a delicate motor which is used to measure the amount of electric current that enters the house circuits.

Watch your meter when the oven of your gas stove is burning and a good deal of gas is being used. How much gas is used between each two "clicks"? Write out the reading of the meter in the figure.

261. How is the Electric Meter Read? — Electricity cannot be measured by the cubic foot, but is measured in **watt-hours** or **kilowatt-hours**. On the large scale, electricity is sold by the **kilowatt-year**. A kilowatt is 1,000 watts. A watt-hour is an electric power of one watt working for one hour. The watt is named for James Watt, who invented the steam engine. When did he live?

In the electric meter (see Fig. 185) the dial on the **right** registers up to 10 kilowatt-hours, the next one to 100, the third one to 1000, and the one on the **left** to 10,000. How do the readings differ from those of the gas meter? Write down the readings of the meter shown in the figure.

262. What is the Right Way to Use Light? — When you go home in the afternoon to study your next day's lessons, do you pay any attention to the way in which

Fig. 186. — The right and the wrong way to use a table lamp. Which is which? A strong light should **never** be reflected directly to the eye.

you seat yourself near the window from which you are to get light? Then, when you sit down to read in the evening, do you think whether the bright light of the lamp comes directly into your eyes, or whether it is reflected into your eyes by the page of your book (see Fig. 186), or whether it comes to your eyes in mellow, diffused form, strong enough for easy reading, but not strong enough to be dazzling and uncomfortable? Don't you think you ought to be concerned to get as good light as possible for your eyes? The reward of having good eyesight is certainly worth the little effort it takes.

In the first place, we should **never** read or do sewing with **direct sunlight** upon the page or the work, because the sun's light is too bright to be reflected directly into our eyes. Neither should we attempt to read or write or do sewing in a **waning** light, as in the evening twilight. As the light grows more and more dim, the eye is strained in trying to adjust itself.

The light by which we see our work should come, if possible, from **above** us. That is the natural way for light to come, is it not? We must remember that our eyes are protected from the sun's light in the **middle** of the day. They are set in deep sockets, and protected by the forehead, the eyebrows, and the eyelashes. But all these fail to shield the eyes from light which comes to us on a **level** with our eyes, or from **below**. Think how hard it is for us to see when a bright sun is shining upon snow, or upon water, or upon a white concrete pavement at midday.

Inside a building also, as in an office or a schoolroom, light should come to us from the **upper** part of windows, rather than from the lower part, if this is possible, so that it may not strike our eyes **horizontally.** It should not come to us from the **front**; for then it shines directly into our eyes; nor should it come from **behind** us; for then our desk or table will be in the shadow of our body. If we are right-handed, the light should **not** come to us **from the right** when we are writing or working problems; for then the shadow of our hand and arm will be upon the part of the page upon which we are working. So it is best for the right-handed person to have the light come **over the left shoulder.**

263. What is Indirect Lighting? — Have you ever noticed the windows of a photograph gallery? From which direction does it get its light? From the **north**, does it not? Is it not strange that a photographer in the Northern Hemisphere should prefer to get light from the north, when the sun is in the southern part of the sky? But the photographer wants light that is of the same brightness everywhere; so he takes his light from the northern sky. Here sunlight is **diffused** (see § 240), or spread out, because it is all reflected irregularly by the atmosphere.

Have you ever seen factories with **saw-tooth** roofs, in which there are several sections of the roof; so that a large number of windows can be near the ceiling and their light can come from the north? If a roof has a nearly flat skylight, from what parts of the sky will the light come? Some schoolrooms are lighted in a similar way.

Is it possible to get this diffused, irregularly reflected light when we have **artificial** lighting? The rules we must follow are like those we use in lighting by diffused sunlight. The light should come *from above;* but in order that it may be spread evenly through the room it should **not** come from a single bright light placed in the center of the room. Rather it should come from many *smaller* lamps placed on the walls. Have you not seen the large chandeliers in the center of some halls, which send a mass of dazzling light into a person's eyes as he tries to look at the speaker on the platform? Many houses have their lighting spoiled in the same way.

In the so-called **indirect system** of lighting we do not get the direct light of the lamps at all (see Fig. 187). You have probably seen this system in use in some library, or hall, or office, or bank; perhaps in some house. You do not see the source of the light because the lamps are in a **recess**, or groove, near the top of the walls, and you get only

(*Courtesy of the National Lamp Works.*)

FIG. 187. — In indirect lighting the light rays are reflected to the eye entirely from the ceiling and walls of the room; none come directly from the lamp.

the irregularly reflected light from the ceiling and the upper part of the walls.

Even if we cannot have a **real** indirect lighting system in the house, we can have some of its advantages. If we have a central cluster of lamps in a room, we can get much of the effect of indirect lighting if we have a large, white bowl under the cluster. The light that gets through is much more comfortable to the eyes, and a large amount of it is reflected from the ceiling. Then, too, the various kinds of mantle and electric lamps have ground or opal glass globes or shades, which we can use to get a more diffused light in our room. If we have to study by the light of a table lamp, it should by all means have a green shade. If we have to study by a direct ceiling light, we should wear such a shade ourselves. Can you tell why the green of the shade is so agreeable to our eyes?

We must remember that much of the effect of any lighting system depends upon the **color** of the walls of a room, upon whether they are **rough or smooth**, and upon the **decorations** used. A well-lighted home does not just "happen"; it must be planned with intelligence.

264. Exercises. — 1. Report to the class a method by which you could make illuminating gas. See Fig. 25, § 36.

2. Report to the class all the uses of glass that you can think of.

3. How is window glass cut into pieces of a certain size?

4. In case a small gasoline or kerosene stove were tipped over while lighted, what would you do? Would it be best to put water upon the fire? Would you put a rug over it? What do you think would be the effect of throwing baking soda upon the fire? Note: Baking soda gives off carbon dioxide very easily when heated.

5. If you blow out a kerosene lamp flame, you can relight it if you bring a lighted match at once above the wick. Tell why. See § 28.

6. If you wish a match to burn, do you hold its head up, or down? Why?

7. Do you think it is a good practice to heat a closed room with a kerosene lamp? Why?

8. Why does a gas "mantle" give off more light than the flame which heats it?

9. Is it worth while to continue to use an incandescent bulb which becomes very hot when lighted? Why?

10. What kind of gas is used in your house? How much does it cost for a thousand cubic feet? How much did you use last month?

11. How many incandescent bulbs are there in your house? Do you use electricity for any other purpose than for lighting? How much electricity did you use last month? How much for each bulb? What is the cost of your electricity for each kilowatt-hour?

12. Give all the reasons you can think of for having as many windows as possible in a house.

Summary. — **Sunlight** is needed in our houses, for **health** as well as for light.

Early methods of lighting were open **fires**, wick **lamps**, and **candles.**

Kerosene lamps had wicks and burners, as well as chimneys, to bring a constant supply of air to the burning fuel.

Gas is " natural gas " or " artificial gas." Artificial gas is made from coal, or from coal and steam.

Gas stoves and **mantle lights** use the principle of the **Bunsen** burner.

Fuse boxes are used in our house circuits to prevent an overheated electric wire from setting fire to the house.

Gas and electricity are measured by **meters.**

We should use **care** with regard to the amount of light by which we work or read, and with regard to the way in which it strikes our eyes.

Diffused light is better than direct light, and **indirect** lighting in our houses and buildings is most comfortable to the eye.

The **color** and the **decorations** of our rooms have a great deal to do with the lighting.

CHAPTER XXVIII

THE SOUNDS WE HEAR

265. What Causes a Sound? — Hasn't someone ever startled you with this remark: "How still it is tonight"? The sounds made by insects, trains, automobiles, water, the wind through the trees, birds, horses, and the sounds made by human beings, all had suddenly stopped. These sounds come to us practically all the time; so that we grow used to hearing them. Then if they cease, as they sometimes do, we are aware of the silence. What is the nature of sound? Is it like light, possessed by certain bodies only? Where does it come from? In answer to these questions carry out the following **experiments**:

Hold a common **table fork** (or, better, a **tuning** fork) lightly by the handle, and strike its **tines** against the table. Then hold the fork in the air. What happens? You say it makes a ringing sound. Why does it give off sound? The fork was lying on the table a few minutes before, and no sound came from it. Strike the fork again, and hold it against a sheet of paper, such as a folded newspaper, while it rings. What happens? Strike it once more, and this time let it touch the edge of an empty glass. Also try it upon the surface of a glassful of water. What happens to the water while the fork is ringing? The fact is that the paper, the glass, and the water are being struck by the sounding fork and set in motion by it. See Fig. 188. The reason why a sound results after you strike the fork, is that the fork is **moving** rapidly **to and fro.** We say it is **vibrating.** All sound is due to the vibration, or motion, of some material. It may be a sounding violin string, or it may be a clap of thunder; but it is some material in motion. A piano stands without a sound until some one touches a key. This key is so arranged that when it is pressed, it causes a **wire** to be struck, and made to vibrate. In speaking or singing we set two **membranes** in the throat (the **vocal cords**) to vibrating (see § 388). We do this by forcing air through a **slit** between them. These vibrations of matter cause the air to vibrate and the air vibration is carried to the ear, causing us to **hear**.

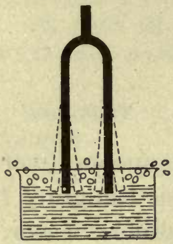


FIG. 188. — The sounding fork is moving so rapidly our eyes cannot follow it, but the sprays of water tell the story.

Will **any substance** besides air carry sound? Hold your ear close to one end of an iron steam or water pipe, and have someone scratch with a pin, or a small nail, at the other end of the pipe. Can you hear the sound? Can you hear it as well when your ear is not near the pipe? Try the same problem with a wooden pole, or a yard stick. Do iron and wood conduct sound as well as air, or better? Sound may be carried by water, the earth, and other things also, but air is the most common carrier. You can make a **string telephone** out of two tin cans and a long enough string and talk to a friend one or two hundred feet away. The string is passed through a small hole in the bottom of each can, and knotted to keep it from slipping out. The string must be tightly stretched, and must not

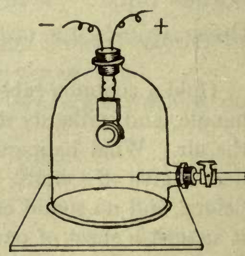


FIG. 189. — If a bell is rung in a jar containing air, the sound grows fainter and fainter as the air is removed.

touch anything but the cans. A waxed linen thread can be used instead of the string, also a fine copper wire. Sound will not be carried through a **vacuum** (see Fig. 189). Sound travels through the air much more slowly than light, but even so it goes about **1126 feet a second.** About how long will it take to travel a mile? What is the speed of light? If you hear the thunder caused by a flash of lightning 10 seconds after you see the flash, how far away is the flash? Sound travels in **waves** that spread out in all directions (see Fig. 190) from the sounding body.

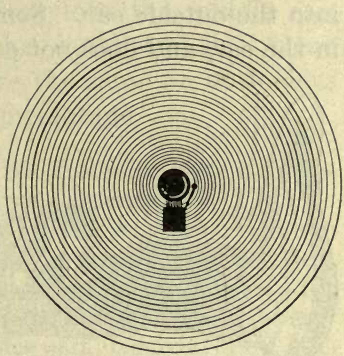


FIG. 190. — Sound is carried by the air in great spherical waves, except as their shape is changed by objects in the way. Why does a sound grow fainter with distance?

When we say that **sound** travels 1126 feet a second, we do **not** mean that the **air particles** travel that far. They may move only a **very short** distance, but they give their **motion** to the particles next to them, and these pass the motion to those still farther on. So the **wave** of sound travels great distances, while the air particles move only a short distance.

266. How Do We Hear? — Think how wonderful our hearing is. The **ear**, our instrument for receiving sound waves and for giving the sensation of hearing to our brain, is just a small cavity in the bone at the side of the head, but much of our pleasure, as well as usefulness in life, depends upon it. Therefore we should take care to prevent defective hearing. School children who seem dull and stupid are often suffering from bad hearing. If you have the earache or cannot hear easily, you should see a good physician immediately. Never remove the wax from your ear with a pointed instrument. Nature provides for a gradual removal of wax by pushing it out into the outside ear. Sometimes wax forms a hard lump in the ear, and does not come out easily. Then a doctor should be the one to remove it, as he can do it skillfully, without injury to the delicate ear tissues.

FIG. 191. — The ear is a wonderful mechanism for carrying sound disturbances from the outer air to the nerve of hearing and then to the brain.

The ear is composed of **three parts**, namely: the **outer** ear, the **middle** ear, and the **inner** ear (Fig. 191). The sound waves are caught in the funnel-shaped outer ear, and pass through the **auditory canal.** The auditory canal is really a part of the outer ear, and leads to the middle ear, from which it is separated by a *membrane* (the **tympanic** (tĭm-păn′ĭk) or "drum" membrane). The middle ear is called the **ear drum.** The membrane stretched across the auditory canal corresponds to the **drumhead.** To it is attached a small bone commonly called the **hammer.** This is joined to another bone, the **anvil**, which in turn is fastened to another, the **stirrup**. This chain of three bones reaches across the middle ear, and the last bone rests against the membrane separating the middle ear from the inner ear. Another canal, called the **Eustachian** (yūs-tāk'ĭ-ăn) **tube**, forms a passage from the **throat** into the middle ear. There is no membrane over this canal, and it is there simply to make the air pressure the same on both sides of the drumhead, or tympanic membrane.

To understand the way in which the Eustachian tube helps the tympanic membrane, perform the following **experiment**:

Take a clay pipe such as you use in blowing soap bubbles, stretch a thin rubber membrane moderately tightly over the bowl, and tie it securely. Then blow a little air through the stem of the pipe. The air makes the membrane **bulge out**, and if the rubber is fastened tightly enough at the edges, it stretches until it bursts. Now if an **equal amount** of pressure were being put upon the rubber from the outside, the thin sheet of rubber would not bulge either way. It is the same in the ear. When we hear a loud noise, great sound waves rush into the ear and hit the tympanic membrane, making a pressure upon it. At the same time, other parts of the waves enter the nose and mouth and go up the Eustachian tube. There they **equalize** to some extent the pressure on the outer side of the membrane, so that the membrane is not in danger of being broken. Of course the pressure is not **entirely** equalized, or there would be no vibration of the tympanum, and we should hear no sound. Often earache is caused by a bad sore throat, because the Eustachian tube is swollen and cannot do its work properly. In rapidly ascending an elevation, such as Pikes Peak, why do you feel better if you open your mouth? When cannon are being fired, the gunners near by are taught to open their mouths, so that the pressure at the time of the explosion will be nearly the same on both sides of the tympanic membranes of their ears.

The **inner ear** is filled with liquid. The first part of it is called the **vestibule**, and the end is a snail-shaped canal called the **cochlea** (kŏk′lē-ă). In this part are the **fibers** of the **auditory nerve**, or nerve of hearing. All the rest of the ear exists for this part. The sound waves are caught by the outer ear and passed down the auditory canal, causing the tympanic membrane to vibrate. The three middle-ear bones are set to vibrating, because the first is attached to the tympanum. The last bone causes a vibration of the membrane between the middle ear and the inner ear. This membrane moves the liquid in the inner ear. The nerves in the cochlea register the movement of the liquid, and send a **sound message** to the brain. Then we hear. Can you trace the sound wave from the time it is caused by the moving tuning fork until we hear the sound?

In the inner ear there are also found the **semicircular canals**. These are not hearing organs, but give us the sense of **balance**. By them we know when we are standing erect, when leaning, and in what direction. Does an aviator have any special use for these?

267. What Causes an Echo? — Much as a ball thrown against a wall *bounds back*, and as a ray of light strikes a mirror and is reflected back, so the air vibration we call sound strikes a surface and is thrown back again. We call this **echo**. If we stand in an open place and call, we often hear our call come back to us after a second or two (see Fig. 192). We sent the sound wave out into the air; it traveled through the air until it struck a cliff, or a side of a building, or a wall, or some other surface. There it was turned and sent back to us. By the time the *repeated* call returns, the first call has been heard. Now it is heard a second time in its echo.

FIG. 192. — The sound waves that come to us as an echo take a definite time to go to the reflecting surface and back again.

In a **small** room the sound waves strike the wall and return so quickly that the echo mingles with the original sound, and we do not hear the echo. In some **large** halls the sound waves are reflected back in such a way that you receive the echo of one word while another is being spoken. This is very confusing; hence an architect tries to construct his walls in such a manner that the reflecting surfaces do not give an echo. **Hanging draperies** are often used to break such an echo; so are **wires** strung across a hall. The walls of a hall, if properly built, aid a speaker by their reflecting surfaces. That is why it is easier to speak indoors than it is in the open. In a mountainous country, a sound is thrown from one cliff to another and may be heard many times before it finally dies away. The rumbling of thunder is the original sound combined with several echoes made when the first sound is reflected back from clouds or the earth.

268. What is the Difference between Noise and Tone? — When a chair is knocked over, it sets up vibrations in the air, but the waves are irregular, depending upon how many things the chair strikes. We hear a **noise.** But if a violin string is touched by the bow, the string vibrates **regularly**, with the same time between every two vibrations. Thus regular waves are set up in the air, and produce a pleasant effect upon the ear. The regular vibrations make a **tone.** Noise is a confused mingling of sound waves, and has an unpleasant effect upon our ears. **Any hard body**, such as a dish, a glass, a stone, a piece of steel, a piece of iron, or a block of wood, has a distinct tone when struck. Prove this by experiment. What is a **bell?**

The greater the number of vibrations in a second, the higher the **pitch** of the sound. " Middle C " of a piano is a wire vibrating 256 times per second. The **human voice**, from lowest bass to highest soprano, ranges from 80 to 1000 vibrations a second. The human ear cannot hear a sound which is produced by more than about 40,000 vibrations a second.

269. What are the Classes of Musical Instruments? — Name all the **kinds** of musical instruments you can think of (see Fig. 193). Which really consist of vibrating string or wires? We call these **stringed** instruments. Which ones consist of a vibrating column of air? We call them *air-chambered*, or **wind**, instruments. What causes the sound of a toy whistle?

In the air-chambered instruments we make use of both open and closed **pipes.** You have all found that you can make a whistle by blowing over the open end of a hollow tube of glass, wood, metal, or other material. The pipe organ makes use of such tubes, or pipes. Other wind instruments are the flute, clarinet, bugle, cornet, and trombone. What kind of instrument is a phonograph?

To make the different notes on a **flute**, the player opens holes in the side of the instrument; thus he makes air columns of different lengths vibrate as he blows into the instrument. In the **trombone** the player slides portions of one single pipe back and forth, and so

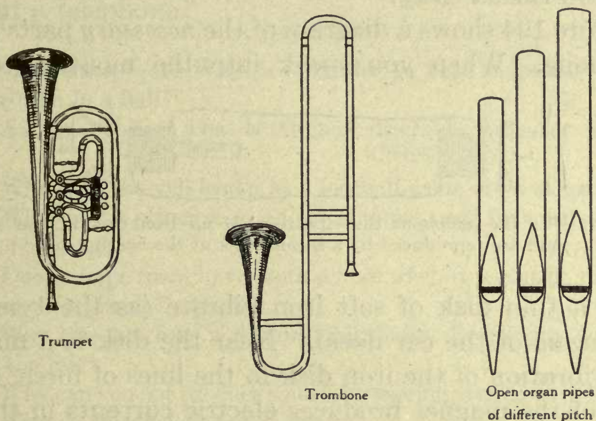


FIG. 193. — Three wind instruments, which are devices for setting air columns of different lengths in vibration, so as to produce different notes.

gets the different air columns that are needed to give the different notes. A **pipe organ** must have a different pipe for each note.

Each instrument has its own **tone quality**. When the number of vibrations is the same in two instruments, as in the bugle and the piano, the sounds have the same pitch, or note; but the **quality** is so different that you have no trouble in telling the note of the one instrument from that of the other. In the same way the quality of different human voices differs so much that you can tell your friends apart by their voices.

270. How Does a Telephone Carry Sound? — The sound instrument which, next to the human voice and ear, has built up the commercial, the industrial, and the social life of today, is the **telephone.** This is an age in which things must be done swiftly, and the telephone is one of the things which has made speed possible. The telephone was invented in 1875 by Alexander Graham Bell and Elisha Gray.

Figure 194 shows a diagram of the *necessary* parts of the telephone. When you speak into the mouthpiece you

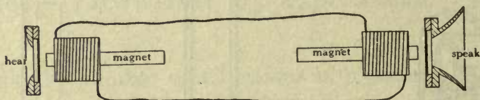


FIG. 194. — In the telephone the vibrations of an iron disk at the speaking end are reproduced by a second disk at the hearing end.

make a thin **disk** of soft iron vibrate (as the tympanic membrane of the ear does). Near the disk is a **magnet.** The vibration of the iron disk in the lines of force, or the field, of the magnet produces **electric currents** in the coil around the magnet (see §§ 218 and 236).

These currents are carried over the wire into the coil in the receiver of the telephone at which your friend is listening. Inside of this **second** instrument there are also a **coil**, a **magnet**, and a **disk.** The incoming currents cause the lines of force of the magnet to become changed, so that the disk is set to **vibrating** in the receiver. The vibrations of the second disk are exactly the same as those of the first disk. Therefore, the sound heard at the receiver is exactly like the one made in the original mouthpiece. It is interesting for us to understand that one end of the telephone resembles a **dynamo** and the other end a **motor**. In one end motion is changed into an electric current; while in the other an electric current is changed into motion. Tell which is which.

Have you ever stopped to think how many extra steps would be caused, if you, your neighbors, the grocer, the business man, in fact everyone, were suddenly to be without a telephone?

271. Exercises. — 1. Why is it harder to hear a speaker in the open air than in a hall?

2. Ask an architect what is the most desirable shape for an auditorium.

3. Why does the yell leader at a football game use a megaphone?

4. What is the principle of an ear trumpet used by a person who is hard of hearing?

5. Does a large room have more echoes when it is empty, or when it is filled with people? Explain.

6. Why can you hear a distant train better by putting your ear against the rail?

7. Why can you not produce a noise by waving your arms in the air?

8. Why do telephone wires "hum"?

9. Why does the wind "whistle"?

10. How do locusts and katydids make their shrill notes?

11. How are phonograph records made? How do they reproduce sounds?

12. What makes the different notes of a piano? Of a harp? Of a violin? Of a flute?

Summary. — **Sound** is due to the **vibration** of bodies. It travels through the air at about 1126 feet a second. It also travels through other gases as well as liquids and solids, but it does not go through a **vacuum**.

The **ear** is a delicate organ for carrying the sound waves to the sensitive nerve endings of the **inner ear**, so that the **auditory nerve** may carry the sound message to the **brain.**

An **echo** is the bounding back of sound waves to the one making the sound.

Tone is due to **regular** vibration of the sounding body; **noise** is the result of **irregular** vibration.

Musical **instruments** may be **stringed** instruments or **wind** instruments, or vibrating **metal**, as a bell.

A **telephone** is an instrument in which a **disk** of soft iron is made to vibrate near an **electromagnet** and to cause disturbances in the **current** passing through the coil. These disturbances extend to the electromagnet of the **receiving** instrument and cause a second disk to repeat the vibrations of the first one.

CHAPTER XXIX

MAN'S SIMPLE MACHINES

272. How Does Man Lighten His Work? — A few generations ago, if you had gone into a cornfield in the spring, you would have seen oxen pulling a crude wooden plow (see Fig. 2, § 5) which just stirred the soil of one row. The farmer himself, probably stooped and tired, would have been walking beside the team. Today the plow is a **steel machine** (see § 183, Fig. 98) which digs deep and turns over the soil of several rows. The farmer rides comfortably in a seat which is provided with springs. Perhaps four horses or a tractor are pulling the plow. This is only one way in which man has made his work easier.

Man has within himself **energy**, or the power to do work; this is derived from the oxidation of his food (see § 188). But as he became more and more civilized, he found that there were many devices, or tools, with which he could do his work without using so much of his own energy. He could also do much greater tasks than his own strength made possible. We have already spoken of the plow. When man wanted to lift a load of hay into a hayloft (Fig. 195), he learned to use a **pulley** and **rope**. It is easier to pull *down* on the rope than to push *up* on the weight. Why? Does a man's own weight help him? Man also learned to pry a stone out of the ground with a **crowbar** (Fig. 196), instead of lifting it out. He learned to split logs with an **ax** and a **wedge** (Fig. 210, § 279).

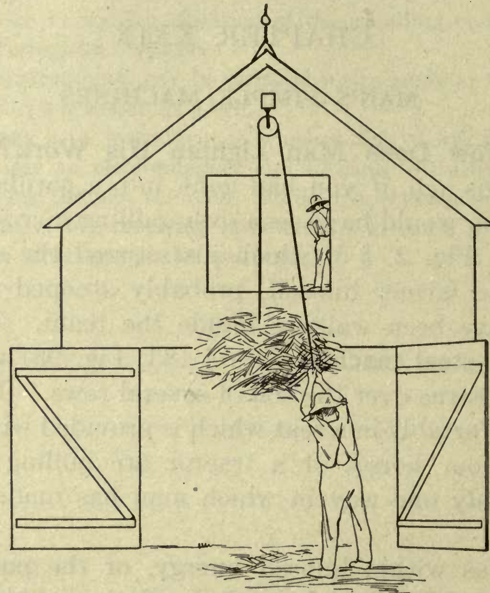


FIG. 195. — By using a pulley and a rope, a man can lift a weight more easily than by carrying it. Can a man lift more than his own weight in this way?

If he wished to move a heavy load, he learned to put **rollers** under it, instead of trying to drag it along the ground.

273. What Advantage Do We Get from Machines? — Let us think of this problem: How can we get a 200-pound barrel of flour into a wagon without lifting the whole weight of the barrel? See Fig. 197. Suppose that we use a plank 15 feet long, and that the higher end, which rests on the wagon, is 3 feet above the ground. How does this help us? We roll the barrel 15 feet up the

FIG. 196. — By using a crowbar with a support a man can lift a heavy stone from the ground.

plank to raise it 3 feet from the ground; that is, we roll it **five** times as far as we need to lift it. What is the value of doing this? The value is that we need exert only $\frac{1}{5}$ as much force as we should use to lift the barrel

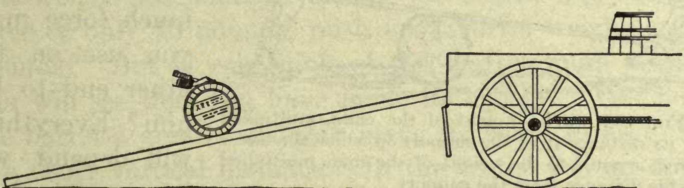


FIG. 197. — By rolling a barrel up a long, inclined plank a man need not exert nearly the force he would need to lift it into the wagon.

directly into the wagon. So a force of 40 pounds will roll a 200-pound barrel up such a plank. Now a grown man can easily exert a force of 40 pounds, although he might not be able to exert one of 200 pounds.

Do we use the principle of the **inclined plane** in other ways? Think how much easier it is for us to climb a gradual slope than a steep one, or a stairway with low "risers" rather than high ones. Whenever we climb a sloping ladder, or a train climbs a grade in the mountains, or a horse pulls a load up a hill, the inclined plane is being used. But in going up a slope, we make an **exchange**: we go farther than if we went straight up.

Have you ever seen some of the famous railway grades, like the letter-S curve of the Pennsylvania Railroad near Altoona?

274. Is a "Teeter" a Machine? — Let us think of another problem: Suppose that you weighed 50 pounds, and that you made a "teeter" 15 feet long (Fig. 198). If your father, weighing 200 pounds, were on one end, how much force must you use on the other end to lift him? Everything will depend, will it not, upon where you put the log under the teeter board? If you put the middle of the board over the log, you will need to weigh a little more than 200 pounds yourself, to be able to bring your end of the board down. But you are supposed to weigh only 50 pounds. If you should put the log 5 feet from your father's end of the teeter, and 10 feet from your end, you would need to weigh 100 pounds to lift

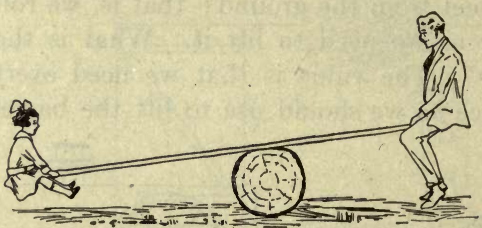


FIG. 198. — The weight of the child, multiplied by its distance from the support on which the teeter turns, is equal to the weight of the man multiplied by his distance from the support.

your father. That is, as your distance from the log would be twice your father's you must weigh at least half as much as he to lift him. But if the log is 3 feet from your father's end of the board, and 12 feet from your end, you, with your 50 pounds, could balance your father, who weighs 200 pounds. However, **note** one thing **carefully**: Suppose you and he teeter up and down, how far must you move downward to lift your father one foot? You must go down 4 feet, must you not? To put it in another way, he by going down one foot can raise you 4 feet. Which gets the longer ride on the teeter, the heavy person, or the light one?

As you first think of these two cases of the sloping board and the teeter, you may imagine that in some mysterious way you have **made energy**; if not, how is it that you, weighing only 50 pounds, can lift your father, who weighs 200 pounds; or how can a man who exerts a force of only 40 pounds, push up a barrel weighing 200 pounds? But if you think of the matter more deeply, you will see that you have made no energy. You push the barrel a greater distance *along the board* so as to lift it a short **vertical** distance. In the teeter you go down a greater distance to let your father go up a shorter distance. These facts show us what the law of machines is: *The power put forth, multiplied by the distance the power moves, is equal to the weight lifted, multiplied by the distance the weight moves.* In using machines, then, we make an exchange of energy; we never get something for nothing.

275. How Many Machines Do We Use? — This question does not mean how many *pieces of machinery* are there in the world, but how many "simple machines" can we find in all the machinery and tools which man uses to help him in his work. The answer is that there are **six** of these **simple machines.** The combinations of machinery which are used in such wonderful devices as the steam engine, the weaving loom, and the clock, are made up of these six in one form or another. Thus the teeter is a form of a simple machine which we call the **lever**; the sloping plank, up which we roll a barrel, is an example of another simple machine called the **inclined plane.** All six of them are given in the following list:

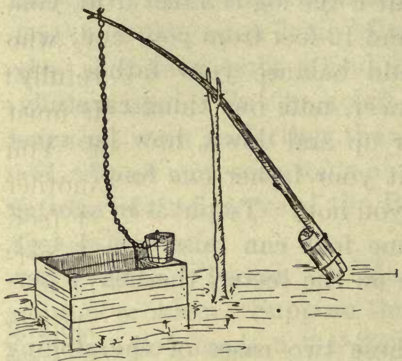


FIG. 199. — The wellsweep is a lever having a weight at the longer end, to help lift the pail of water out of the well.

(1) The lever
(2) The pulley
(3) The wheel and axle
(4) The inclined plane
(5) The wedge
(6) The screw

The simple machines helped man greatly in his work, but at first he had to exert all the force himself (see Fig. 199). The pioneers of every land have had to do the same (see Fig. 200); but whenever possible men have used the strength of **animals** to exert force for them by harnessing the animal to the machine. What animals have they used? Later still, men learned to use the energy which nature has stored away in wind, water power, coal, and electricity, and with this energy operated their machines. Men's work could thus be done more easily and more quickly. Think how women's work has been lightened by the improvements in the weaving of cloth, for example. At first, cloth was probably made much as we make wicker baskets; then the hand-operated, large, wooden weaving looms (see Fig. 201) were used. Now we use steel machines which are run by electricity or water power, and weave cloth with very little use of human muscular energy.

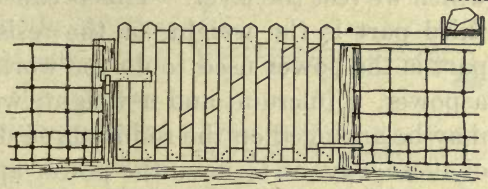
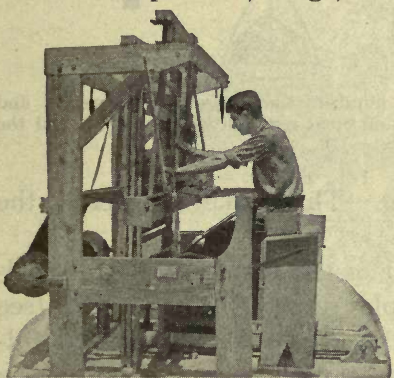


FIG. 200. — The weighted gate is a lever with a heavy stone on one end of it, to balance the weight of the gate.



(*Courtesy of the Biltmore Industries, Asheville, N. C.*)

FIG. 201. — An old-fashioned weaving loom, on which cloth and rugs may be woven.

276. How Does a Lever Help Us? — We learned in § 274 that the teeter is a lever; the crowbar is another (see § 272). When you use a plank to pry an automobile out of a mudhole, or a fork to pry a cork out of a bottle, you see a lever in action. In every lever there are **four**

parts to be considered. Suppose it is a crowbar. There is, first, the strong, rigid bar. Second is the **support** on which we rest the lever. This is called the **fulcrum**. The third part is the **weight**, or the resistance. The fourth part is the **power** used to do the work. Now, if we have a power, a fulcrum, and a weight, we can see that they may be arranged on the rod in **three** different ways. One of these ways is to have the power applied at one end of the lever, the weight to be lifted at the other end, and

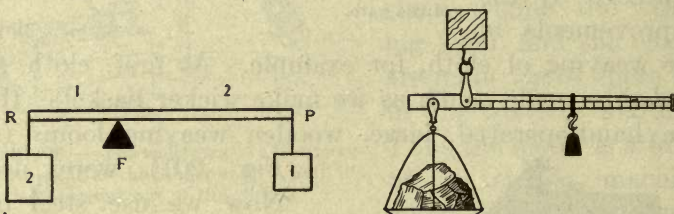


FIG. 202. — The product of the numbers that represent the weight and weight arm is equal to the product of those representing the power and the power arm.

the **fulcrum between** them. This makes a lever of the **first class** (see Fig. 196).

The teeter is also a lever of the first class. Most balances and scales are examples of the first-class lever (see Fig. 66, § 98, and Fig. 202). In the balances the fulcrum, or **bearing**, is in the center; from one end of the beam hangs the pan for the object to be weighed, and from the other end hangs the pan upon which we put the weights (the power).

The **second-class** lever (Fig. 203) is well represented by the **wheelbarrow**. In this case the **weight** is **between** the fulcrum and the power. Where was the fulcrum of the first-class lever? In the wheelbarrow (Fig. 204) the axle serves as the fulcrum, the weight is in the body of the wheelbarrow, and the power (our hands) is applied at the handles.

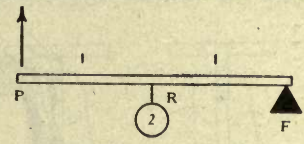


FIG. 203. — In the second-class lever the fulcrum is at one end and the power at the other, with the weight between the other two.

What other machine can you think of which is a second-class lever? What is the **nutcracker** — the kind which holds the nut between the two handles, so that we break the nut by pressing the handles together?

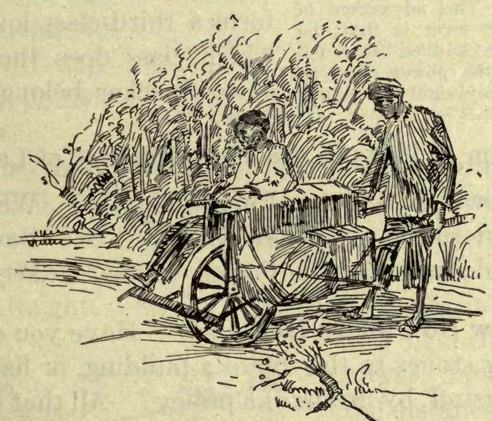


FIG. 204. — How they carry goods and passengers on wheelbarrows in China.

In levers of the **third class** the **power** is **between** the fulcrum and the weight. How does this compare with the other two classes?

Do you think that machines are used only by *man?*

No; **nature** uses them too. The human **forearm** (Fig. 205) is a third-class lever. The muscle which exerts the power is the **biceps** muscle of your upper arm. It contracts, and draws up a weight which you hold in your hand, at the free end of the lever; while the support, or fulcrum, is at your **elbow.**

FIG. 205. — The advantage of this third-class lever is that the power can be applied near the fulcrum, but the power must be greater than the weight it is to lift.

Examine a pair of sugar tongs, and pick up a lump of sugar with them. Do they form a third-class lever? To which class does the beak of a woodpecker belong?

Relation of Parts in the Three Classes of Levers

(1)	Power . . .	Fulcrum . . .	Weight
(2)	Fulcrum . . .	Weight . . .	Power
(3)	Fulcrum . . .	Power . . .	Weight

277. How Do Pulleys Help Us? — Have you ever seen men raising stones to the top of a building, or flags to the top of a flagstaff, by means of a pulley? All that is needed is a rope passed over a pulley wheel. The object to be raised is fastened to one end of the rope, and we pull downward on the other end (see Figs. 195, 206, and 207).

Is there any **gain** in power by the simple pulley? No, of course not; the only advantage is that we pull **down** instead of pushing **up.** But the case is different if we use a combination of two pulleys, as in Fig. 206, *B*. Here **two** lengths of rope support the weight, while we pull down on the third length. Do you see that we must pull downward **twice** as far as we can raise the weight? Is there any gain in this? The gain is that a force of **one** pound used as power will support **two** pounds of weight.

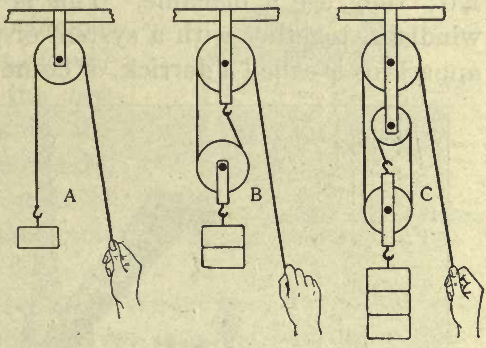


FIG. 206. — One **simple** and two **compound** pulleys. In *A* a one-pound pull on the one cord will lift 1 pound on the other cord. In *B* and *C* a one-pound pull will lift 2 and 3 pounds respectively.

If we use **three** pulleys to support the weight, as in Fig. 206, *C*, **one** pound can support **three** pounds, and so on. However, we must pull down three feet of rope for every foot we lift the weight. So in the pulley, as in the lever and inclined plane, the power, multiplied by the distance the power moves, is equal to the weight, multiplied by the distance the weight moves.

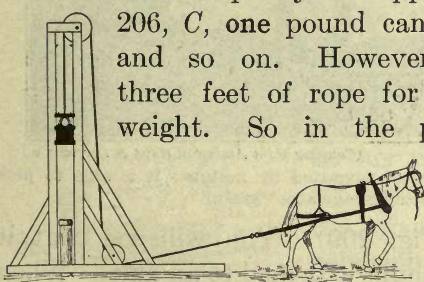
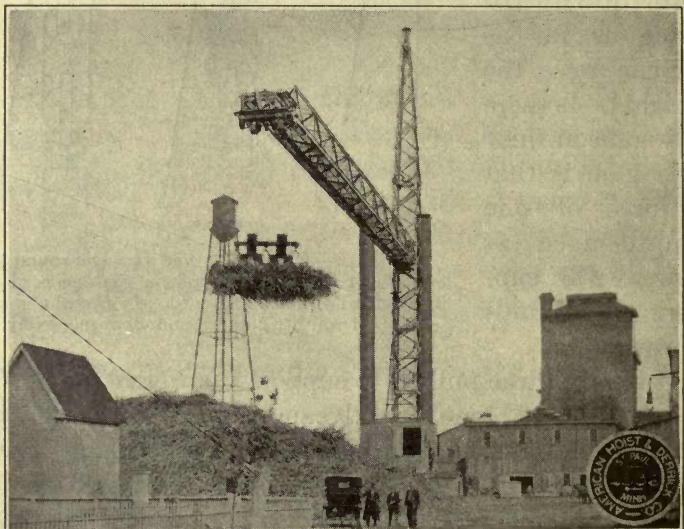


FIG. 207. — This **pile-driver** has a simple pulley, but there is a second wheel near the ground, so that the horse can pull in a horizontal direction.

278. Why Do We Use a Wheel and Axle? — Have you ever seen workmen raising large timbers, or steel girders, or loads of bricks or stone, to the top of a tall building? Do they carry these materials to the top? No; they use a machine. This is usually a **winch**, or **windlass**, together with a system of pulleys. The whole apparatus is called a **derrick**, or **crane** (Fig. 208).



(*Courtesy of the American Hoist & Derrick Co.*)

FIG. 208. — A powerful modern crane operated by motors; it is able to pick up 3 tons of sugarcane at a "grab."

Examine a winch (Fig. 209). You will see that it consists of a **crank**, or handle, attached to an **axle**. When the crank is turned, a rope or cable may be wound up on the axle. But as the handle of the crank must be turned through a **large** circle to wind a **little** of the rope on the axle, a small force applied to the crank will lift a great weight attached to the axle.

The winch is a form of the simple machine called the **wheel and axle.** Examine the works of an old **clock.** Do you find any cases of the wheel and axle principle there? Why is it used? Do you see that the law of machines is true in the case of the wheel and axle, as well as in the case of the lever, inclined plane, and pulley?

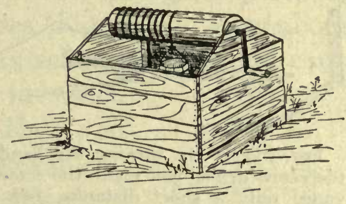


FIG. 209. — Another way of raising water from a well (see Fig. 199).

279. Of What Use is a Wedge? — Have you ever seen a woodman split a great log into boards or rails? He uses a block of hardwood, or of iron, that is thick on one side, and tapers down to a thin edge (Fig. 210). This simple machine is called a **wedge**; it is really a double inclined plane.

FIG. 210. — How a log may be split in two.

The thin edge of the wedge must be driven into the log by means of a hammer, or **maul.** The deeper it is driven in, the farther the two halves of the log are forced apart. It is easy for the woodman to overcome the **cohesion** of the wood (see § 107), if he need force the wood apart only a **little** way at a time. Can you see that the more slender the wedge is, the farther he must drive it in, but the greater is the force with which the wedge pushes the wood apart?

280. Of What Use is the Screw? — Have you ever climbed to the top of a tower or a lighthouse? You could have climbed a ladder straight up to the top, but this would be very tiring, and would take a great deal of effort. In most towers you will find a spiral stairway which winds around and around the tower. In using the stairway you will have to walk many times the distance to the top, but you will not find yourself nearly so tired when you reach the top, because the ascent is so gradual.

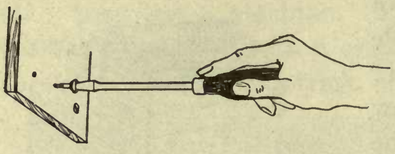


Fig. 211. — By turning the handle of the screw driver you make the screw advance only a short distance, but with great force.

Examine a metal **screw**, or a screw bolt, such as is used to hold boards, or pieces of metal, together; is not the **thread** of the screw, also, a spiral inclined plane? When you use the screw driver (Fig. 211), your hand must go through a **large** circle to make the screw move forward the short distance **between** the threads. But as a result of this great difference, a small force applied on the handle of the screw driver exerts a very great force on the threads, and forces the screw into the wood.

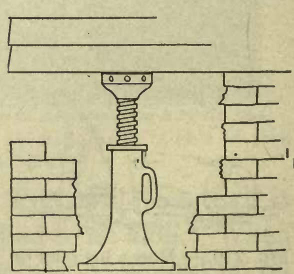


Fig. 212. — How a jackscrew may be used to lift a house.

You are familiar with the **jackscrew** used to raise a house (Fig. 212), or a wagon in repairing its wheel, or an automobile in changing tires.

Compare the force you must exert in using the jackscrew with the weight you can lift with it.

The screw is used also to produce the great **pressure** needed in book and letter presses (Fig. 213). How about the **baling press** in which many schools collect and compress their waste paper, and in which farmers bale **hay** and **straw**? Have you ever used a screw-press nut-cracker?

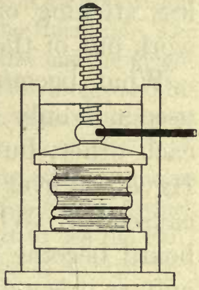


FIG. 213. — The book press has a screw to give great pressure.

281. Why Do We Oil a Machine? — Do you know of a surface that is perfectly **smooth**? No; not even the finest workmen can get a surface free from all roughness, and every engineer knows that although the bearings of his engine are made as smooth as possible, yet each of the two surfaces which rub together wears the other down, instead of sliding perfectly over it. We have already learned (see § 103) that this rubbing together is called **friction**.

From Fig. 195, § 272, we learned how we can lift hay into a hayloft by means of a pulley and a rope. Could we not lift the hay by passing the rope over a horizontal **pole** instead of the wheel, and then pulling down on the rope? Of course we could, but we would have to pull much harder, because there should be so much more friction between the pole and the rope than between the pulley wheel and its axle. What are some other illustrations of the fact that **rolling friction** is less than **sliding** friction? How about the wheelbarrow? Why are there casters on furniture? Wheels on wagons and cars?

How is the friction in a **sewing machine**, or a carriage, reduced as much as possible? You know that we use **oil** or grease; we do the same in a railroad car, an automobile, or a wheelbarrow. The oil and grease we use permit the two surfaces that touch each other to pass with less sticking or rubbing; therefore we get more useful work out of the machine.

What becomes of the energy lost in friction? It is used not only in rubbing off the two surfaces that pass each other, but is partly changed into **heat** (see § 234). Have you ever heard of a "hot box" on a train? What causes it? Why does a **drill** used in making a hole in a board become hot? So far we have thought of friction only as it is a **disadvantage**, and causes us to get less work from a machine than we ought to. Is friction ever necessary? Suppose the rope passing over the wheel of a pulley did not stick a little to the wheel, in order to turn it? Could you roll a barrel up an inclined plane, if the barrel did not stick somewhat to the plane? Is it easy for you to walk upon a highly polished floor? Why not?

282. Exercises. — 1. How many simple machines can you discover in an egg beater? A door knob? A pair of cutting pliers? A window shade?

2. What simple machines do you make use of when you open a weighted window, close a door against the wind, draw a nail with a claw hammer, crank an automobile engine, cut meat with your knife, saw a board, take off the cover of a Mason jar, turn a key, or turn a grindstone?

3. Why are casters put under tables or other heavy furniture? Why are glides used instead in some cases?

4. Examine several of the can-openers used for "tin" cans, and

find one that is a lever of the first class; also one of the second class. Describe each. Which is the more efficient?

5. What kind of lever is a full suitcase when you are trying to close it? The pump handle shown in Fig. 86, *A*, § 135?

6. With a pair of shears try to cut a match stick. Where must you place the stick in order to cut it most easily? Tell why.

7. Place a book before you, and put upon the cover an iron weight or a heavy stone. Lift the cover. What forms the fulcrum? The power? The weight? What class of lever is it? Now put the weight near the free edge of the cover, grasp the cover near the hinge, and lift it. What class of lever is the cover now? In which case is it easier to lift the cover?

8. Examine a screw eye, and try to force it into wood by means of your fingers. Then try to do so with the help of a long nail which is put through the "eye." Of what advantage is it to use the nail? Why is it easier to force a screw into wood by the use of a carpenter's brace than with an ordinary screw driver?

9. How many different kinds of wrenches can you find in a hardware store? For what is each used? How many kinds of saws can you find?

10. How many different kinds of machines could you use in cracking a nut? What simple machine is there in a bread-mixer?

Summary. — Man lightens his work by means of **machines**.

The **advantage** we obtain from machines is that we can use a **small effort** through a **great distance** to exert a **great force** through a **small distance**, or we can make the reverse exchange, if we wish; but we **never** create energy, and we never get something for nothing.

There are **six** simple machines.

Levers may be of the *first, second,* or *third* class. In the first class the **fulcrum** is **between** the **power** and the **weight**; in the second class the **weight** is **between** the other two; in the third the **power** is applied **between** the other two.

In a compound **pulley** we pull a good deal of rope over the pulley wheels in order to lift a great weight a short distance.

The **winch** is a form of the **wheel and axle**. By means of it we use a small force upon the handle, or crank, to lift a great weight attached to the axle.

The **inclined plane** is a machine in which we move a heavy object a long distance up an incline in order to lift it a short **vertical** distance.

A **wedge** is a double inclined plane.

A **screw** is a spiral inclined plane.

Friction is the resistance one body meets when moving in contact with another. The **lost motion** due to friction is changed largely into **heat**. Oils and greases (lubricants) are used to make friction as small as possible. **Rolling** friction is less than **sliding** friction.

CHAPTER XXX

MAN'S GREAT MACHINES

283. How Does a Sailboat Use the Wind? — Have you ever watched a sailboat (Fig. 214) making a landing?

(Courtesy of A. M. Lythgoe, Metropolitan Museum of Art, New York City.)

Fig. 214. — Boats on the Nile.

Did you notice that no matter from what *direction* the wind was blowing, so long as there was a wind at all, the pilot could make the boat come to the dock? How is this done? We can easily understand sailing when the wind is blowing **behind** the boat. The sail is then only a large surface that receives the pressure of the wind, and as the sail is pushed through the air, it draws the boat through the water. But how can a boat sail in other di-

(*Courtesy of A. M. Lythgoe.*)

FIG. 215. — Traveling-boat, with sail set. Found by the Metropolitan Museum Egyptian Expedition, in March, 1920, in the tomb of the Prince Mehenkwetre, at Thebes, XIth dynasty (about 2000 B.C.). This boat is now in the Cairo Museum.

rections? To give the answer we must know that a sail-boat has not only a sail, but a **keel**. The sail makes use of the pressure of the air, but the keel uses the resistance, or **inertia** (see § 101), of the water to help direct the boat in its motion.

Put a wide board, **edge down**, into the water and try pushing it *sidewise;* you cannot easily do it. In the same way a keel helps a boat; it prevents the boat from being pushed sidewise by the wind. Sidewise motion is called **drifting.** If a sailboat drifts badly, the pilot cannot direct its course. In a small sailboat the keel is a movable board, which can be pulled up into the boat; it is called a **centerboard.**

Suppose that a sail is set as in *A* of Fig. 216, and that the wind is blowing from the direction shown by the *arrow;* the boat **cannot move** at all, because all of the wind slips past the sail without pushing against it. If

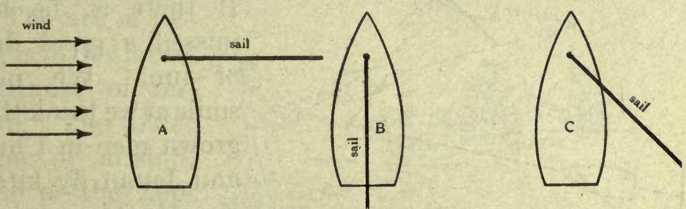


Fig. 216. — Three ways in which the wind may strike a sail.

the sail were set as in *B*, the boat could only drift slowly **sidewise**, with the keel resisting the boat's motion. But if the sail is set as in *C*, part of the wind's force is used in pushing the boat sidewise, with the keel resisting the motion, while another part of the force pushes the boat **forward** through the water. Of course a boat cannot sail directly into the wind, but by "tacking," or "beating against the wind" (Fig. 217), with the wind pushing first on **one side** of the sail and then on the **other**, a good boat can finally go wherever the pilot wants it to go.

What sort of machine shall we say a sailboat is? It is a device which man uses to go wherever he wishes on a water surface, whether the wind is a favorable one or not. By the use of sail and keel we can exchange rapid progress "before the wind" for slower progress "against the wind." What can you say of the effect of the sailboat upon the growth of early civilization?

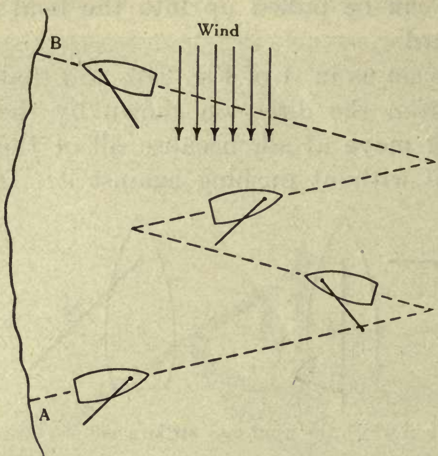


FIG. 217. — Positions of boat and sail in "beating against the wind."

284. Why Do Kites Fly? — Is there a boy who has not made and flown a kite? If there is, he has missed a great deal of fun. We may smile as we think that **grown** men in China and Japan fly kites; if we do this, we show ourselves ignorant of the fact that the wonderful **airplanes** of the present day are only great kites with engines inside them to drive them forward against the pressure of the air.

What raises a kite into the air? Is there a wind going upward from the earth? We learned that winds are **horizontal** currents (see § 79). In a sailboat part of the force of the wind tries to push the boat sidewise, while another part pushes it forward. In the kite (Fig. 218) part of the wind's force causes the **pull** on the string and part **lifts** the kite into the air. If the kite were held upright, and the wind were blowing directly against it, the kite could not fly. If the kite were held horizontal, the wind would slide past it, and it could not fly. But if it is inclined to the horizontal wind, as in the figure, it is lifted into the air.

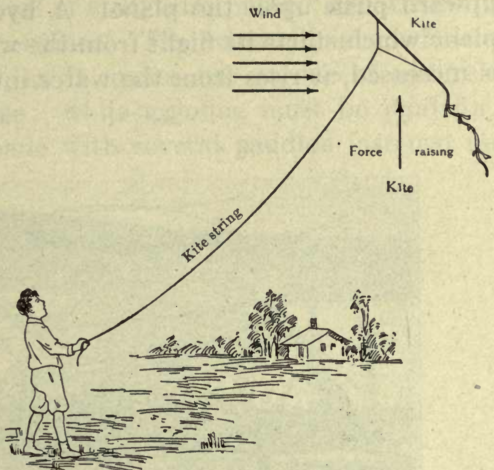


FIG. 218. — Part of the force of the horizontal wind raises the kite into the air.

285. Why Do Airplanes Rise? — The art of flying is man's latest **conquest** of nature. The older type of airship, such as the **Zeppelin** (Fig. 219), is a great balloon provided with motors to drive it, and with rudders for steering it. It is filled with a gas lighter than air, and rises for that reason. What gas is the best for making the airship light (see § 115)?

The **airplane** (Fig. 220) is, as we have already learned, a great kite, and the principle according to which it works is that of the **inclined plane**. The toy kite rises because part of the force of the moving air (the wind) pushes it upward. In the case of the airplane the air is at rest, and it is the plane that is in motion; but the **lifting force** is just the same; it is the resistance of the air through which the plane moves at such great speed. Part of this resistance acts directly against the forward motion of the airplane; but another part of it acts as an upward **push** upon the plane. A **hydroplane** is an airplane which starts its flight from the water. As its speed is increased, it rises from the water into the air. Would

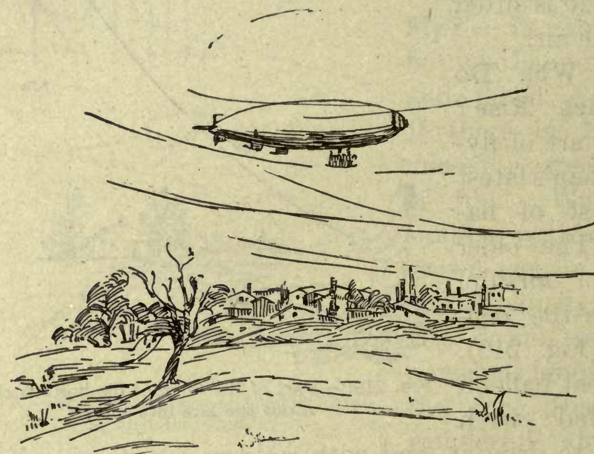


FIG. 219. — A dirigible airship.

an airplane rise more rapidly if it were moving **with** the wind, or **against** it?

Examine Fig. 14, § 19. Is the density of air at a height of 30,000 feet more, or less, than at sea level? Do you think that in order to reach and keep such a height, an airplane will need to go more, or less, rapidly than it would near the surface of the earth? Tell why.

286. Why Do Windmills Turn? — Have you ever been on an old-fashioned farm and seen how much work there is in just pumping and carrying water to the farm animals, the garden, and the house? Today much of this work is done by the **windmill** (Fig. 221). Prosperous farmers who have a great deal of stock also pump their water by means of gasoline engines. The windmill is much less expensive, however, as it makes use of one of nature's forces, which is free; while gasoline must be paid for. The windmill is made with several **paddles** fastened on

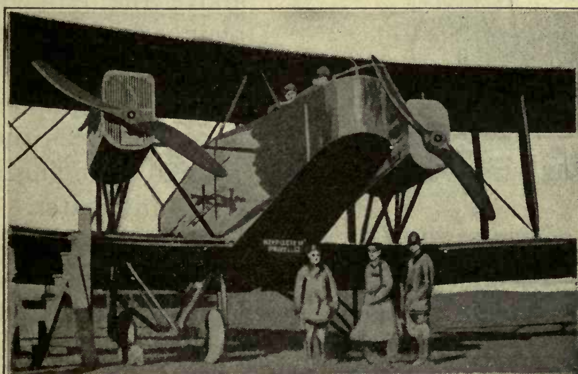


FIG. 220. — An airplane that carries aërial mail.

a **hub**, or wheel. The hub is turned by a **vane**, so that the paddles must always face the wind. Then, as with the sails of a boat, or the planes of an airplane, the wind's pressure on their inclined surfaces forces the paddles to turn. The revolving hub is connected with a **piston** that moves up and down in the pump (see § 135); water is thus raised out of the well.

The windmill runs constantly on windy days; but when a calm day comes, there will be no pumping done.

To prepare for the windless day, a high **tank** is provided. Water is stored in this tank when the mill is running. Such a tank makes a **water system** and plumbing possible in the farmhouse. The water leaving the tank has a **pressure** corresponding to its height above the ground. Explain this. Thus the farmer may have water running into tanks some distance from the well without pumping or carrying any water.

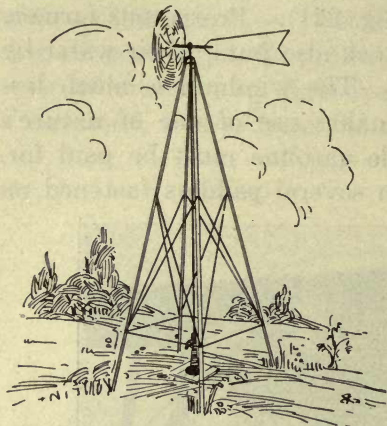


FIG. 221. — How we can use the force of the wind in pumping water.

In Alaska, windmills are used to operate **dynamos**, by which a current is generated to furnish electric light.

Make a pin wheel, and see how the air currents set it in motion.

287. How Has Man Harnessed Water? — About the first work done by machinery was done in mills which used **water power** (see § 236). Such mills were our first beginnings of factories. Water, pulled down by gravity, was allowed to strike the paddles of the water wheel and force it forward and around. Several types of water wheels are shown in Fig. 222, including the wonderful **turbines** (tŭr′bĭns) used in turning water power into an electric current. The revolving wheel is attached to other machinery. In the old days crude **saws**, and **millstones** and other forms of grain **grinders** were thus run. Now water power is used to run very complex machinery,

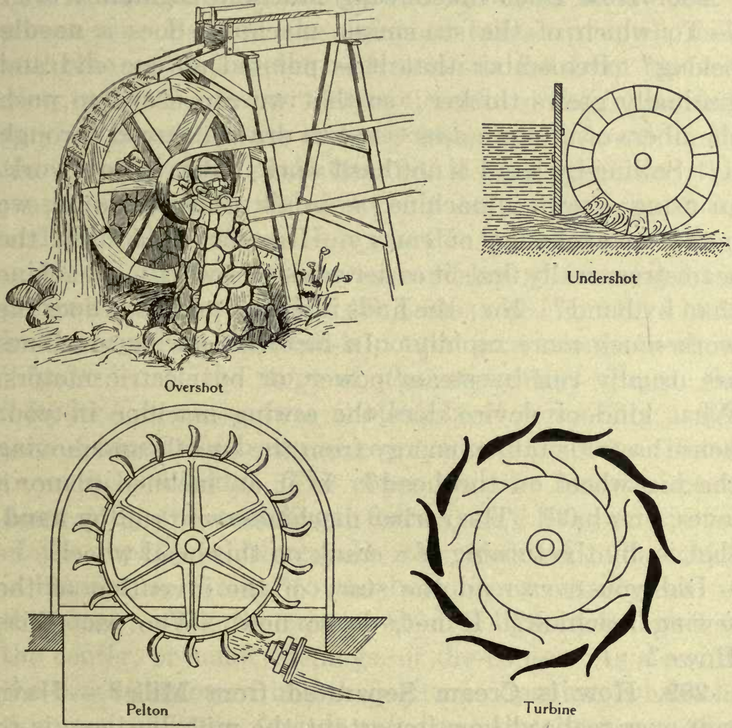


FIG. 222. — Kinds of water wheels: Overshot; Undershot; Pelton; Water Turbine in cross section.

as well as dynamos. Thus both the power of rushing water and of rushing air are valuable gifts of nature, which man may use to lighten his work. Do you think men will ever be able to use the power of the **tides** to do their work? Can you imagine that man may in the years to come harness **sunshine** more and more for his use?

288. How Does the Sewing Machine Lighten Work? — To which of the six simple machines does a **needle** belong? Remember that it is pointed at one end and gradually grows thicker; so that we can use it to push the fibers of a fabric apart and to draw a thread through it. Sewing by hand is not **hard** work, but it is **slow** work. In using a sewing machine, as in all other machines, we make an **exchange** of energy. Do you think that the seamstress really finds it easier work to sew with a machine than by hand? No; she finds it harder; but she does the work much more rapidly. In factories sewing machines are usually run by steam power, or by electric motors. What kind of device does the sewing machine in your house have for taking energy from the treadle and moving the big wheel on the head? Is it an inclined plane, a lever, or what? The earlier machines were run **by hand**, that is, by the turning of a crank on this head wheel.

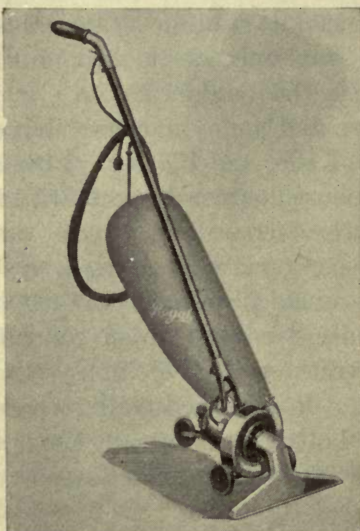
Did you ever read the story of the invention of the sewing machine? If not, do so now. Who was Elias Howe?

289. How is Cream Separated from Milk? — Have you ever realized how important the **milk** business is to the life of the community? The milk is used, not only directly as a food, but as the source of butter, cheese, milk sugar, and other products. As you know, the cream of milk contains a great deal of butter fat, and is used to make butter. How is the cream **separated** from the milk?

The old-fashioned way was to use a spoon, or some other form of *skimmer*. This is not entirely satisfactory, for the reason that while the cream rises to the top because it is lighter than the skimmed milk, not all of the cream comes up. Besides, the skimmer takes up much milk with the cream, so the separation is far from perfect. Now, when the farmer delivers cream to the butter factory, or **creamery**, the cream is tested, and is paid for by the exact weight of butter fat it contains. For this reason the farmer wishes to ship **only** cream (no milk) and **all** of the cream. How can this be done?

All the modern creameries, and many farmers, have **cream separators** (see Fig. 70, § 106, and Fig. 110, § 189). In this machine the milk is poured into a large **bowl**, or "feeder," at the top of the separator. From the "feeder" it passes into another bowl containing a system of **cones** which can be revolved from 5,000 to 15,000 times in a minute. The cones are like funnels upside down. By the **centrifugal force** (see § 105), or inertia, of the rapidly whirling milk, the skimmed milk, which is **heavier**, is thrown to the bottom, or outside rim, of the cones; while the cream, which is **lighter**, is forced to the center, or small openings, of the cones. As a result, the cream is forced out through one opening, while the skimmed milk is forced out through another. Thus they are **separated**. There is a very fine **strainer** in the separator, which collects all the dirt in the milk, and the amount of dirt, even in milk that has already been strained, is surprising. The separator is worth having just as a cleanser of the milk.

The skimmed milk may be made into cottage cheese, or it may be fed to pigs and chickens. It should not be wasted, for it contains a great deal of food material. Selling cream is a profitable business for the farmer who does not care to peddle milk or to make butter himself. However, enough **whole milk** should always be kept for the use of the family, and high prices should never tempt the farmer to sell all his cream. Why?



(*Courtesy of The P. A. Geier Company, Cleveland.*)

FIG. 223. — The outer air rushes into the vacuum cleaner, carrying the dirt with it.

290. How Does a Vacuum Cleaner Work? — Who could have foretold that we would ever sweep by the help of electricity? Yet that is just what we do when we use an electric **vacuum cleaner.** Such a cleaner (Fig. 223) consists of a **suction** apparatus and a long handle to guide it over the floor. The apparatus is run by a motor. There is a long **slot** in the apparatus, and in some forms a **brush** much like that of a carpet sweeper. There is also a **bag** for receiving the dust. The slot fits tightly against the floor, so that when the motor is running and the cleaner is sucking in the air, the air cannot come in at the **side**, but must be drawn **through** the rug or other material upon which the slot is resting. When the air is drawn rapidly through the material, it brings the dust with it; thus the material is cleaned. For cleaning rugs, carpets, draperies, mattresses, and such articles, a vacuum cleaner is very valuable, as it saves time and labor, and cleans more thoroughly than the older methods do. It also does less damage to the fabric. Why is it not easy to use a vacuum cleaner on hardwood floors which are not covered with rugs?

291. How Can We Wash Clothing by Electricity? — Of course you can see that we do not really clean rugs and the like **by electricity.** What we do is to create a rapid **air current**; this removes the dust. The motor which gives us the necessary motion is run by an electric current, but we might use other sources of power. So it is in the case of the **electric washer**; we use a **motor** to produce motion; it is most convenient for those who can get electricity to use an **electric** motor; but one run by water power or by a gasoline engine would do just as well.

Do you think the housekeeper really likes the coming of washday? The electric washer lightens the day's work. Both the tub and the wringer are set in motion by the motor (see Fig. 106, § 183); so that all the laundress has to do is to put the clothing into the washer, and then to transfer it through the **rinsing** waters, directing the machine to do the hard work of washing and wringing. If the laundress has electric irons, which she can use constantly without having to stop to change them, and has a drying press, or "mangle," for straight towels and other plain linen, she can escape most of the drudgery of the washday of the past. Will it not be a great day when **all** people, both rich and poor, can have modern labor-savers for their homes?

292. How Do Gases Cause Motion? — We have already learned that air expands when it is heated, and that if the heated air is held in, or *confined*, it produces pressure by trying to expand (see §§ 13 and 14). **Steam** and all expanding gases act in the same way as air.

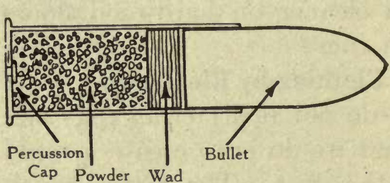


FIG. 224. — A cartridge is a device for producing a great deal of gas in a small space, and then using the gas pressure to do work.

Do you know how a **cartridge** "works" in a gun? It will show us in a small way how expanding gases work. The cartridge in modern firearms (Fig. 224) is partly filled with **powder**; the open end is then closed by a **bullet**. When the hammer of the gun gives the cartridge a blow, a "percussion cap" in the cartridge sets the powder on fire. When the powder "burns," as it does in a flash, a **gas** is formed, just as in the burning of wood or coal (see § 37). However, if the gas which is formed were **released**, it would take up perhaps **300** times as much room as that occupied by the powder. All this gas is in the cartridge, and held in a very small space. In its efforts to **expand** and find enough room for itself, it produces great **pressure**. The pressure is strong enough to drive the bullet out of the cartridge, and to send it rapidly through the air.

When water expands to form steam, the same principle is at work. Steam requires more space than water does: a cubic foot of water gives perhaps **1,600** cubic feet of steam. If the steam is held in a small place and not allowed to escape, pressure — **steam pressure** — is produced.

293. How Does a Steam Engine Run? — Think what an enormous influence the steam engine has upon our lives. Little by little its parts were invented until it obtained its modern form. Yet, complicated and important as the engines of stationary engines, steamships and locomotives are, they are simply devices for using the **force of expanding steam.** You have all noticed the cloud of **fog** coming out of the kettle of boiling water. Close to the nozzle of the kettle you see nothing; but the gas coming out is the real steam, which is **invisible.** For use in the steam engine, steam is produced in a boiler and is held in until it has a high pressure. Then it is allowed to expand, first on one side and then on the other side of the sliding **piston** (see Fig. 225). In the figure both positions are shown. Thus the piston is driven first **forward**, and then **back**, by the force of the expanding steam. The rapid backward and forward motion of the piston is changed to motion in a circle by means of a **shaft.** The **eccentric** turns with the shaft and moves the **valve** backward and forward; this motion controls the entrance of the steam that is to move the piston. You are familiar with the huge driving shaft on a locomotive. Do you know where the driving shaft of an automobile is? What is the use of the exhaust which is labeled in the figure? Why, do you think, does an engine have a large and heavy **flywheel** such as is shown in the figure?

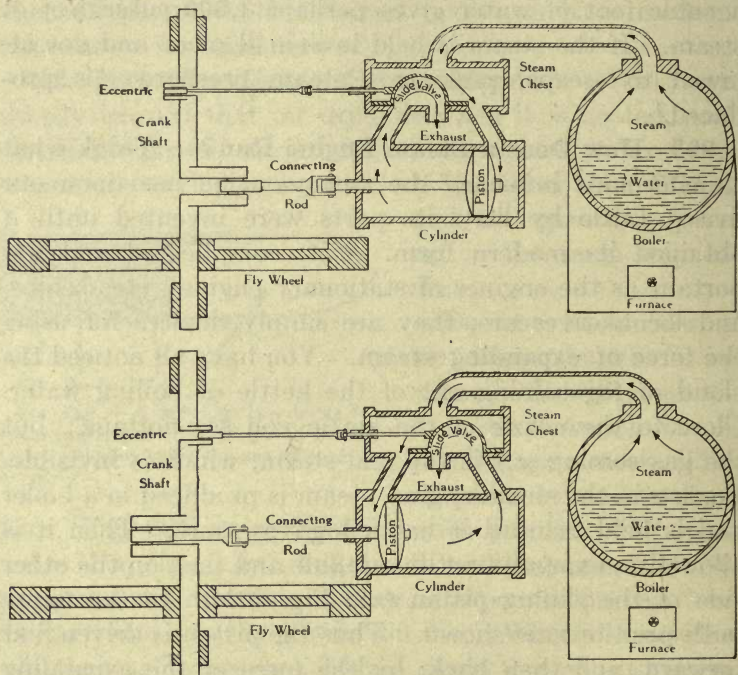


FIG. 225. — Principle by which expanding steam is made to drive an engine. Note the two positions of the slide valve, piston, eccentric, and connecting rod, as the steam enters, first on one side and then on the other.

294. What Makes the Automobile Run? — Is the power of the automobile, like that of the steam engine, obtained from the pressure of expanding gases? Yes, it is; but the expansion is produced by an **explosion** (Fig. 226) of a mixture of gasoline vapor and air instead of by the expansion of steam produced in a separate boiler. As a result, the weight of the heavy boiler is avoided, and the whole engine can be much lighter.

Gasoline is mixed with air in the **carburetor**, and then the mixture is drawn into the cylinders. The gasoline

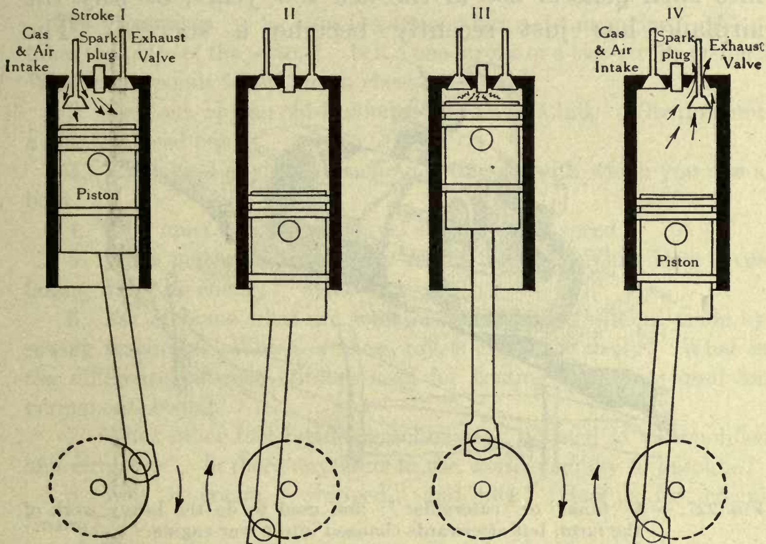


FIG. 226. — The four strokes of the ordinary gasoline engine. Note the position, at each stroke, of the valve admitting gas and air, the exhaust valve, the wheel, and the piston. In which stroke is there a spark from the spark plug?

vapor will **burn** in air; therefore the mixture of the two is explosive, like a mixture of hydrogen and air. The explosion is started by a **hot wire**, or an electric **spark.** The hot gases which are formed (chiefly steam and carbon dioxide) give a powerful **push** to the piston and set it in motion. Here again we use the forward and backward motion of the piston to get motion **in a circle**, such as is needed to turn the wheels of the car. What device does this in the steam engine?

Have you ever thought why automobiles have come into such general use in the last few years, or why the airplane has just recently become a success? The

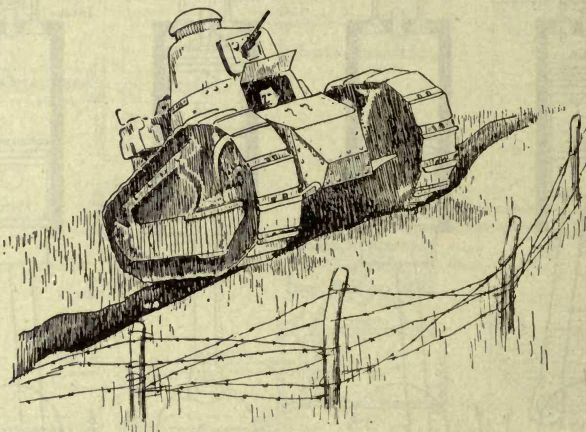


FIG. 227. — A "tank," or "caterpillar"; first used to do the heavy work of the farm, but afterwards changed into a war engine.

answer is that both of these wonderful devices of man were made possible because the **gasoline engine** was made a success. The gasoline engine is very **light** for the amount of power it can produce, and its fuel, the gasoline, is also very light (see Appendix III). Thus it is that one of man's inventions generally depends upon another.

Did you realize that the gasoline **tractor**, used instead of horses to do the heavy work of the farm, is practically the same as an automobile, and that the "tank," or **caterpillar** (Fig. 227), used in the later years of the Great War, is really an **armored** automobile, with a peculiar **endless chain** instead of tires, by means of which it crawls over rough ground with great force?

295. Exercises. — 1. How is a cannon like a steam engine? What takes the place of the piston? Is it a one-stroke or a two-stroke piston? What corresponds to the steam chest?

2. Find out why an old-fashioned kite needs a tail. Why does not a box kite need one?

3. What kind of simple machine is the oar with which you row a boat?

4. Why must an airplane travel at such great speed?

5. What machines are run by falling water? What force gives falling water its energy?

6. Ask at home what are some of the different stitches made by sewing machines. Which of these ravels out most easily? What is the difference between stitches used for basting and those used for permanent sewing?

7. What other fuel besides gasoline may be used in automobiles and airplanes? Is there any limit to the world's supply of gasoline?

8. Why is cream "whipped," and how? How is ice cream frozen?

9. Is the dirt collected by a vacuum cleaner drawn in, or forced in? Explain the difference.

10. Find out what was used to set powder on fire in the flintlock muskets of Revolutionary days (see § 22).

11. What is the difference in principle between the screw propeller and the paddle wheel of steamboats?

12. Why is a toy balloon filled with air unable to rise from the ground?

Summary. — A **sailboat** is a machine in which we can exchange rapid motion **before** the wind for slow motion **against** the wind. Its sail uses the principle of the inclined plane.

In a **kite** part of the force of a horizontal wind striking the inclined surface raises the kite into the air.

Airplanes are kites depending upon their own forward motion to raise themselves into the air.

Windmills have inclined planes by which the force of a horizontal wind is used to produce motion in a **circle**.

In **waterwheels** the water may flow under, or over, the wheel; or it may strike curved paddles, or **turbines**.

In a **sewing machine** the seamstress does harder work than by hand, but does it more rapidly.

Cream is separated from milk by means of **centrifugal force**: the milk is heavier than the cream, and is thrown out farther when whirled.

In a **vacuum cleaner** the force of the inrushing air carries the dirt with it.

The **electric washer** moves the clothes through the water, or the water through the clothes.

Gases cause **motion** by their rapid **expansion** from a compressed condition. In a **steam engine** steam under great pressure is allowed to expand alternately on each side of a **piston**, so as to produce rapid forward and backward motion.

In an **automobile** the **explosion** of a mixture of gasoline and air produces hot gases at high pressure; the escape of these produces motion in the engine.

PART VI

LIVING THINGS AND THEIR RELATION TO US

CHAPTER XXXI

THE WORLD OF PLANTS

296. How Do Plants Live? — Have you ever thought what a wonderful world the world of plants is, and wished you could know more of the ways in which plants live and grow? It is not easy for us to realize what a multitude of plants there are. There are the **wild** plants that cover almost the whole earth; there are also **cultivated** plants, which man cares for and protects, so that they may give him food, clothing, and shelter. There are shy wood plants so frail that to touch them is almost to destroy them; there are oaks and pines, which stand the storms of centuries, and are our symbol of strength and endurance. Then, too, there are plants so simple that they are made of but a **single cell**, like the green stain on the north side of fences and trees (see Fig. 228); and there are plants having such complex organs as the flower of a **daisy**, or the insect-catching apparatus of a **sundew** (see Fig. 229) or a

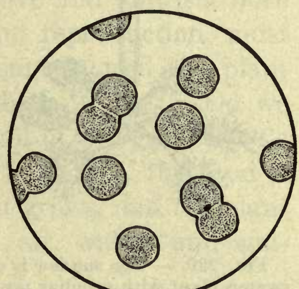


FIG. 228. — The Pleurococcus is a one-celled plant; it is so small that it must be magnified many times to look as large as in the figure. Some cells are dividing, to form two cells each.

Venus's flytrap. Have you ever seen either of these plants? **Botany**, the science of plants, is one of the most interesting of the sciences, and **farming** is really a great **experiment** of man and nature, carried on from year to year, to find out how perfect and abundant a crop of cultivated plants can be raised upon a certain piece of land.

FIG. 229. — The sundew is a swamp plant with peculiar projecting spines on its leaves. If a small insect alights upon the leaf, the spines surround it and crush it, so that the plant may extract nutriment from its body.

Plants must have **food** and **water.** We recognize the need of water when we "water" our garden plants, or the grass of the lawn, in dry weather; but we do not always think of the need of a plant's having **food**. The plant must have the different sorts of food, just like man and other animals (see § 188). It needs this food to get the **energy** for doing its work, to get the materials for making **growth**, and to **repair** the tissues which wear out. But there is this difference between **animals** on the one hand, and **plants** on the other: plants are able to take their food **directly** from the soil and the air, while animals are not, but depend on the food which plants have prepared. Is it not wonderful that plants are able to take up water, minerals, decaying vegetable and animal matter, and gases of the air, and out of these to make the delicate and beautiful structures we see and the nutritious food we eat? How does the plant do this work? We know something about the process, but by no means all; it still remains one of nature's mysteries. As we have already learned, about 10 of the chemical elements are needed for plant growth (see § 157).

297. What Parts Has a Plant? — What are the parts, or **organs**, of one of our common plants? They are the **root, stem, leaves, flower,** and **seeds,** are they not? As we think of a plant and of the things it does, we see that a plant's organs are all for one of two uses. In the first place, the plant must live, and to live it must have food. Those organs which enable the plant to get and to digest food are the **organs of nutrition.** In the second place, if any special **kind** of plant is to survive, there must be some way of starting new plants like it. Those organs which provide for the forming of young plants are called **organs of reproduction.** If plants are to live and flourish, both of these plant duties, **nutrition** and **reproduction,** must be carried out well. To carry them out well the plant must be fitted for the place in which it lives. Do we expect water lilies to grow in the soil of our garden, as a rose does? Then, too, if a plant is to live, the food it needs must be in the **soil** in which it grows, and the plant must have the right temperature, air, water, and sunlight.

Name some plants that like **sunlight,** and some that like **shady** places. Some that live in **water,** some that prefer a fairly **dry soil,** and some that live and thrive in a very dry (arid) soil. Name some that grow only under tropical conditions, and some that like a cold climate. Can you name some plants which are not **green?**

298. How Do Seeds Begin Growing? — How can we learn the way in which a plant **begins** its life? One method is to grow a young plant indoors (see Fig. 230), so that you can watch all the wonderful things it does. Place a few large garden **beans** in lukewarm (not hot) water overnight, and look at them in the morning. You will find that they have swollen. What entered into the bean to make it swell? How did it get in?

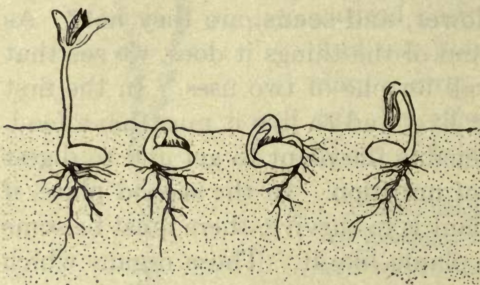


FIG. 230. — Scarlet runner beans growing. Note how the stems curve in order to get up to the light.

The bean has a tough outer **covering**; remove it from one of the soaked beans, and you will find inside the two " halves " of the bean. Is this all? If you separate the halves carefully, you will find a tiny bean-plant between them; this is called the **germ**, or **embryo**, of the bean. The process by which a germ grows into an independent plant, which can take up its own food and live by itself, is called **germination**, or sprouting.

Plant some of the soaked beans in a box of good earth, and add enough water from day to day to keep the earth moist, but not soggy. Put the box where it will get the best sunlight. In a few days you will see that the germ has begun growing. It pushes up a crooked " stem," which raises the dirt, straightens itself, and finally lifts the two halves of the bean into the air. The two halves are called **cotyledons** (kŏt′ĭ-lē′dŏns). Between them you can now see two tiny **leaves.**

Under the ground the stem pushes downward, and develops **roots.** The plant may now be called a **seedling.** It is able to care for itself.

After a while the cotyledons turn green; finally they fall off. Their work is done; the young plant has used all their stored-up food. The bean plant continues growing by adding two leaves at a time, always at the growing tip, while the roots spread out in the ground.

Plant some other seeds, such as squash seeds, lima beans, castor beans, peas, and corn, at the same time you plant the bean, and compare their growth with that of the bean.

299. What are Leaves Like? — You must have noticed what different **shapes** the leaves of different plants have. Their edges and veining are also different; so are their thickness, the feel of their surfaces, and their shade of green.

Collect as many kinds of leaves as you can, and compare them (see Fig. 231). Some leaves are **broad**, like

FIG. 231. — Leaves of the lilac, sycamore, and wild lily-of-the-valley. Which is which? Tell the kind of veining in each.

those of the maple and elephant's-ear; some are moderately **narrow**, like those of grass and sumach; while some are very narrow and **thick**, like the needles of spruce, pine, and fir. Some leaves, like those of the elm, have small, saw-toothed edges; others, like the maple, are deeply cut; while some are hardly cut into at all, as in the case of the lilac, nasturtium, and lily-of-the-valley.

The broad part of a leaf is called the **blade**. The stalk found on some leaves is called the **petiole** (pĕt′ĭ-ōl). Some plants produce tiny blades called **stipules** (stĭp′-yūls), where the petiole joins the stem. Do you find any leaves with petioles? Stipules?

Down the center of the blade there is a heavy, large vein called the **midvein.** There is a network of small veins in the rest of the leaf; these are arranged in one of **three** general ways. A maple leaf illustrates one of them, with veins radiating from one center, as in a palm-leaf fan. Such a leaf is **palm-veined.** The lilac leaf is **feather-veined,** because the veins run off from the midvein, as the barbs do in a feather. The lily-of-the-valley is **parallel-veined**; the veins run in almost parallel lines from the petiole to the tip.

Examine the leaves you have collected, and name the kind of **veining** in each. To what class do the leaves of corn, elm, grass, geranium, apple, birch, and oak belong?

Some leaves are broken up into several small **leaflets,** as in the clover and the rose; they are called **compound** leaves.

300. What are Leaves Made Of? — Since nature makes so many wonderful kinds of leaves, you might guess that the **inside** of the leaf is wonderful too. This is true. It is made of **spongy**, green tissue, with an outer covering, or **epidermis** (ĕp′ĭ-dĕr′mĭs). If you peel off the epidermis of a geranium leaf, you will see that it is colorless.

To see the real beauty of the inside of a leaf we must use a **microscope.** We shall find the leaf, like all living things, made up of **cells** (see Fig. 232). Cells are the **units** of living matter; in Fig. 114, § 195, we saw how the **starch cells** of a potato look when magnified. The epidermis is usually made up of colorless cells. In it there are a multitude of slits, called **stomata** (stōm′ă-tă), or "mouths," which serve as **breathing** places for the plant. Around each slit there are **guard-cells**; these control the size of the openings. Through these small breathing places the plant takes in the gases it needs, and throws off those it cannot use. The stomata also regulate the amount of water that shall be allowed to evaporate. Why is this regulation necessary?

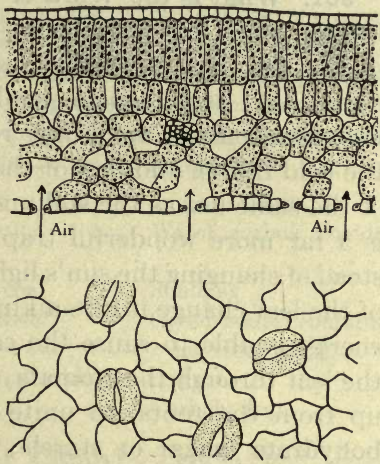


Fig. 232. — A cross section of a leaf (upper figure). Note the openings (stomata) through which the outer air can enter the leaf and through which waste gases can leave it. The lower figure is part of the epidermis magnified.

Does it make any difference whether the stomata are on the **upper** or the **under** side of the leaf? If the leaf is horizontal, and is easily wet by the rain, where should they be? On the under side, of course, so that the leaf can go on with its work, even in a rain. If the leaf floats on water, where should the stomata be? If the leaf is in the air, and stands up **vertically**, where should you expect them to be?

Some leaves have as many as 100,000 stomata to each square inch.

The **spongy tissue** of the leaf is also made up of cells, but in addition to the other living matter there are **green** bodies containing the substance, **chlorophyll**, which gives the cells their green color. These green cells are packed together loosely enough, so that there are **air passages** among them. The passages are connected with the stomata, or openings in the epidermis. Do you see that the inner green cells, while they are protected by the epidermis, are yet open to the entrance of the gases of the outer atmosphere? Can you see how the smoke of a city would interfere with the work of the stomata?

301. What is the Work of Leaves? — Has it occurred to you, while you have been studying about the structure of the leaf, how much the leaf resembles the **cold frame** (see § 251) as a trap for sunlight? Does not the colorless, transparent epidermis resemble the **glass cover** of the cold frame, and do not the green cells have something of the same use as the **soil** under the glass? But the leaf is a far more wonderful trap than any cold frame. Instead of changing the sun's light into heat, the green bodies of the leaf change it into a kind of **chemical energy**. This energy is able to cause the **carbon dioxide**, which enters the leaf through the stomata, and the **water**, which comes up from the roots, to unite in such a way that a **carbohydrate** (sugar or starch; see § 189) and **oxygen** are produced (see Fig. 32, § 43). Think how marvelous this process is. By it plants make food not only for themselves, but for the animal kingdom as well. So the simple, little green leaf, acting in the light which comes to it from the sun, is the world's greatest **factory**, and directly or indirectly produces the food for all life. Other parts of the plant, such as the stem, can do the same thing, if they have the green material that is needed. Name some green stems.

When we think of a factory, we have in mind a large building which turns out a certain product. Let us take, for example, a factory for **bread** — a **bakery**; how would it compare with the leaves of a plant?

Certain **raw materials**: flour, water, salt, sugar, fat, and yeast, are brought to the **bakery**; **carbon dioxide** and **water** are brought to the **plant** as its raw materials. The **energy** required in bread-making comes from the fermentation of the yeast and the heat of the coal or gas used in the stoves. The energy of the plant comes from **sunlight**. The **machinery** required in making bread is the bread-mixer, the pans, and the ovens. What corresponds to machinery in the leaf is probably the green bodies containing the **chlorophyll**. In bread-making at least two substances are given off as **by-products**: alcohol and carbon dioxide (see § 201); the plant gives off **oxygen** as a by-product (see § 43). These facts are put together in the following table:

	Bakery	**Plant**
Raw Materials	Flour, water, salt, sugar, yeast	Water, carbon dioxide
Energy used	Fermentation, coal	Sunlight
Machinery	Mixer, pans, stove	Green bodies containing chlorophyll
By-products	Alcohol, carbon dioxide	Oxygen
Product	Bread	Carbohydrate

302. How Does a Plant Climb? — Have you seen houses made beautiful by the **ivy** that almost covered them? How does the plant climb the walls? We have seen that the leaf has certain definite duties to perform: it serves as a breathing organ for the plant; it controls the evaporation of water from the plant; it is the factory of the plant's food. In a climbing plant there is a need of an organ to hold the plant to some support. Sometimes the plant has used its **leaves** to hold it up, and the leaves have been changed to suit the new conditions. When you grow sweet peas you always provide sticks or strings, do you not, so that the plant can climb. The climbing organs are slender, twisting little stems called **tendrils**. They often twist themselves into the bark of trees. When you examine them carefully, you find that they are really some of the **compound leaves** of the plant, but that they have been modified, or changed, for the work of holding the plant upright. What is their color? Are they able to do the usual work of a leaf?

FIG. 233. — Stem and buds of the buckeye, or horse chestnut. Note the joints, axils, and leaf scars.

Examine the organs which attach a Boston ivy vine to a wall. What are they like? How does a morning-glory climb? A grapevine? A Virginia creeper?

303. What are Stems For? — We usually think of stems as the organs which connect roots and leaves, and so they are; but the stems of different plants differ almost as much as the leaves. Some stems, like those of the morning-glory, are delicate and sensitive, while oak stems are the very picture of lasting strength. The stem carries the **water** and **minerals** from the roots, which take them from the ground, and delivers them to the leaves. Here the combination between carbon dioxide and water takes place.

Leaves usually appear on the stem only at certain places (see Fig. 233); these places are called *joints*, or **nodes**. A bamboo fishing pole shows the joints of a stem in a very clear way. The region of the stem *above* the place at which the leaf is attached is called the **axil** of the leaf. It is in this axil that buds and branches are usually formed. Examine a plant stem, such as that of a geranium or a lilac. Can you find the nodes and the axils? Can you find any **leaf scars?**

Stems are usually above ground, but some plants may have **underground stems**, as, for example, the potato plant. The potato itself is simply an enlarged, underground stem. What we call the "**eyes**" are leafy **scales** with very much reduced leaf buds in the axils. The morning-glory stem is small, and has to depend upon something for support. The strawberry has a stem which runs along **on top of** the ground. The iris, bloodroot, and other plants have stems which run along **under** the ground. What peculiar thing is there about the stem of the barberry, the rose, the sumach, and the willow?

304. What are Buds For? — Have you noticed the buds on the sides and tip of the smaller stems of your trees in the winter time? See Fig. 233. They are usually placed at comparatively regular distances apart. If you pull off the heavy, uninteresting covering of one of these buds, you will find that under its protective **blanket**, which is often woolly inside, the bud is getting ready to burst out suddenly on the first, warm, spring days. Did you ever wonder how so many leaves could come out in one day? Some of these buds are **leaf buds**, and some contain the beginnings of **flowers**. If a tree produces flowers before it produces leaves, which buds should you expect to be farther along in their development? Cut across a few buds from a fruit tree or a rosebush.

FIG. 234. — How a poplar bud looks when cut across. Note how the leaves overlap, and how the inner ones are curled up.

Do you find anything inside that looks at all like Fig. 234?

305. What is the Work of Roots? — When some people think of building a house they think only of the well-finished rooms and ornamental lights, while they forget about the humble **foundation** on which the house rests, and the ugly wires and pipes that bring in gas, electricity, and water and all the other things that give the house its beauty and comfort. So it is with plants. People exclaim over their lovely flowers, but think little of the **roots**. Roots are the hidden foundations of the plant (see Fig. 235). Stems, branches, and leaves are usually found above the ground and seeking after the sunlight. Roots, on the other hand, seem to avoid the light and make their way underground. They have neither nodes nor axils.

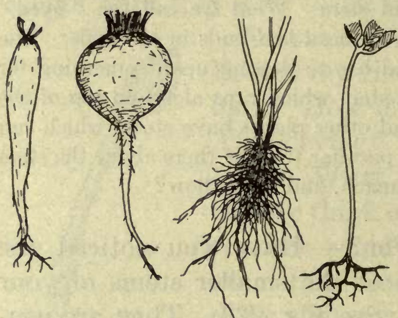


Fig. 235. — Note the taproots that go straight down, and the spreading, fibrous roots. All the rootlets are covered with fine **root hairs**.

The root has **two duties** to perform for the plant. The first is to gain a **hold** in the soil, and to keep the plant secure in its place. Without a firm foundation the plant, like the house, will fall. The other duty of the roots is to take in **food** and **water** from the soil. We have already learned (see §§ 154 and 155) how important it is that the soil shall have the right **structure**, so that roots can do their work. Of course, in the case of **water plants**, roots take their food from the water. **Air plants** obtain moisture and food from the air.

Some roots, like those of the dandelion and radish, go down in one large, long portion; such roots are called **taproots.** Roots which are finely divided, like those of grass, are called **fibrous roots.** To which class does the beet root belong? That of the geranium? Name other examples of each kind.

306. Why Do Plants Have Flowers? — The most beautiful organ of our common plants is the flower; but the flower is even more useful than beautiful. It is through the flower that the plant **reproduces** itself and that new plants are made possible.

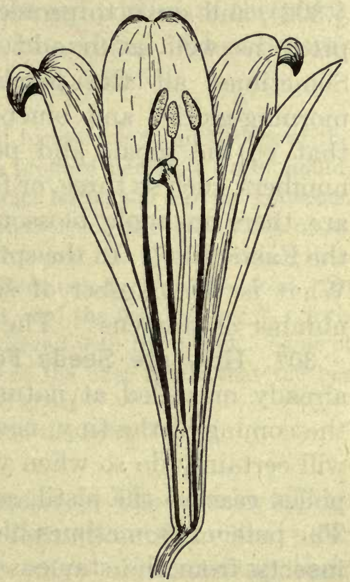


FIG. 236. — An Easter lily, cut through lengthwise. It has 3 sepals and 3 petals.

Flowers are of many different shapes, sizes, and colors; but they are more or less alike when we study them closely. Examine the flowers of the hepatica, the spring beauty, apple or cherry blossoms, or the Easter lily, and describe them. A flower **bud** is usually tucked away inside a green, leaf-like covering. When the bud opens, these coverings are pushed apart and we call this first set of parts the **sepals** (see Fig. 236). The colored, attractive **petals** of the flower are above the sepals and often hide them. The third set of parts is a circle of tiny organs in the center of the group of petals; these are called the **stamens**. The stamens produce a powdery substance, generally yellow, which is called **pollen**. Inside the circle of stamens is another stem-like structure called the **pistil**. Often it is made of several parts, each of which is called a **carpel**. The stamens and the pistil are the plant's real organs for producing new plants, or its **reproductive organs**. The sepals and petals are really changed forms of **leaves** (see § 302), and serve to protect and cover the stamens and pistil, as well as to add attractiveness to the flower. Sometimes all the petals are joined together, as in morning-glories and bluebells. The **outer** flower parts, that is, the sepals and petals, are present in different numbers, such as three, or four, or five. How many petals are there in apple blossoms? In cherry blossoms? In the Easter lily? In the spring beauty? In the hepatica? What is the number of sepals in each of these? The number of stamens? The number of carpels?

307. How are Seeds Formed? — Probably you have already marveled at nature's wonderful preparation for the coming of the tiny, new plant. If you have not, you will certainly do so when you learn the way in which the pollen reaches the pistil, so that the seed can be formed. The pollen is sometimes blown by the **wind**, or carried by **insects**, from the stamens in which it is formed, over to the pistil. The upper tip of the pistil has a sticky surface which catches the pollen. Each pollen grain then grows, and sends down into the lower **enlarged** part of the pistil (the **ovary**) a slender tube down which the pollen cell can travel. In the ovary the pollen cell finds another cell called the **ovum**, or "egg." When these two cells come together, they unite; the uniting is called **fertilization.** Without fertilization the ovum *cannot* develop into the embryo, the tiny plant which we find between the two halves of the bean. The plant covers the embryo with a tough covering, such as is found in the bean. Then it stuffs all the room between the embryo and its covering with **food.** Why?

By this time the ovary, or enlarged portion of the pistil, is entirely changed. In the bean and pea, it has become the **pod**, filled with the fully formed seeds.

What do you think the wonderful forms, colors, and odors of the flowers are for? Some flowers even produce **nectar**, a sweet liquid. As the flowers attract **us**, so they attract **birds**, and especially **insects.** It is so important that the pollen shall reach the pistil that many plants have grown to depend entirely upon the insects, rather than the wind, as the carriers of pollen. **Bees** use the pollen for food. So the flower produces a great deal of it, and the bee, seeking it, crawls down into the flower, and becomes covered with the **pollen.** Some of this is brushed off against the pistil of the next flower that the bee visits, and **fertilization** is thus brought about.

What does the **humming bird** find in the flower?

308. How are Seeds Scattered? — The wonder of the flowers does not stop with the formation of the seed; for plants have developed clever ways of **scattering** their seeds (see Fig. 237). Because of this, a kind of plant may be found not only in one small section of country, but over great areas of the continent. Examine as many seeds as possible, including peas, acorns, hickory nuts, apple seeds, and the **pits** of some fruits. The violet and wild bean and similar plants produce a great many seeds in a **seed pod.** This holds the seeds until they are large and ripe. Then the pod becomes so stretched that it bursts, and the seeds fly out through the air, and fall some distance from the parent plant. Some plant seeds, such as those of the dandelion, maple, and thistle, have **downy** structures, like umbrellas with little wings. The wind catches these seeds up, and carries them for comparatively long distances. Seeds are also carried far away by water. The ocean itself carries seeds from one land to another.

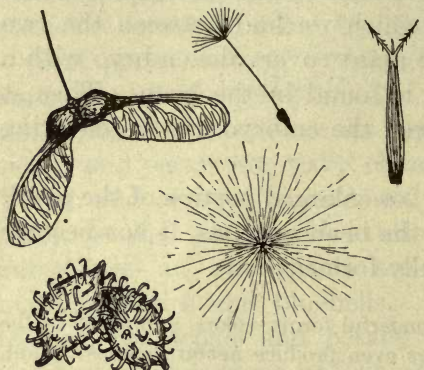


FIG. 237. — Five different devices for the scattering of seeds. Do you know the plant that produces each?

Another device for scattering seed is seen in the **cocklebur** and **burdock**. The plants surround their seeds with **stickers**, which catch on the fur of animals, including the clothing of boys and girls, and are thus carried to new fields to grow. We owe the benefits and pleasures derived from many fruits to the efforts of the plants to scatter their seeds. The **fleshy** part of the fruit which we eat is simply a ripened part of some of the reproductive organs of the plant. The fruit is carried away by man and animals. The fleshy part is eaten, and the seeds grow where they are thrown, in a new location far from the parent plant. Of course **man** has greatly developed many fruits to improve the form which nature gave them (see § 334).

309. What are the Lower Plants Like? — On the north side of tree trunks and on old fences, you have often noticed a green **stain**. This is one of the simplest of plants; it is called **pleurococcus** (plū′rō-kŏk′ŭs). Each plant is so small that it has to be magnified by a microscope to be seen at all. Indeed, each plant consists of only **one cell** (see § 296). This plant does not produce seeds, but simply splits, or **divides**, to form two or more plants instead of one. The new cells each contain part of the original cell, and grow to full size.

Between the pleurococcus and the flowering plants, there are many groups of plants. One of these groups is called the **fungi** (fŭn′jī; the singular is fŭŋ′gŭs). These are such plants as toadstools, mushrooms, and puffballs, which do not produce flowers or true seeds. They have another striking property in that they do not have any chlorophyll, and therefore cannot make their own food. The fungi live upon other plants, animals, or foods. The **yeast**, as we have seen (see § 202), lives upon foods containing sugar. The **mushroom** lives upon decaying wood or leaves.

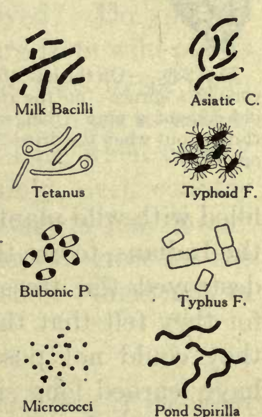


Fig. 238. — Some kinds of the tiny plants we call bacteria, bacilli, and micrococci, all highly magnified.

Bacteria (see Fig. 238) are also a low order of plants. They have only **one cell**. They are reproduced very rapidly by division of cells, as the pleurococcus is. Certain bacteria (see § 204) cause milk to **sour**; certain others make meat **decay**; others still cause some of the different **diseases** which are common to plants and animals.

Mosses and **ferns** do not produce flowers, or true seeds either. Ferns are cultivated by gardeners for their beautiful *fronds*, or leaves.

Fir trees, pines, and hemlocks belong to the **cone-bearing** plants. The stamens and pistils of the flowers are produced in **cones**, and the seed is not inclosed in a special seed case as in the flowering plants (see Fig. 239).

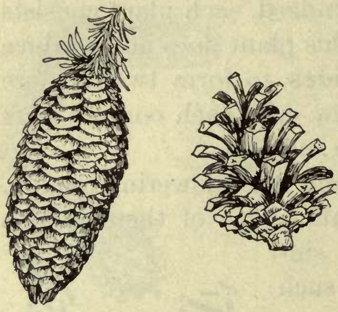


Fig. 239. — On the left, the young cone of a spruce; on the right, the old cone of a pine. The seeds are thrown out when the dried "scales" open.

Have you ever seen the pale-green, strange-looking new cones of the fir or pine in the springtime or early summer, or the dried, little, brown cones of some Christmas trees?

310. Are Wild Flowers Worth Preserving? — When the early settlers came to America, they found a land filled with wild plants and animals, and only a few people, the Indians, to use them. So they killed the animals, and destroyed the trees and other plants as they wished; for they felt that there were so many of every kind that they could not possibly use them up. But Americans have learned long since that some of our native animals will be entirely gone, or " become extinct," if they are not protected. So laws have been made to prevent the killing of deer, wild ducks, and other game, except at certain seasons, and then only in certain amounts. The same is true of certain kinds of fish. The **buffalo** is an animal which once roamed our prairies in numbers, but became almost entirely extinct. Now the government does not allow the buffalo to be hunted. Why is this done?

Perhaps the deepest reason for the preservation of the buffalo in this country is that this animal is a wonderful form of life, which formed a part of **original** America; hence some of these animals ought to be left, in order that Americans of the future may still be able to enjoy seeing them.

How about the **wild flowers** of our country? Did you know that some kinds of our native plants have been almost entirely destroyed by thoughtless people? Is it not worth while for us to think of our wild plants, as of our wild animals, as a part of original America, and to see to it that they are not utterly destroyed? Do you not think that you can get far more pleasure from wild plants if you let them **grow**, so that you can go back to see them from year to year, than from tearing them up to wither and die? Few wild flowers will last long when carried from the country to the city. Certainly, even country children ought to be content to pick only a few flowers of any one kind, and to leave the others to grow for the enjoyment of themselves and their fellow Americans in future years.

311. Exercises. — 1. Name some plants and trees of the desert portions of the United States. What is peculiar about them?

2. How is a celery stalk made white? Why? What is the color of a potato sprout in a dark room? What is the color of grass that grows for a time under a board, or under a pile of leaves? What happens when such grass is brought into sunlight?

3. Have leaves a form which makes it possible for them to shed water?

4. Are young plants ever started from any structures except the seed? How are potatoes planted? What is meant by the "slipping" of such plants as geraniums? Is the strawberry developed from its seeds?

5. What leaves are of importance as commercial products?

6. What is the difference between the embryo plant and the seedling?

7. How does the tumbleweed scatter its seeds?

8. Examine some buds and tell the different ways in which they are protected from cold weather.

9. Describe the stems of the cherry, oak, maple, catalpa, cottonwood, hickory, and linden (boxwood) trees. Describe their leaves. Describe their fruit.

10. Describe the flower of a dandelion. Is it one flower, or many? What is each separate flower like?

Summary. — **Plants** need food for **energy** and for **growth** and **repair**. Unlike animals, green plants can build up their food directly from materials in the soil and air.

The **organs** of a plant are **root**, **stem**, **leaves**, **flower**, and **seeds**.

The two **necessary** plant duties are **nutrition** and **reproduction**.

A **seed** consists of the **embryo**, or **germ**, and the **food** stored for its use.

Germination, or sprouting, is the process by which the embryo becomes an independent plant.

Leaves have a **blade**, usually a **petiole**, and sometimes **stipules**. They may be **parallel-veined**, **feather-veined**, or **palm-veined**. They may also be simple or compound.

A leaf is covered with a colorless **epidermis** containing breathing pores, or **stomata**, through which the interior of the leaf communicates with the outer air.

In **sunlight** the leaf, because of its **chlorophyll**, is able to convert carbon dioxide and water into **carbohydrates** and **oxygen**.

Plants **climb** by means of twining stems, tendrils, and flat disks.

Stems usually produce buds and branches in the **axils** of leaves. Stems may also grow underground, as **rootstocks**.

Roots hold plants firmly in the soil and absorb the plant's food from the soil.

Flowers are the reproductive organs of the higher plants. When complete they consist of **sepals, petals, stamens,** and **pistil.**

The union of **pollen** from the stamens with an **ovum** of the pistil is called **fertilization.** It often depends upon birds and insects.

Many plants have special devices for **scattering** their **seeds.**

Only the higher plants produce seeds in a **closed** seed case. in such plants as firs, pines, and hemlocks the seeds are produced in **cones.**

Wild flowers, like wild animals, are **worth preserving** for future generations.

CHAPTER XXXII

PLANTS OF USE TO MAN

312. How Does Man Make Use of Plants? — We have learned something of the work of plants in nature and that they furnish **food** for animals and man, and much of the **shelter** and **clothing** of man. Do plants do this "on purpose," or because, as they carry on their own life work, they prepare materials which man wants and uses? Thus the bean plant stores the cotyledons of its seed with food for the **young plant** (see § 298); but man eats the seed to nourish himself. So trees grow strong trunks to lift their **leaves** high into the sunlight and to stand firmly against the wind; but man uses the tree trunks for telegraph poles and boards. In the same way the maple tree has in early spring a sugary **sap** intended for the nourishment of the new growth of the tree; but man drills holes into the trunk, and secures a juice which he "boils down" to form maple syrup and maple sugar. Can you name some other cases of the same sort?

Fortunately for man, he has been able to find in almost every land the plants he needs for his life, and in the days in which it was hard for him to travel from one region to another he could make use of what he found in his own neighborhood. Nowadays many plant products which were unknown to our forefathers, or only luxuries, are common articles of food or clothing, because of the rapid transportation made possible by steamships and railroads. What are some foods that come from far-away lands? When these lines of transportation fail, as they did in the Great War, even a highly civilized country may find itself suffering, and in danger of starvation, because of the lack of some articles it has come to depend upon for food.

Man has brought in not only the **products** of the plants of other lands, but he has brought in the **plants** themselves, and tried to grow them. In some cases he has not succeeded; but in many others he has been able to grow the plant as well in its new home as in the old. So we have in our own country some common food plants that are **native** to America, and others which were either brought in by the early settlers, or recently introduced by expert growers. Thus, most of our California **oranges** come from plants originally brought from Brazil; while our cultivated **strawberry** plants are probably descendants of some that came from Chili. Indian corn, tomatoes, and potatoes are native American plants which have been carried to other parts of the world since the discovery of America. Can you name any others?

313. Does Man Eat Grass? — Do you think it is ridiculous for us to speak of man's eating grass? It will not seem so when you learn that not only the grass of our lawns and of country meadows, but our common **grains**, such as wheat, corn, and rice, are really members of the same family, or group; this is called the **grass family**. The grass family of plants is made up of thousands of kinds. These are very different in size and in some other qualities, but they are alike in having very **simple flowers** and in producing a fruit which is **seed-**

like. The flowers grow in close clusters. You would not think them flowers at all, perhaps, for they have only the **stamens** and the **pistils**, and neither sepals nor petals. Have they the really necessary organs? From the fact that the flowers of the grass family are not showy, would you think that they need the help of insects to get the pollen from the stamens to the pistils? Why?

FIG. 240.—A stalk of Indian corn, with its tassels (at the top) and ears (on the sides). Note the silk projecting from the tops of the ears.

The grasses have peculiar little scales, or **bracts**, which serve as a protection for the seed, or grain. It is these bracts that fly off and fill the air of the farm granary at threshing time. We call it **chaff**. Have you ever seen the process of threshing wheat, by which the grain is separated from the stalk and chaff, and is made ready for the mill?

Can you find some grass which has "gone to seed," or some dried stalks of timothy hay? If possible, get some unthreshed wheat, or stalks of oats of last year, and examine its stem and leaves and the dried bracts and grain upon it.

Soak a grain of corn in lukewarm water, and then remove its outer covering. Do you get any evidence of two "halves," as in the case of the bean? No, the corn and all the other grasses have only **one cotyledon** in the seed, instead of two.

Corn (Fig. 240) is different from the other common grasses in the way its organs of reproduction are arranged. It has only the stamens and pistils of the flower, as is the case with the others, but these organs grow some distance apart. The **stamens** are the " tassels," and grow in clusters at the tips of the stalks; the **pistils** grow in the axils of the leaves (see § 303) on the sides of the stalks. The pistils are protected by large bracts. Where do we find the ears of corn? Are the ears developed stamens or pistils? What is the " silk " which projects from the tip of the ear?

314. What Grasses Does Man Use? — We have already learned that wheat, corn, and rice belong to the grass family; the same is true of oats, rye, barley, and millet. We must not forget some grasses which are not used for their seed, but for their juice, or **sap**; these are **sugar cane** and **sorghum**. There is also the important grass that grows to the size of a tree, the **bamboo**. Where does the bamboo grow? Neither must we forget the grasses we dry and use for fodder for the animals of the farm in winter. The most important of these are timothy and redtop. There is also blue grass, so called from its blue-green color, which forms the wonderful pasture grass of Kentucky and the neighboring states and makes such excellent grass for the lawn.

Wheat is grown chiefly in the Northern States, although some kinds of it do well in regions of limited rainfall, such as are found in parts of Texas and Oklahoma. It does not do well in the moist, cold climate of northern Europe, but grows wonderfully in parts of Russia. A large crop comes from Argentina. There are **two kinds** of wheat, according to the time they are planted. One is called **winter** wheat, and the other **spring** wheat. How can wheat planted in October be kept from freezing?

It germinates and makes a little growth before the ground freezes and snow comes. The green shoots may freeze, but the plant as a whole does not and is ready to take advantage of the first warm day of spring. As a result it completes its growth early and is ready for harvesting in early summer, long before the spring wheat.

Have you ever seen the beautiful, green fields of **winter wheat?** It is not the cold weather that harms the wheat so much as alternate thawing and freezing. We can comfort ourselves, when the winter is a hard one and there is a great deal of snow, with the thought that the wheat is safely covered, and is likely to give us a good harvest.

Oats do not require so rich a soil as wheat (see § 159). The seed is planted in early spring. Oats, like wheat, grow better in a cool climate. For what is the oats crop used principally? Do people use oats? Look up the composition of oats in Appendix, Table IV. Do they have a high food value? **Rye** has winter and spring varieties, much as wheat has. **Barley**, like rye and oats, is used as a substitute for wheat when wheat is scarce.

315. How Do Corn and Rice Grow? — Corn, as we have seen (see § 313), is a native grass of America, and was known to the Indians and grown by them as a food crop long before America was known to the white man. It is grown in almost all parts of our country, but there is a region of the Middle West called the "corn belt," where it is the principal crop. Where is the corn belt? In Europe corn does not grow so well as in America, hence what corn is used there is largely imported from this country. What is the chief use of corn?

Name some of the different **kinds** of corn. Of course you will include **sweet** corn, which has a good deal of sugar in it, and **pop** corn (see § 195). The two principal kinds of "field corn" are known as "flint" corn and "dent" corn. The **flint** corn gets its name from the fact that it is hard and **translucent**, like flint; generally it is best for a region where the summer is short, as it ripens very quickly. **Dent** corn is soft and has a larger grain with a dent at the top of the grain. It often grows to a great height: 16 or 20 feet; but it some-

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FIG. 241. — A field of rice planted in flooded ground.

times requires five or six months to ripen properly. Find out what products are made from corn. Do you know any boy or girl who has learned how to **judge** the quality of corn? Is pop corn more like a flint corn or a dent corn?

Rice (Fig. 241) belongs to the grass family, but it differs from other members in beginning its life as a **water plant.** It is planted in flooded land and needs a soil that remains very moist. It is a native of the East Indies, and is the principal food of the peoples of Asia, or of one half of the human race. In our own country rice is an important crop of the Southern States. Look up the food value of rice in Appendix IV, and compare it with that of oats, corn, and beans.

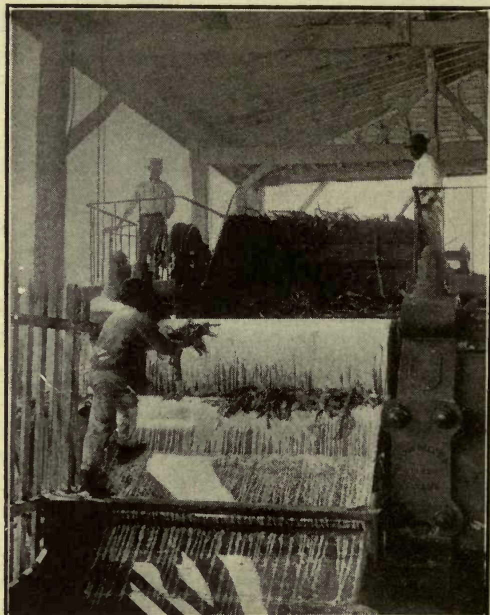

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FIG. 242. — How the juice of the sugar cane is crushed out of the stalk.

316. How Do Sugar Cane and Bamboo Grow? — Have you ever had some of the ripe stalks of the **sugar cane** and chewed them for the sweet sap they contain? They are a great delicacy. As you know, sugar cane is cultivated in our Gulf States; a great deal is grown also in Cuba, Java, the Philippines, and Hawaii. The cane forms a large grass with a solid stem. In order to get the sugary sap out of the stems, men crush them (Fig. 242) between rollers, or **grinders**; the sap is then boiled down to get the sugar to crystallize out (see § 118).

The sugar obtained by this first crystallization is **brown sugar**, colored by some of the other materials of the sugar cane. The sticky liquid from which the sugar crystallizes out is **molasses**. To purify, or **refine**, the brown sugar, men dissolve it again in water, and filter the water solution (see § 139) through a filter of **charcoal**. The charcoal removes the dark color of the brown sugar solution, and when the solution is boiled down once more, the sugar which crystallizes out is our familiar **white** sugar. The solution from which the refined sugar separates is **sirup**. You would not think that black charcoal could take dark colors out of sugar solutions, but it is so. Sugar is a **definite** substance (see § 110), and is found in other plants besides the sugar cane. In Europe most of the sugar is obtained from sugar **beets**.

Have you ever used a **bamboo** fishing pole? It probably came from the South, and is a small kind of bamboo that grows in the canebrakes. The real bamboo grows in Asia, and is of the greatest importance to the people. Some kinds of bamboo reach a height of **100** feet and are a foot in diameter. You can see that such great stalks could be used for building **bridges** and **houses**, for water pipes, rain troughs, and fences; and this is just what the people do with them. They also use bamboo in split form and weave from it **baskets**, mats, and screens. In fact, it largely takes the place of wood and of metals.

317. Why Is Wheat Used for Bread? — Have you ever wondered why, with so many grains, such as barley, rye, oats, rice, and corn to choose from, our people should insist on using wheat for their yeast bread? In the countries of Europe, where wheat is difficult to grow, barley and rye breads have been used for centuries instead of wheat breads. Do you remember the experiment we carried out in § 190, in which we separated the starch of wheat flour from the gluten? Review this experiment. **Gluten** is good not only because it furnishes us **nitrogen** in our bread, but because it is **sticky**, and holds the dough together. Now, when yeast ferments the bread, producing carbon dioxide (see §§ 201 and 202), it is necessary that the dough shall **hold** the carbon dioxide and prevent it from escaping until it has collected in a large amount. As we have learned, it is the gas bubbles that make the bread porous and light. Wheat has more gluten in it than any of the grains, and this is the reason it is so good for bread-making. **Rye** is next best in its amount of sticky material, and in spite of a darker color than wheat, makes a nutritious and wholesome bread. Breads can be made by proper methods from the other food grains, especially if their flours are mixed with a certain amount of wheat flour, or rye, so that they have the advantage of the large supply of sticky material found in the wheat and rye.

Wheat flour is the wheat grain ground to powder. If the seed coat, corresponding to the "skin" of the bean, is left with the flour, we have **Graham** flour; if the seed coat, and nothing else, is removed, we have **whole wheat** flour. The seed coat forms "bran." If the flour is "bolted," that is, **sifted** through very finely woven cloth, any bits of the seed coat that remain, and the darker, harder, outside portions of the grain are removed, and the flour is **whiter**. It has lost, however, some of the nutritious material found on the outside of the wheat grain.

Both winter and spring wheats have varieties known as "**hard**" and "**soft**" wheats. Hard wheats are those with a great deal more **gluten** in them, and less starch, than the soft wheats. The "**maca-**

roni" wheats have so much sticky material that they are not good for making yeast bread. Can you tell why?

318. What are the Legumes? — Legume (lĕg′yūm) is an uncommon word, but it stands for some very common plants. Really, legume is the name of the peculiar **pod** which forms the seed case for these plants. You have all seen this pod in the case of green peas and string beans, as well as when the pods are ripe and ready to split into their two parts, or valves. The legumes, or **leguminous plants**, as they should be called, all have two cotyledons in the seed (see § 298). They include such plants as clover, alfalfa, peas, beans, lentils, wisteria, bluebonnet, the locust and redbud trees, and many others. Have you ever seen the beautiful flowers of the **redbud** in early spring, before the leaf buds of the tree opened? All the legumes have their flowers in clusters.

Have you seen any other flowers of the legumes? Of course you have, in the **sweet peas** at the florist's, even if you have not raised them at home. What is the shape of the sweet pea, and how many **sepals** and **petals** has it? You remember that one of the petals is much larger than the others, and stands upright, like a **banner**, or *standard;* two of the petals are like **wings**; while the remaining two look somewhat like the **keel** of a boat, and form a little box for the stamens and pistil. Do the attractive **color** and **odor** of the sweet pea suggest that the plant has need of insects or other creatures? As a matter of fact, the "keel" of the flower is a special device by which the plant causes an insect which visits it to carry the pollen of one flower to the pistil of another.

When we speak of the plants which the farmer raises in his pasture or meadow as **food** for his **cattle**, we must not forget **clover** and **alfalfa**. These are not grasses at all, but legumes. The clover does not seem to have flowers much like peas and beans, unless you examine them closely; but they are really all alike, except that those of the clover are in a close **head**. Have you ever examined a clover head gone to seed? What are some different kinds of clover? Does the clover produce anything that is attractive to bees, and causes them to pay it frequent visits?

Alfalfa is also called *lucerne*. It was brought into America from Europe as a forage plant that could be grown profitably in the drier regions of some Western States; but it is now grown in many other parts of the country.

Have you ever thought of another common legume? How about the **peanut?** Open the halves of a peanut: an unroasted one, if possible, and see if you can find the **germ**. What is it like? Do you know the peculiar way in which peanuts are harvested? They are **dug** from the ground, like potatoes. The plant produces the flower above ground, but when the pod begins to develop, the plant forces it into the ground to ripen. The peanut is also called a **goober**.

319. How Do Legumes Capture the Nitrogen? — We have one more very important thing to learn about the legumes. Do you remember that in our study of foods (see §§ 188 and 190) we found that our bodies need some foods containing **nitrogen** to build up our tissues? The same is true of all living things. Strangely enough, while all plants need nitrogen, the legumes are almost the only food plants which contain it in large quantities. There is a great deal of nitrogen in the air, but plants cannot use it; so when nitrogen is added to a plant's food, it must come from the nitrogen compounds dissolved in the soil, and be taken up by the **roots** of the plant.

Therefore we would expect that as the legumes contain a great deal of nitrogen, and as they must get it from the soil, the ground on which legumes are grown would lose a good deal of its nitrogen. But the opposite is true: if a crop of clover, or alfalfa, or beans, is grown upon a piece of land, the land becomes actually **richer** in nitrogen than before.

Men have known for years that growing clover or alfalfa upon soil **improved** the soil for other plants, but only recently have they learned the reason. If you pull up a half-grown clover plant, you will find on its roots little, wart-like growths which are called root **tubercles** (tū'bĕr-kls; see Fig. 243). Inside the tubercles are multitudes of **bacteria** of a special kind, which have the power to unite the **nitrogen** of the air with **oxygen** and other substances and produce nitrogen **compounds**. The roots of the clover and other legumes provide homes for these bacteria, and then are able to feed upon some of the nitrogen foods which they produce. The clover, or other legume, does not use **all** of these foods; hence when the plant is removed, some nitrogen food is left for the next plant to be grown upon that soil. Is not this a wonderful **partnership** between the nitrogen-gathering bacteria on the one hand, and the legumes on the other?

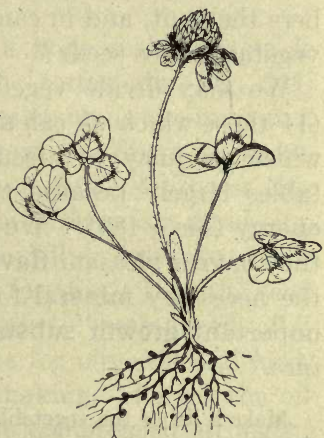

FIG. 243. — A red clover in blossom. Note the tubercles on the roots.

This, then, is the reason why the legumes are not only able to live upon a soil that is poor in nitrogen, but to leave the soil richer in nitrogen than it was before. Have you ever heard that farmers often grow clover or alfalfa in a field, and then **plow it under**, in order that the ground may be more valuable for other crops? Review § 159.

320. Why Do We Eat Vegetables? — By "a vegetable" we mean part of a plant which is **edible**, or fit to be eaten. We have already learned (see § 193) that our common garden vegetables include the **seeds**, **stems**, **roots**, and **leaves** of certain plants. Thus the **sweet potato** is a root, while the potato is an underground **stem.** In the asparagus, celery, and rhubarb we eat the **stalk**, in lettuce and cabbage the leaves, in tomatoes and cucumbers the fruit, and in cauliflower the **flower** itself. What vegetables are seeds?

We may divide vegetables roughly into two classes: (1) those which we call **starchy** vegetables; and (2) those which are **juicy**, or succulent. We eat the starchy vegetables largely because they are good fuel and give us **energy** (see § 189). We eat the juicy vegetables because they have a pleasant **flavor**, add **bulk** to our food, provide the necessary **mineral** food (see § 191), and give us the important **growth substances**, commonly called "*vitamines.*"

Make a list of the vegetables with which you are familiar, and tell which might be called starchy and which juicy. Do you try to have some of each class every day? Scientists say that three fourths of the American people do not eat enough vegetables.

321. What Fabrics Do We Get from Plants? — We have already learned some things regarding the materials of clothing (see § 181) and of the difference between their fibers. What are the most important plant fabrics besides cotton and linen? They are **hemp** and **straw**, are they not?

The **cotton plant** needs a long growing season, so it is grown in regions which combine the right soil conditions with a warm climate. India, Egypt, and our own Southern States have both the soil and the climate. **Sea-island** cotton is that grown in the low lands of our south-eastern coast; it has especially long and silky fibers. **Upland** cotton is that grown away from the coast. The cotton seeds and fibers are inclosed in a seed case, called a **boll**.

The cultivation of cotton on a large scale was made profitable by the invention of the **cotton gin** (Fig. 244) by Eli Whitney in 1792. Until this machine was invented, the seeds had to be separated from the fibers by hand. You may imagine what a slow and difficult process this was. But by the use of the gin the process is a rapid one, and the **seed**, as well as the cotton fiber, has great commercial importance. The reason for this is that the seed contains a great deal of **fat**, called "**cottonseed oil**," which can be used as a substitute for olive oil and lard, and for the fats needed in **soap-making**. To get the oil out of the seed, the seed must be **compressed** strongly; what is left is called **seedcake**, and is sold as food for cattle. When you learn that about **two** pounds of cotton seed are produced for every pound of cotton, you will realize how important it is that these by-products of cotton-raising shall be put to use.

We turn now to **linen**. Ancient books speak often of linen garments, so we know that the **flax** plant, from which linen is made, has been useful to man for thousands of years. The linen fiber comes not from the seed, as is true of cotton, but from the **stem**. The fibers of the flax are so closely held in the stems that they must be put through a long process of **retting**, or **rotting**, before the fibers can be separated. Then the fibers can be made into linen thread or cloth.

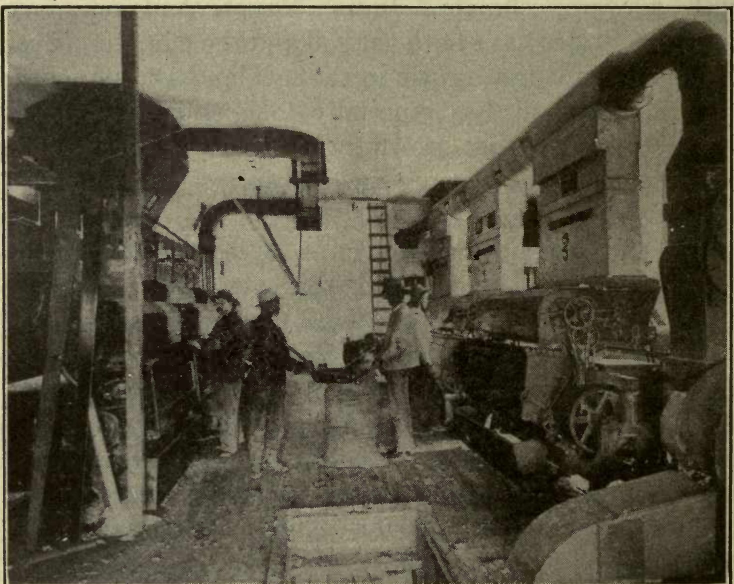

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FIG. 244. — In the cotton gin (short for "engine") the cotton seed is separated from the fiber. In the figure men are shoveling up the seed.

The **seeds** of the flax are also used, as in the case of cotton; from them we obtain **linseed oil** (see § 33), which is used in large amounts for the making of paints. Do you know of any other use of flaxseed?

Hemp, like flax, is not a plant native to the United States, but has been brought here from the Old World. There are many substitutes for the true hemp. Thus, **Manila hemp** is a fiber obtained from a **banana** grown in the Philippines. For what is hemp used?

Straw is the dried stalk of many grain plants, such as wheat, oats, and rice. What is straw used for, besides as fodder for cattle?

322. What is a Fruit? — What is the difference between a vegetable and a fruit? In the case of some plants the work of the plant is done when the embryo is developed, and the seed case is stuffed with food for the embryo to use when it begins to germinate. But in many plants this is not all: important changes take place in other parts of the reproductive organs as well, and we get **edible fruits**. Really a fruit is the ripened **ovary**, or egg case, and its contents; but in popular language we use the word fruit without thinking much of the seed, and only of the pulpy tissue which comes with it. We might call such fruits "fleshy" fruits.

Name some **berries**. A real berry (Fig. 245) is an ovary with its seeds and fleshy material, and with a thin outside "skin." Grapes, gooseberries, and blueberries are real berries, are they not? How about **raspberries?** A raspberry is really a cluster of berries, which comes off from the knob, or **receptacle**, that forms the top of the flower stem. What is a **strawberry?** Have you ever bitten or cut a strawberry in two, and noticed the fine lines running from the outside of the berry to its center? These are tubes that connect the seeds with the top of the flower stalk. It is

FIG. 245. — How some of our "berries" look, when cut through. What is the real berry in each case?

this pulpy top, or receptacle, that we enjoy eating; the seeds are the gritty particles which are embedded in it. In **blackberries** we eat both the cluster of berries and the receptacle.

What are **citrous** fruits? They are fruits like oranges, lemons, and grapefruits. In their case the thin skin of the berry has become a tough, leathery **hide**. Pumpkins and melons go a step farther, and the ovary walls become rinds. Fruits which contain stones, or **pits**, such as cherries, plums, peaches, and apricots, are the result of the wall developing in **two** layers: (1) a hard layer surrounding the seed; and (2) a pulpy layer covered by a thin skin.

What kind of fruit is the **banana**? It is really a berry, as you can see if you cut it across. Its seeds are, however, mere remnants of seeds, and unable to develop into new plants. We learned in § 321 that we eat **juicy** vegetables, not for the fuel they give us, but for their flavor, minerals, and the like. The same is true of most pulpy fruits. But the banana has the qualities **both** of a fruit and of a starchy vegetable, such as a potato. How does the banana skin differ from other, tough, fruit skins, such as those of an orange or a watermelon?

323. Exercises. — 1. What are some plant foods used by us that were very rare a hundred years ago?

2. Can you think how a "spineless" cactus could be produced from a spiny one? Of what use would a spineless cactus be?

3. How was the seedless orange developed? Who did it?

4. What was the importance to the world of the invention of the reaper by Cyrus McCormick? What was the date?

5. What is corn sirup? For what is it used? Examine a paper bag in which cornmeal has been kept. Do you get any evidence of an oily substance in corn?

6. Examine a "head" of red clover. Is the head one flower, or many? What is each separate flower like? Which part of the clover ripens first, the outer, or the inner, part?

7. Why is corn allowed to stand in great stacks, or shocks, after being cut?

8. What is meant by the "curing" of hay and clover? What is the purpose of the curing?

9. Does the value of vegetables and fruits as food depend on the energy we get from them? Explain.

10. Why is a hard-working horse fed upon oats in addition to hay?

11. What are some of the varieties of the potato? Of what value is the potato as food?

12. Is beet sugar produced in the United States? Where?

Summary. — As plants carry on their **life work**, they produce materials which man can use.

Man brings into his own land not only the **products** of foreign plants but, in many cases, the **plants** themselves.

The **grass** family includes not only "grass," but our grains, cane sugar, and bamboo.

Wheat is useful for bread, not only because of its food value, but because of its **sticky** material, or **gluten**, which allows the bread to be "raised" by yeast.

Beans, peas, clover, alfalfa, and similar plants produce their seed in a peculiar pod, called a **legume**.

Leguminous plants capture nitrogen from the air by means of the **bacteria** colonies that grow upon their roots.

We eat vegetables for their **starch** and for their **minerals** and **growth** substances, or "vitamines."

Cotton gives us cotton and **cottonseed oil**; **flax** gives us linen and **linseed oil**.

From the point of view of the **plant**, a fruit is the ripened seed case with whatever is attached to it. From **our** point of view, a fruit is usually the **pulpy tissue** which surrounds, or is a part of, the real fruit, and which we like to eat.

CHAPTER XXXIII

OUR PLANT FRIENDS AND FOES

324. How are Trees Our Friends? — Have you ever been in a great forest and thought of Longfellow's lines?

This is the forest primeval. The murmuring pines and the hemlocks,
Bearded with moss, and in garments green, indistinct in the twilight,
Stand like Druids of eld.

In such a forest of pines and hemlocks the lower parts of the trees have no branches, and the trunks stand straight and tall for perhaps 80 or 90 feet before the branches and foliage begin. When this is the case, it is not hard for us to imagine ourselves in a wonderful cathedral, with trees for its great columns, and leaves and branches forming its roof and letting in only a dim, green light to illuminate the floor below. As a matter of fact, the temples of the Greeks, the ruins of which show us the glory of Greek art, were originally of **wood**, and the columns supporting the high roof were tree trunks. Then, as the people learned to work in stone, and one by one the wooden columns decayed, **stone** columns, adorned in the style of each succeeding age, took their place.

Do you realize how many years large trees have been in growing; and that some of them are much older than any animal living upon the earth? Indeed, some of the **Big Trees** of California are believed to be at least 3000 years old. Some of them are 35 feet in diameter and nearly 300 feet high (Fig. 246). Think of a tree that was at least 250 years old when Rome was founded. What is this date?

But when you think of a tree, you may not have in mind a tree in a great forest, nor one of the Big Trees of California, but a cool shade tree in a city park, or the trim rows of little trees of a peach orchard in Michigan, or a cherry orchard in Wisconsin or Utah, or an orange grove in Florida or California; or you may think only of a comfortable apple tree in your own yard, which gives you both shade and refreshment on a hot day in summer. The trees are indeed our friends, and the more we understand them the more we shall appreciate them.

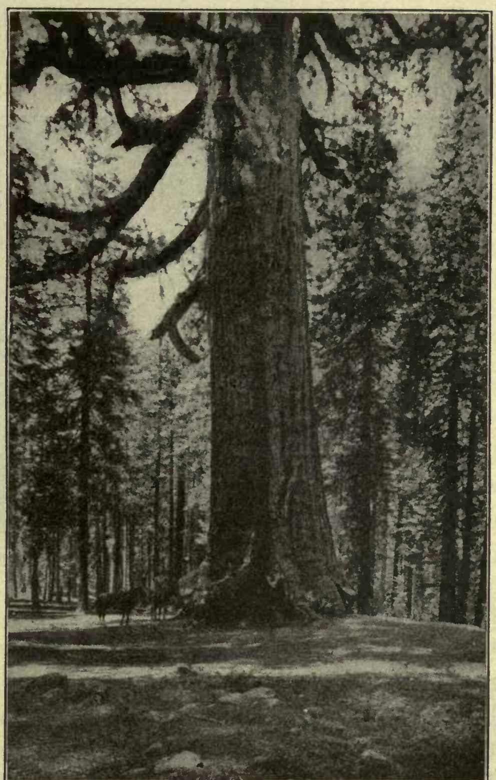

FIG. 246. — A California Big Tree.

325. How Does a Tree Get Its Shape? — Look at the branches of a spreading elm or hard maple or birch as they stand out against the sunset sky in winter, and see how graceful and beautiful they are. Branches are the arms of the tree, spread open to receive the gifts of the sky.

If you think of it, you will realize that the shape of a tree is due to its **branches**, and that trees usually branch in one of two ways. What is the shape of a Christmas

FIG. 247. — An elm and a poplar, showing the two types of branching.

tree? It is that of a **cone**, is it not? Why does it have this shape? Is it not because its branches come out with regular spaces between them, and each set of branches is a little shorter than the set just below it? So we have trees that are cone-shaped and taper toward the top. Name some other cone-shaped trees (Fig. 247).

Suppose that the trunk of the tree, instead of going straight up to the top, divides into branches, and these divide in their turn into smaller branches. What shape will the tree have? It will be **spreading**, will it not, like an elm tree or a willow tree? Name some other trees that are spreading. Which class of trees makes the better shade, the cone-shaped, or the spreading?

You can see how much the stem has to do with the shape of a plant, shrub, or tree. If the stem is strong and stiff, it will be able to bear a great deal of weight; if it is weak, it will need a support, as in climbing vines, such as the Virginia creeper. Notice the different kinds of trees in a high wind. Which are most stiff, and which yield most to the wind?

326. What is the Inside of a Tree Trunk Like? — Interesting as the outside of a tree is, the inside shows us still more wonderful things. If you cut across a young stem, such as that of a lilac, birch, maple, box elder, or pine, you will be surprised at the ringlike structure, beginning with a circular center and extending to the bark on the outside. Look at the cutting across a large tree, as seen in the end of a log, and you will see a similar structure. Perhaps you have heard people say that these are the "rings of growth" of the tree, and that one is added every year. Probably it would be better to say that one is added for every *growing season.* What is the difference?

Let us see what we can make out of this ringlike structure. The botanist has shown us that there are **four** distinct regions in such a stem (Fig. 248):

(1) The outer covering, or skin. In the leaf (see § 300) we called this the **epidermis**; it has the same name here.

(2) The next layer inside the epidermis is soft tissue, which is generally green. It is called the **cortex**.

(3) The third layer from the outside is the layer of **wood.**

(4) The very central part of the stem is the **pith**. When a tree decays at the center, which of these layers has decayed most?

The rays, like spokes of a wheel, that pass out from the pith through the wood, until they reach the green cortex, are called the **pith rays**. They divide the wood into bundles.

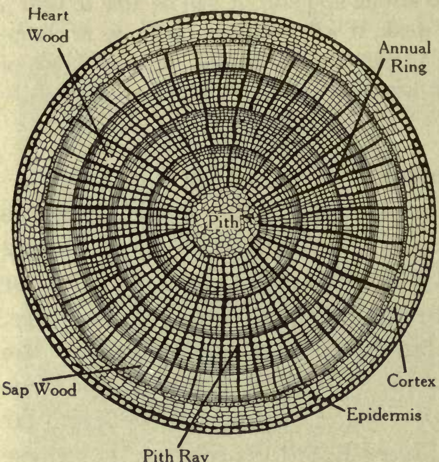

FIG. 248. — How a cutting across a woody stem looks, when smoothed so as to show the markings.

Do all plants have this arrangement? If you look at the stem of Indian corn, or of a lily, or a rhubarb, you will see that the woody bundles in these plants are not arranged in circles *around* the pith, but are scattered **through** the pith. Woody plants with **two cotyledons** in the embryo, like our common trees, have this ringlike structure, while plants with only **one cotyledon**, like Indian corn and the lily, do not. Is it not strange that there should be such a difference in the way in which wood is arranged in a stem? See Fig. 249.

What is the **bark** of a tree? Is it not the old layers of the epidermis, dead, but not cast off from the tree? Why does the bark of a tree split? Can you not see that since the bark cannot stretch very much, the time will come when the growing tree will be too large for its bark, and the bark will crack? In which direction does the bark crack? What does this show as to the way in which the bark is being stretched? Usually the bark adheres to the tree for a long time, and protects the growing stem. How?

Examine the bark of several trees, and see how they differ from one another. Describe the bark of the birch, the shagbark hickory, the pine, and the sycamore, if you can find these trees. Do you think you ought to strip the bark from a growing birch tree?

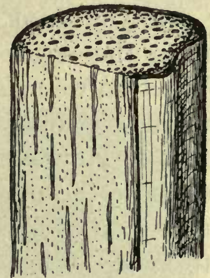

FIG. 249. — A cutting across the stem of Indian corn. The lengthwise cutting at the side goes through some woody bundles.

327. What are Sapwood and Heartwood? — Have you ever seen a **hollow** tree, in which the pith and a great deal of wood next to it have disappeared, while the tree still has branches and leaves and carries on its life? Sometimes a tree trunk is split into several **strips**, and yet each one lives. How can this be? The explanation is that in a large tree the really living part of a tree trunk is near the outside, and that in some diseased trees the inner part has disappeared. We know that the water and dissolved food (the sap) rise from the roots to the leaves, and so must pass up through the stem. The sap passes only through the **woody** part of the stem. But as the tree grows older, the sap stops flowing through the inner wood, which is near the pith, and passes up only through the outer, younger rings of wood, near the cortex. This does not mean that the inner wood necessarily rots. The inner, older wood is called the **heartwood**; the younger wood is called **sapwood**. Which do you think makes better wood for lumber? The heartwood is the better by far, for it does not **warp** so much (what is this?) nor rot so readily as the sapwood.

Do you think it possible for men to take **too much** sap from the sugar maple in the making of maple sirup? What do we mean by saying that a grapevine "bleeds" when we cut it in early spring?

328. How Are Trees Cut into Lumber? — How do you suppose the pioneers in this country got the **boards** for their houses before the days of lumber mills? They had to **split** the logs into rough boards by the use of wedge and maul, and then (see Fig. 210, § 279) to "**dress**" the boards by means of the ax and smoothing plane. All this was slow, hard work. Then came the time when mills were set up on the banks of streams having rapidly falling water; here saws, turned by the mill wheel, cut the tree trunks into boards. Finally came the days of the **steam** sawmill, with its powerful machinery and its great saws. So great has been the demand for lumber, and so reckless have men been in cutting our trees, that many of our immense forests have already been used up, and wood is becoming scarce.

Have you ever read stories of the **logging camps**, in which large companies of men gather to cut trees? The logs cut in greatest numbers in this country are "soft" woods, such as pine, spruce, and hemlock. They are cut in the winter and hauled to the banks of streams. Then, in the spring, when the snow melts, and the streams are full of water, great **rafts** of the logs are floated down the stream to the mill.

A **lumber mill** (Fig. 250) is a thrilling sight. The log is pulled out of the water and carried into the mill by a moving "endless" chain. Inside the mill it is seized by steel "dogs," which hold it firmly as it rides in its "carriage" to the great saw. A man rides in the carriage, too, and directs its movements. The saw cuts off **three** of the rounded sides of the log; these are "slabs." Then the log is cut into boards. The boards are piled up in the open, or in sheds, with spaces between them, so that they may dry, or "season."

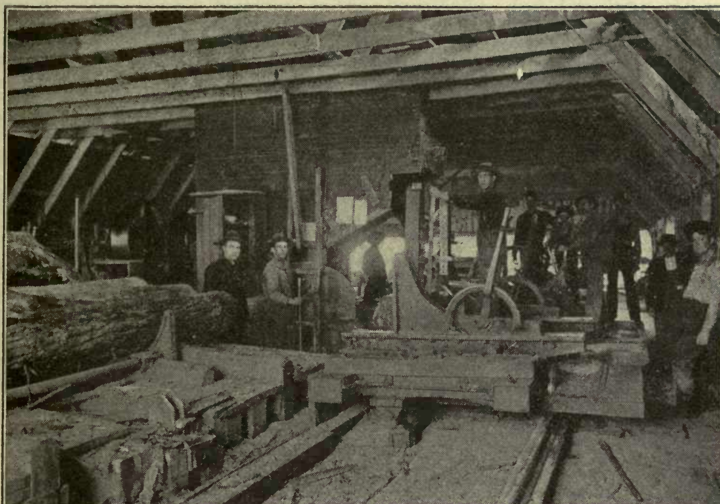

FIG. 250. — What the inside of a lumber mill looks like.

Examine a hemlock or pine board with **knots** in it. What are the knots? They are the remains of **branches** which grew upon the tree when it was young. In old trees the knots are covered up by the later wood of the tree.

329. What are the Uses of Wood? — Why do we use so much wood? It is because wood is split, or sawed, so easily into boards, and because the boards can be cut and smoothed by simple tools into objects of many shapes. Then, too, boards can be **fastened** together by means of nails, screws, and glue, and the wooden object can be **decorated** by carving, staining, and painting to make it attractive. It is for these reasons that houses, fences, furniture, boxes, wagons, pencils, and the like are made of wood.

Look at the drawer of a dresser or table, and see if its boards are fastened together by means of a "dovetail" joint. Ask a carpenter what a "mortise and tenon" joint is.

Why does the wood of some trees split so easily "with the grain"? It is because the **woody bundles** of these trees (see § 326) are arranged in long, straight lines in each ring of growth. When boards are sawed, the saw rarely cuts exactly "with the grain," so that in the surface of the boards we see the rings of growth partly **cut across.** These give pleasing designs, especially in such woods as oak, maple, birch, and hemlock. "**Quarter-sawed**" oak, which has an especially attractive, flaky appearance, is the result of sawing the oak log always from the circumference toward the center. The "cut" is thus made lengthwise through the pith rays; these give the wood its beautiful markings.

With all its convenience, the use of wood about our buildings always means risk, for it brings the danger of **fire.** What objects do you know that were once made of wood, but are now made of some material which is fireproof?

What is the meaning of **hardwoods** and **softwoods**? People usually mean that the trees that have **broad** leaves and lose them in the fall

— **deciduous** (dē-sĭd'ū-ŭs) trees — are hardwoods, while trees that have **narrow**, needle-shaped leaves and have their seeds in cones — our **evergreens** — are softwood trees. These names are not very accurate, however, for the *poplar* and *basswood* are broad-leaved trees, yet they have soft, easily worked wood; while some needle-leaved trees, such as the *Southern pine* and the *tamarack*, have a rather hard wood. White and Norway pines, hemlocks, and firs give us our ordinary softwood; the oak, beech, maple, cherry, walnut, and mahogany give us hardwoods. When men build a wooden house, they usually have softwood for the outside and hardwood for the inside. Can you find out why? The Southern pine is often used (as "hard" pine) for inside woodwork.

Ask a carpenter why cedar and Washington fir are used for **shingles**. What is meant by laying shingles "four inches to the weather"?

Do you think that trees have no other **uses** than to give us fruit, shade, and wood? We have already learned that the **sap** of the maple gives us maple sirup and maple sugar. Another sap is very important in this age of rubber overshoes and rubber tires, and that is the sap of the **rubber** trees of South America and Africa; when the sap is boiled down, it gives us rubber. We get **turpentine** from the resinous liquids of the Southern pine. What is it used for (see § 33)? By heating the leaves and wood of the **camphor** tree we get camphor. From the bark of the **cork** tree we get corks, and from the bark of the oak and hemlock we obtain the material for **tanning leather** (see § 341).

330. How Is Paper Made? — Why do we speak of **paper** along with the uses of wood? Does the white paper on which the **news** is printed look at all like wood? Yet it is true that the greater part of our paper, such as that used for our newspapers, magazines, and our ordinary books, is made from **wood pulp**. How is wood pulp obtained? The wood used is one of the softwoods, such as the **spruce**. It is cut into chips, and the chips are heated, under pressure, in great boilers, with sodium hydroxide (see § 177), or a substance called " bisulphite." In this way almost everything in the wood is removed except the **cellulose** (see § 195).

You can see what the pressed paper pulp looks like by examining a piece of **filter paper**, or blotting paper. Men make newspaper and wrapping paper from the pulp by " filling " it, in order that it may be less porous. **Clay** is one of the " fillers " used. For a writing paper, or a good printing paper, on which ink will not " run," the pulp must not only be " filled," but it must have a " sizing " of some such substance as gelatine, rosin, or alum. Finally men **polish** the paper by passing it between rollers. Have you ever seen a newspaper or magazine page which has been exposed to light for some time, and has gone back to the brownish or pinkish color of the wood from which it was made? Have you ever seen the nest of the paper wasp? Find out how the wasp makes its " paper."

331. What are the Enemies of Our Trees? — Does it seem strange that trees have **enemies**, against which they must be protected, if they are to grow properly? These enemies are plants or animals, are they not, that feed upon some part of the tree, using it for their **food?** But **man**, by being careless with a tree, can also be its enemy. Suppose he hitches horses to trees, or lays leaky gas pipes near their roots, or cuts off large masses of roots to lay a sidewalk, or fills up the low place in which a tree is growing, and so prevents its roots from getting air, is he a friend of trees? Have you not seen trees badly defaced by having their important branches cut off in order to make way for telephone or lighting wires, or to permit an old house to be moved along a street? Is this really necessary?

Then there are the **bacteria** of decay, which get into a tree through a jagged, broken limb, or one that is improperly sawed off, or through an injured place on the trunk, and so cause the tree to **rot**. Have you seen shade trees treated by " tree surgery ": the rotten material cut out; the wound painted with **creosote** and tar to kill the bacteria; the cavity filled with **cement**? In this way the lives of valuable shade trees are lengthened by many years. How are large branches of shade trees prevented from breaking off?

There are also **insects** of many sorts that feed upon some parts of trees, and injure them. Think how attractive the sweet, juicy fruits, the fresh leaves, the nourishing growing layer under the bark, and the tender roots must be to the insects that need these foods for their growth and development. But since man is growing trees for his own use, and not for the insects' use, he must destroy the insects. We shall learn about some of these pests in § 348.

Do you know the month and day of **Arbor Day?** " Arbor " means tree, so Arbor Day is really **Tree Day.** Since trees give us so much pleasure, and supply us with so many useful things, and have to contend with so many enemies, do you not think we ought to plant trees to take the place of those that must soon die or be used up? Arbor Day should be a day not merely for *planting* trees, but for *helping* those we already have, so that they may live longer lives and be free from pests and disease.

Make a **tree census** of your block, and tell how many trees need care and help. How many more trees could be planted, without crowding, in the **parking** of your block?

332. What is a Weed? — Do you know what "dirt" is? Some one has said it is "matter out of place." So we may say that a weed is a *plant out of place*, or where we do not want it to grow. Thus, grass is not a weed on a lawn, but it is a weed in a strawberry patch. The oxeye daisy has beautiful flowers, but it is a pest in a hayfield.

What weeds do you know when you **see** them? Do you know the shepherd's-purse, lamb's-quarters, pigweed, wild mustard, mullein, milkweed, smartweed, cinquefoil (meaning "five leaves"), quack grass, fireweed, and Canada thistle? How about the sorrel, dandelion, plantain, and dock? What a multitude of weeds there are, and how hard they are to get rid of! Do you realize that men have been trying to destroy weeds for thousands of years, and that many of our weeds have been successfully fighting for their lives against all man's efforts? Only those that were especially **hardy** and could take advantage of every opportunity have lived on. No wonder it is hard for us to get rid of them! Weeds choke up canals and irrigation ditches, cover railroad tracks, take moisture and plant foods from our gardens, shade growing garden plants and cut off their sunlight, fasten themselves to other plants, as **parasites** (see § 195), and rob plants of their sap. Besides doing these things some weeds produce substances that injure our cattle, or give milk or meat a disagreeable taste.

If the seeds of weeds become mixed with the seeds of the grass and clover which the farmer sows for his **hay**, they are very hard to get rid of; but in the garden we can usually pull them up or destroy them by **hoeing**. How can we get rid of **dandelions** on a lawn? Is it of much use for your neighbor to dig the dandelions out of his lawn, if you let them go to seed in yours? How long a dandelion root have you seen? Does it do much good to break off the top of a dandelion plant? Have you ever tried to pull up the common **sorrel**? What are its roots like? **Cultivating** between the rows of plant crops and trees (see § 155) is not only for the purpose of making the top layer of ground **powdery**, but to destroy **weeds**. May the cut weeds sometimes be useful as fertilizers of the soil?

333. How Can We Plant for Beauty? — Are plants of value to us only because they are useful, or because they also please our sense of the beautiful? Is it not true that we cannot help having a feeling of appreciation and delight when we enter a well-arranged **flower garden**? We need to learn that a flower garden is not simply a place where flowering plants **grow**, but that there are ways for **arranging** the plants to make them appear to the best advantage. A few simple **rules** will help us (see Fig. 251):

(1) A large variety of flowers in a garden is often not nearly so pleasing as a **mass** of the same flowers, or masses of a very few varieties.

(2) When we are putting flowering plants near one another, we should take care to get flowers of colors which **harmonize**, or look well together. This is especially true of different kinds of flowers in the same bed. Of course, if the flowers bloom at different seasons, as tulips in the spring, asters in the summer, and chrysanthemums in the fall, many combinations can be made. This is often done, and makes an attractive bed all the time.

(3) **Small plants** should be placed outside, or **in front of**, tall plants or shrubs. Shrubs around foundations of a house hide unsightly bricks or stones, and make the house look as though it belonged where we find it.

(4) The **lawn** should **never** appear to be **dotted** with shrubs and flower beds, but a soft expanse of green sod should be left by itself, as it is very pretty.

(5) **Flower beds** around the roots of trees are not artistic.

(6) Trees and shrubbery should **not** be so **dense** that the view from or to the house is completely shut off.

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FIG. 251. — A beautiful lawn. How does it illustrate the rules of "Planting for Beauty"?

(7) Shrubs should be **trimmed up**, so that grass will grow near them, and so that the ground under the shrubs can be cultivated. Shrubbery following a path is very pretty. **Terracing**, or making the lawn or garden on different levels, whenever it is possible, adds a great deal of beauty to a lawn or garden. Make a map of some lawn in your neighborhood, marking the position of trees and shrubs. How can it be improved? Suggest how you could get both use and beauty out of a back-yard city garden.

334. Can Man Improve upon Nature? — Do we want to get "back to nature" in the growing of our food plants? The farmer looks over the ears of corn from his **best** field, and picks out the most **perfect** ear to save for his **seed corn.** He knows from experience that one ear is not so good as another for planting. Luther Burbank and other scientists have realized this also, and have done wonderful things to **improve** the plants which nature has provided.

Men have developed many varieties of plants simply by **choosing** an individual plant which has the **qualities** that they desire. Perhaps it is height, or shape, or time of blossoming. For one thing, they take care to see that the plant is **self-pollinated**, that is, that its pollen comes only from the plant that produces the seed. Then these seeds are planted. Some of the young plants will be like the parent, others will be different. Only those young plants are saved which are like the parent plant. This careful **selection** is carried on through many generations. Each time only the right plants are saved and used, until finally the variety is developed as we desired it to be.

This improving of plants is also carried out by **crossbreeding.** For instance, wheat that is tall and easily attacked by rusts is "crossed" with wheat which is short and able to resist rusts. This means that the pollen of one variety is used to fertilize the "egg" of the other variety. Then only that wheat is saved which is tall and resists rusts. If we select such wheat for many generations, we may develop a variety that rusts cannot injure.

By crossbreeding and careful selection, our fleshy **fruits** (what are they?) have been improved in flavor, size, and other qualities;

flowers have been made larger, and more beautiful, and of unusual colors; **cereals** and other grasses have been made more useful and hardy; new **foods** have been produced for our use. This work of improving our plants is very interesting, and is a field which can never be exhausted. Read something of what Burbank has done.

335. Exercises. — 1. Why do lumbermen prefer to get logs out of a northern swamp in winter rather than in summer? When would the wood be more dry?

2. What must be true of the pores of wood, if the wood takes up stains readily?

3. Why should we leave as much soil as possible upon the roots of a tree when transplanting it?

4. What is soap bark? Peruvian bark? For what is each used? For what did the American Indian use birch bark?

5. Put a piece of knotty yellow pine or hemlock in the hot rays of the sun, or near a hot radiator or stove. What happens to the knots? What causes the odor? What material is in the knots?

6. What are the advantages of a wooden house over a brick house? What are the disadvantages?

7. Why does the ink "run" when we try to write upon blotting paper? What phenomenon is this? See § 125.

8. Name some plants that scratch you when you touch them. Some that poison you. Some that have a disagreeable odor.

9. How can a tree be protected from caterpillars that crawl up its trunk?

10. Find out the meaning of chrysanthemum. How has the flower been developed to so great a size?

Summary. — **Trees** are our friends because of their beauty, their shade, and the fruit, nuts, wood, and other material they give us.

The **shape** of each kind of tree depends on the way in which its branches are arranged.

The **trunks** of our common trees have **pith** at the center, then **heartwood, sapwood,** the green layer, or **cortex**, and the **epidermis.**

Trees with only **one** cotyledon in the seed have the wood bundles **scattered** through the pith.

The **bark** is the old epidermis still adhering to the tree.

Knots are the remains of old branches.

Wood is so **useful** because it can be fitted together, is light, and can easily be decorated.

Most of our **hardwood** comes from *deciduous* trees, and most **soft-wood** from *evergreens*.

Most of our **paper** is made from wood pulp.

Arbor Day is set apart for the planting and preserving of trees.

A **weed** is a plant out of place.

Beauty in a lawn or garden depends upon the **choice** and **arrange-ment** of plants.

Man has developed plants by " **selection** " and by " **crossbreed-ing.**"

CHAPTER XXXIV

ANIMALS OF IMPORTANCE TO MAN

336. How Many Animals are There? — We have learned something of the wonderful world of plants and how they grow, also how man makes use of such as he wishes, and seeks to destroy those that injure him or his cattle or his cultivated plants. The world of **animals** is just as wonderful as that of plants; perhaps even more so. Think of the **number** of forms nature has produced, from the tiniest insects to great animals like the whale and the elephant. The microscope shows us forms much smaller than the smallest insects, until, as in the case of plants, we get down to animals having only a **single cell.** Yet even these tiniest creatures are able to do the things needed to support their life and to produce new beings like themselves (see § 297). Of insects alone men know perhaps more than 200,000 different kinds, or species (spē′shēz); of birds perhaps 10,000; of fishes about 12,000. You will see from these figures that it is hardly possible for one person to know all the animals there are. Besides the animals now living, there are thousands of forms which lived in the past, and which we can know only through their **fossils** (see § 147). Have you seen some of these animal fossils in museums?

Zoology (zō-ŏl′ō-jĭ) is the science of animals; the name comes from the word "zō′ŏn," meaning an animal. What is a "Zoo"? What is its full name?

337. Have Animals Helped, or Hindered, Man's Progress? — When we think of the number of people killed by wild animals, such as tigers, lions, wolves, and snakes, even in recent years, after men had invented powerful weapons of protection, we may imagine that **early** man, with his poor weapons, or none at all, had a hard time of it. See Fig. 252. Some animals he killed for food; many others were his enemies, and hunted him. But the story is different when man had learned to **tame** animals, and to use them in his work. These animals then became his **helpers** in his march to civilization. Would it not be interesting if we could have the true story of the way in which man first caught dogs, horses, cows, sheep, goats, and chickens, and made them feel **at home** with him? To understand man's early history correctly, we must know something of these first pets of his, and how he made them his companions and helpers by domesticating them. What does

FIG. 252. — A drawing of a mammoth, made by early man upon an ivory tusk. After Lartet, but greatly simplified.

domesticate mean? It comes from the Latin word **domus**, a house, and means that man made these animals a part of his **household**.

Have you ever thought that while man domesticated certain wild animals, and made a home for them, they, in their turn, helped to keep him **at** home and to make that home in some **one place**? For

(*Courtesy of the U. S. Department of Agriculture.*)

Fig. 253. — Buffaloes.

a long while after man had domesticated animals, he wandered about with his flocks and herds, in search of food and pasture, just as certain **nomadic** (nō-măd′ĭk) tribes of Asia and northern Africa do today. Gradually, however, man learned to domesticate, not only animals, but **plants** also, and to feed the plants, or their seed or fruit, to his animals, and to eat the food himself. Instead of remaining a nomad, he became a **farmer**, and began to build up communities and **nations**.

Has man altogether lost his love of hunting wild animals? Think how we still love to hunt and to fish, partly, of course, because of the food we catch, but largely for the "joy of the chase." Reckless hunters, if not controlled by law, would soon exterminate many of our native wild animals (see § 310 and Fig. 253).

338. What are Man's Beasts of Burden? — What would you think if you should see a **dog** harnessed to a large cart, bringing a milk can or other heavy burden to your door? The sight is not common in America, but very common in western Europe. Is the dog a beast of burden anywhere else? Of course you remember that the Eskimos and Polar explorers use dogs to pull their sleds. In northern Europe and Asia the reindeer is the beast of burden, and it has been introduced into our own Alaska. It can get its own food, even in the winter, by nosing away the snow, and finding the green moss underneath.

When we think of man's beasts of burden, we think, of course, of the **horse**; but we must not forget the patient **ox**, which probably pulled man's carts and did his plowing long before the horse. Even in parts of America today, farmers sometimes come to town in ox-carts. The **mule** is also an important beast of burden. What animal is called the "Ship of the Desert"? In what countries is the water buffalo used?

The horse is man's favorite animal for his own riding, and was probably developed first for its **swiftness** and as an aid in **war**. The **Arabian** horse has been looked upon as the most spirited and beautiful type of the animal. For thousands of years the Arab has brought up the horse with tender care, and made it his constant companion.

For **farm** work, with its hauling and plowing, quite a different type of horse is needed. Did you know that one of the probable reasons why man did not reach the same stage of development in America as in Europe, was that in America he had no beasts of burden, like the horse and ox, to help him in his work? But why did not the Indians use their **ponies** for such work, you ask. The answer is that before

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Fig. 254. — A pack train of llamas, San Mateo, Peru.

the coming of the white man the Indian had no ponies; all the Indian ponies are the descendants of horses which were brought over by the early explorers and settlers, and which ran wild. Yet the horse probably developed **first** in America. The fossils of the earliest horse show an animal of about the size of a fox; later fossils show it in constantly increasing size. But for some reason the race of horses died out in America, and developed to its fullness only in the Eastern Hemisphere.

The beast of burden of the ancient Incas, or inhabitants of Peru, was the **llama**, sometimes called the South American camel (Fig. 254);

but its use never spread to much of our continent. Were the Incas among the most advanced, or the most backward, races found on the American continent? Have you read "The Conquest of Peru," by Prescott?

339. What Four-footed Animals Give Us Meat? — When we speak of our **meat** supply, we think first of what animals? Of our common **cattle**, of course. Yet there are many other four-footed beasts, the flesh of which serves for our food. We think of **sheep**, which yield mutton, and of **swine**, which yield pork. In the early days of the Colonies, the flesh of the buffalo, deer, and bear were used as food. The meat of the **deer** is still used in the winter in our Northern States and in Canada. What is deer meat called?

Among the **smaller** game used as food we think of rabbits and squirrels. In Australia and some of our Western States rabbits have become a pest, because of the damage they do to crops; hence large numbers of them are killed every year, and eaten or shipped elsewhere for food. The Australian soldiers in France during the Great War had frozen rabbit meat shipped to them from their far-away home.

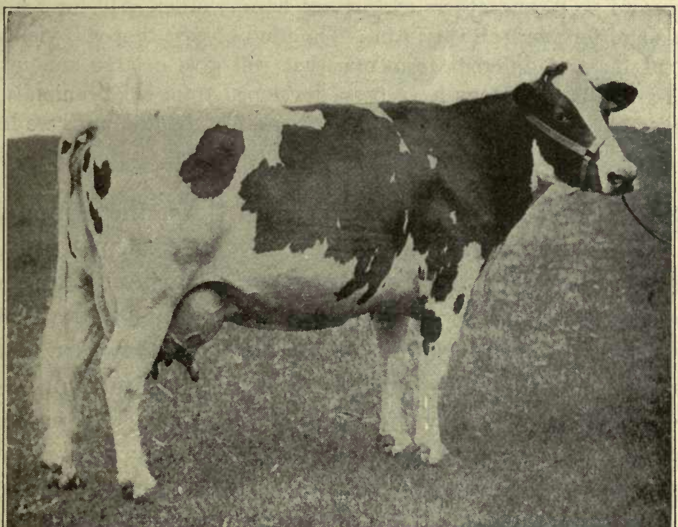
The kind of meat eaten by a community used to depend upon what the community raised. In the "cattle country" of the West the chief meat is **beef**. If you remained overnight in the hut of a sheep-herder in Utah, you would be served **mutton** or lamb. If you dined with a herdsman in the Alps, very likely your meat would be **goat's meat**, and the milk served would be goat's milk. In some countries horse's meat is used as food, and the Polar explorer is glad to save his life by feeding upon the meat of the **walrus**.

With the coming of " cold storage " the meat problem of the world has changed. We have already learned of the large refrigerators, cooled by cold brine (see § 126, Fig. 82), in which meat can be kept from spoiling. **Refrigerator cars** can be used to carry meat to a seaport, and **cold storage** rooms on shipboard keep the meat frozen on its trip overseas. You can understand that with such modern methods of transportation, men are not compelled to eat the meat raised in their own neighborhood, but can draw upon other parts of the world for it. The same is true of fruits and other " perishable " food (see § 312).

340. Why is Milk So Valuable? — Review § 191 for some of the reasons why milk is so valuable a food for growing boys and girls. To millions of babies it is the **only** food. Is it not important, then, that milk shall be rich in nutritive materials, free from dirt, perfectly fresh, and without harmful bacteria? For the grown person milk is only a part of the diet; for the baby it is the whole diet.

Because milk is so good a food, it is a wonderful breeding place for bacteria. But in **cold** milk the bacteria cannot grow nearly so rapidly as in warm milk. This is the reason why there should be a refrigerator of some sort in every family in which there are children. Do you see the value of the campaign that takes place every summer in the cities, for money to get " free ice" for the poor, in order to " save the babies "?

Special care is necessary in **milking** cows, so that no dirt shall get into the milk (see § 289). The milk should be **cooled** as quickly as possible, and should be put **at once** into clean glass bottles, with secure, new covers, for delivery to customers. What would you think of a dealer who would pour milk from cans into bottles rinsed merely in **hydrant** water, and then use pasteboard covers which had been used before? Do you think milk will be clean and fresh, if it is allowed to remain on the dusty floor of a grocery until customers come in and take it



(Courtesy of the U. S. Department of Agriculture.)

FIG. 255. — A good cow for producing milk — a Holstein.

away? The producer and dealer in milk should do his part; but we should do ours, too. Does your family cleanse the cover and neck of a milk bottle in any way before pouring the milk out for use?

How did men ever develop cattle that give such large yields of milk (Fig. 255) and such delicious cuts of meat as we obtain today? These animals certainly cannot do so well in a "state of nature."

The answer is the same as in the case of the different breeds of chickens, dogs, cats, pigeons, and horses. Man has **developed** these, as he has developed his cultivated plants. He has **picked out** the ones that had the qualities he desired, and then he has bred these individuals, generation after generation, picking out the best ones each time. In this way he has obtained **thoroughbreds.** Man has bred some kinds of **horses** to be racers, others as carriage horses, others still for hauling loads and for work on the farm. The kind of **cow** that will yield excellent meat is different from one that will give a large amount of high-grade milk. **Hogs** have been developed from small animals, or " razor-back " creatures with long legs and lean bodies, until we have the fat, short-legged porker raised by farmers today.

341. What is Leather? — Do you think that the parts of cows that cannot be used as meat are thrown away? By no means. The **hide** is made into leather; the hoofs and horns and part of the hides are changed into **glue**; the fat is used for **soap** (see § 185); brushes are made from the **hair**; while the scraps which cannot be used for other things may be heated with lime to produce **ammonia**, or turned into **fertilizer** for soil (see § 159). The ammonia is used as household ammonia (see § 142), or to cool the brine of ice plants and cold-storage warehouses (see § 126). Buttons and combs may be made out of the **bones** of animals.

Leather is made out of an animal skin, by changes which keep the skin **pliable**, prevent it from " spoiling," or decaying, and prevent it from being acted upon by **water.** Fresh skins soon spoil if kept moist, because of the action of bacteria (see § 205); if, on the other hand, they are allowed to dry, they become hard and horny. If fresh skins are boiled with water, they become glue. Would glue do for leather? So you see the need of changing skin into leather, if we wish to keep it for our use.

The animal skin consists of an outer skin, or **epidermis** (see §§ 300 and 326), an innermost layer of **fatty** tissue, and between them the true skin, or **dermis.** It is the dermis, consisting of densely matted fibers of **connective tissue**, that is made into leather (see § 195).

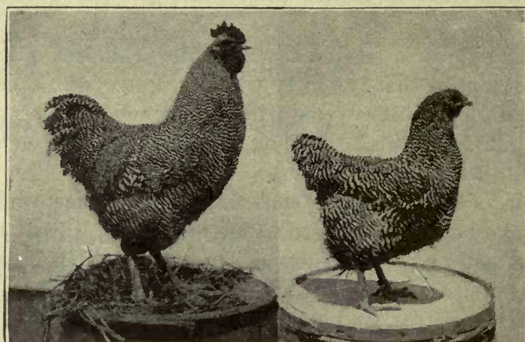
First the hide is so treated that the **outer** skin, including the hair, is removed, and so that the fatty tissue is destroyed. Then the true skin is **tanned** by being covered with oak or hemlock bark (see § 329) or by certain chemicals. Tanning changes the connective tissue of the skin into leather.

The skin of **large** animals, such as the cow, horse, and walrus, is used to make heavy, strong leather for shoe soles, leather trunks, and the leather belting of machinery. The skin of goats, calves, sheep, and dogs is used for the "uppers" of shoes, and for gloves, belts, book covers, leather purses, and the like. What kind of ball is called a "pigskin"? Why?

342. What Birds Give Us Food? — What birds has man *domesticated?* Chickens are the most important, of course, and then ducks, geese, turkeys, and pigeons. Chickens are valuable for their meat and eggs, turkeys and pigeons for their meat, and geese for both meat and feathers. What do we use goose feathers for? The word "pen" (used for writing) comes from the word for *feather;* can you tell why? Feathers are really a form of the epidermis, or outer skin, and correspond to the hair of animals. They form an almost perfect covering to keep the heat of the body from being radiated (see § 70).

Examine the feathery covering of a chicken, and see what a wonderful structure it is.

Turkeys are natives of America, and have been domesticated only since its discovery. In some parts of the country the wild bird still exists. The domestic turkeys are still far from being tamed, for they do not thrive when kept closely in the barnyard; they wander away to



(Courtesy of the U. S. Department of Agriculture.)

FIG. 256. — Barred Rock rooster and hen.

lay their eggs and to bring up their young, like their wild ancestors. Have you ever seen a hen with a flock of turkeys she has hatched, all of them much larger than herself?

The raising of ducks has become a quite important industry, especially of those kinds, such as Indian Runners, that can get along without much water for swimming. They lay large eggs, and lay them frequently, and their meat is excellent eating.

How many eggs do you suppose the hens of America produce in a year? About twelve billion (12,000,000,000), we are told. How many eggs are there for each person in the country?

Why are eggs used to such an extent? They are very **nutritious** food, and easily digested, and they can be kept a long time, especially if cold (see § 126). In **baking** they are used so largely because they can be beaten into a foam which "sets" when heated, and which makes the dough with which it is mixed light and easily digested. What does the egg-beater beat into the egg?

There is a great deal of pleasure, as well as profit, derived from the raising of chickens (Fig. 256). As you know, the eggs contain the embryos of the chicks (see § 298), and if kept warm for about 21 days will develop chicks. Instead of a mother hen, chicken-raisers often use a heated box, or **incubator**. But eggs will not "hatch" unless they are **fertilized** eggs. A good chicken-raiser "**candles**" his eggs after they have lain under the setting hen, or in the incubator, for 7 or 8 days; that is, he puts the eggs between himself and a strong light, and finds out what is happening inside. If the interior of the egg is clear, he knows there is no chick inside; but if a dark mass appears, he knows that the chick is developing. You can make a simple "candling" box (Fig. 257) by putting an electric bulb inside a pasteboard box, such as is used for breakfast cereals. Cut a smooth, round hole, not quite large enough for an egg to pass through, into one end of the box, hold the egg in front of the hole, and look through it toward the light. The **infertile** eggs can be removed from those that are developing, boiled hard, and fed to the chicks which hatch.

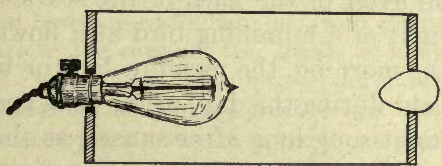


Fig. 257. — A candling box for testing eggs.

Some kinds of chickens are especially valuable because they grow rapidly, and have fine meat; others because they lay many eggs. "General purpose" chickens are such as are useful from both points of view.

343. Why Should We Protect Birds? — How many kinds of wild birds do you know by **sight?** By their **songs** or calls? There are English sparrows and song sparrows, eagles, owls, hawks, crows, kingbirds and kingfishers, woodpeckers, jays, ravens, cowbirds and catbirds, robins, thrushes, wrens, vireos, herons, orioles, bobolinks, meadow larks, humming birds, and thousands more (see § 336).

We should protect birds because of the **beauty** they give to our surroundings, both by their graceful, often brilliantly colored bodies and by their sweet songs. What can take the place, to one who loves this world in which he lives, of the flash of the scarlet tanager's wing, or the sight of a humming bird at a flower, of the lark's song in the morning, the meadow lark or bobolink rising from the field during the day, or the song sparrow singing his good-night song long after sunset, as the dark settles down?

Then we should make life as safe as possible for birds for the wonderful **nests** that they build and for the tender care they give their **young**. Have you ever thought of the parent birds during the spring storms, covering their eggs or their young, facing pelting rain and hail, and swaying boughs and lightning flashes, while we are warm and dry in the house? Have you watched parent birds teaching their young to fly, encouraging them and protecting them from cats and snakes and other enemies, until they could "feel the air" and fly alone? Think how many of our ideas of the faithfulness of parents to their offspring come from what we see each spring and summer in the devotion of birds.

The last, but not the least, reason why we should protect birds is that they are so very **useful** to us. But someone will say that certain birds eat some of our grains, or some of our fruit, or some useful insects. Even if we admit that this is true, we must remember that the **benefit** which birds do to us is so much greater than the injury, that we would lose dreadfully if birds were taken away from us. We have studied about **weeds** (see § 332); birds eat enormous quantities of weed seeds, and so prevent them from sprouting. Did you note, in § 336, how many species of **insects** there are? It is with insects that man must struggle in raising crops for himself and his domestic animals. The cultivated crop is far more attractive to the insect, in too many cases, than the weeds upon which the insect used to live; so it proceeds to devour the crop. The greatest agents in the temperate zones — far more important even than poisons and sprays — for the destruction of insects are the birds, and these are largely our **song** birds. Only a **few** birds are really harmful; with the exception of the English sparrow, the cowbird, two species of hawk, and the great horned owl — but not the other owls — and a very few others, perhaps, all the birds are doing man a great service. The robin pays abundantly for the cherries it eats. Even the crows, which eat our corn and the eggs of song birds, also eat many destructive field mice and cutworms. Men used to suppose that the kingbird, or "bee martin," ate bees; but it has been found to kill very few bees — and these mostly useless **drones** (see § 347) — while nine tenths of its food consists of insects which are harmful, or at any rate not useful to us.

How do you suppose men find out what the different birds eat, and whether a certain bird does more good than harm? It is necessary that men shall kill a few birds of each kind in order to examine the "crop," in which the bird's food is stored before it is digested. Then it is possible to count the insects and weed seeds and grain which the bird has eaten.

344. How Shall We Protect Birds? — What do you think of people who will kill robins for **food?** It does not seem possible that any one would destroy so valuable a bird for the tiny bit of meat it yields; yet it is true that many hundreds of thousands of song birds are killed every summer in this way. Each person who cares for the birds should see to it that the men who hunt such birds are made to realize what a dreadful thing they are doing.

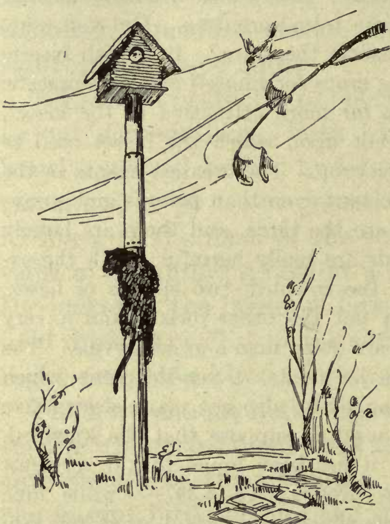


FIG. 258. — A bird house in which the birds are protected from climbing cats by a strip of tin or zinc encircling the post.

But there is another thing we can do to protect song birds, and this is really to "domesticate" our **cats**. What do you think of people who go away for the summer and leave the family cat free to rove about without food? What can the cat do? It does as its ancestors did before it, and becomes a hunter of birds. If cats are well fed and cared for, they are much less likely to hunt for prey. Men have found that most of the damage is done in the **early** morning; hence if cats are kept indoors at night, and not let out in the morning until they have been fed, they will do much less harm. It has been estimated that a full-grown cat, kept in grounds having many shrubs and trees, will kill about

50 birds every year; and it is also estimated that in this country of ours, east of the Mississippi River, cats destroy about 80,000,000 birds every year, or almost one for every person in the whole country. Perhaps we are paying too high a price for the privilege of keeping cats.

We can attract birds about our homes by building **bird houses.** Many very useful and pretty houses can be made easily, or bought. A bird house should be set upon a pole at least 8 feet above the ground, and should be protected by a strip of tin or zinc about 18 to 24 inches wide going entirely around the pole, and placed about 5 feet from the ground. The smooth metal strip makes a place beyond which a cat cannot climb (Fig. 258).

345. What Fishes Are Used by Man? — Get a perch, bass, or herring at a fish market, and study it. Also watch the movements of a living fish in an aquarium. To most of us fishing is only a part of the pleasure of a summer vacation, but to a great many men and women it is the serious business of life. Have you ever read Kipling's "Captains Courageous," with its story of the dangers of New England fishermen upon the Grand Banks of Newfoundland? This is only one of many stories that tell of the hardships of the fisherman's life. Mankind eats a great deal of fish; in fact to a large portion of the human race fish forms almost the only meat food.

The most important fishes of America, from a commercial point of view, are the **salmon** on the Pacific Coast and the **cod** upon the Atlantic. The best fish in the Great Lakes are undoubtedly the **whitefish**; but they are much less abundant than formerly. Herring, shad, and mackerel are the other very important salt-water fish, and perch and bass those of first importance in the inland lakes and rivers of the country. When fish swim in close groups, called **schools**, or *shoals*, they are easily caught in large numbers by means of nets.

You would think that salt-water fish would remain always in the ocean, but it is not so. By some strange instinct, when it becomes time for the eggs to be laid and fertilized (time of **spawning**), such fish as the salmon, shad, and cod swim up into rivers in search of a quiet place for their young to develop. Perhaps the ocean is too rough for the purpose. This is the great time of the fishermen, for in their journey up the stream the fish are sometimes so crowded that they cannot help being caught in large numbers.

Have you read the stories of the **salmon** as they journey up the rivers of the Pacific Coast, in Washington, Oregon, and Alaska? How they swim against the swift currents of the rapids and even climb the waterfalls in their determination to get into the quiet, upper portion of the river? Some of them, torn and battered by the rocks, finally succeed, having escaped the rushing water and the nets of the fishermen. When the young fishes (the "fry") are old enough to make the journey, they swim downstream to the sea, to live as salt-water fish until the time comes for them to spawn in their turn. Then they repeat the dangerous journey of their parents, and so on, generation after generation. **Canning** salmon is a very important industry, worth many millions of dollars annually (see § 212).

The **government** tries to keep up the supply of fish, both by hatching many fish eggs, and by protecting the fish. The young fry are guarded until they are ready to care for themselves, and the adult fish are protected from fishermen at the time when the eggs are laid. What is the meaning of "open" and of "closed" season?

346. What are Insects Like? — When we speak of **insects** we think at once of flies, mosquitoes, May beetles, crickets, grasshoppers, ants, bees, wasps, and a multitude of other creatures like them. What does the word "insect" mean? It means "cut into parts." This name is given because of the many **jointed** parts of which the insect's body is made. The main divisions of the insect's body, like those of our own, are: **head**, **thorax**, or chest, and **abdomen** (ăb-dō'mĕn). But the insect's abdomen is made up of many jointed rings, instead of a single structure. The **legs** of an insect, and its **wings**, when these are present, are attached to the thorax. In **spiders** the head and thorax are united into one structure.

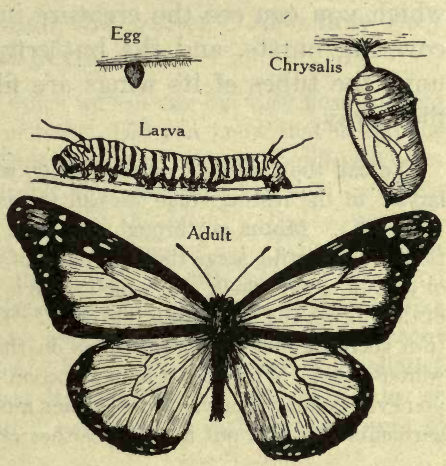


Fig. 259. — Stages in the development of a monarch butterfly.

We have all heard or read of the wonderful changes through which many insects pass, between the time they **hatch** from the egg and the time when they are fully formed, or **adult** (see Fig. 259). These changes may be called: (1) the **feeding** stage; (2) the **resting** stage; and (3) the **adult**, or egg-producing, stage. You would not think that butterflies and moths, which are so beautiful, and which visit flowers for their nectar, and aid plants in fertilization (see § 307), were ever the **caterpillars** that devour our plants and spoil our fruit; but it is so. Have you ever seen the caterpillar of the **monarch** butterfly devouring the leaves of the milkweed? When it is through eating, and has stored away a great deal of rich food, it becomes quiet, and attaches itself to the under side of a leaf or stem. Then a **change** takes place in its body. The body shrinks in size, and becomes surrounded by a thin, green " skin " that is *translucent*, and through which you can see the creature inside. Finally the thin covering bursts, and the butterfly comes out. It waits until the tubes of its wings are filled with air, and then flies away.

We call the " worm," or caterpillar, which eats so ravenously, the **larva**; in the resting stage we call the creature a **pupa**, or *chrysalis* (krĭs′ă-lĭs). **Moths** go through the same stages as butterflies, except that in the resting stage the caterpillar of the moth spins a warm case, or **cocoon**, about itself. In which stage is the silkworm? Is the **adult** of the silkworm a moth, or a butterfly? Have you ever seen the beautiful **cecropia** moth, or its cocoons on the under side of a branch in winter-time? Why does it spin a cocoon for its resting stage? Have you ever found the larva of the **clothes moth** eating holes in the woolen garments that you put into the clothes closet for the summer?

347. What Insects Give Us Food? — When someone speaks of insects which help feed us, of course we think at once of the honey **bee** and its honey. Have you read of the wonderful **society** which bees form, how they care for their young, make houses, store food, and act like the members of a community, with duties to the colony, or **swarm**, to which they belong? How have the bees learned to do these remarkable things?

The "ruler" of the swarm is the "queen," which lays the eggs. The male bee is only a **drone**. The undeveloped females, or "workers," do all the work of building the honey cells, providing the honey and feeding the young larvæ (lăr′vē), or **grubs**, when they hatch. If the queen bee dies, the workers feed one of their number with a special food, so that it develops into a queen. From what plants do bees get most of their honey? Find out how bees live through the winter. Also how they regulate the temperature of the hive.

Ants do not provide food which we can use, but they form colonies fully as wonderful as those of bees. Did you know that in the ant colonies there are different **kinds** of workers, able to do different sorts of work? Does it seem possible that creatures like ants can have **slaves** to do part of their labor? Yet this seems to be the case; for some ants capture the larvæ of other kinds of ants, and then, when these become adults, make them work for the colony. Have you ever read of the ants that carry, or lead, **plant lice** to good feeding places on the leaves of plants, and are then rewarded by the sweet liquid which the lice produce? Surely you have seen the **galleries** of an ant colony, when it was disturbed by the removal of a log or stone. What were the white "rice grains" that the ants were so anxious to carry away?

348. What are Our Insect Enemies? — If we try to make a list of all the insects with which we have a quarrel, because they want the same things that we want, the list will be a long one. There is the clothes moth, for example, which every housewife dreads and tries to get rid of. Ants that come into the house for food are other pests. The South suffers immense damage every year owing to the ravages of the **boll weevil**, a beetle which attacks the boll, or seed case, of the cotton plant. Then there are those insects which destroy our trees, grain crops, and garden plants, while, as **larvæ**, they are trying to get enough food stored up to carry them through the resting stage to that of a butterfly or moth.

How can farmers get rid of these unwelcome guests? We have learned (see § 343) of the great benefit which the **song birds** confer upon us by eating so many insects. Modern farmers have also learned to use insecticides (ĭn-sĕkt′ĭ-sīdz), or substances that will destroy insects, in order to save their plants. **Biting insects**, such as the elm beetle and the potato beetle, eat the whole leaf; we can kill these by putting a poison, such as Paris green or lead arsenate (ăr′sĕn-āt) upon the leaf, so that the beetle will eat the poison too. To put poison upon the leaves and blossoms of trees, men use **sprayers** that will force the poisonous solution in a fine mist all over the tree. Have you ever seen sprayers at work? Have you ever seen tobacco solution put upon house plants to kill plant lice and other insects?

Sucking insects, such as plant lice and scales, are not easily killed by poisons put upon the outside of the leaf. These insects must be destroyed by a liquid that closes their *breathing pores*, so that they cannot get air. An **emulsion** of kerosene and soapy water (see § 184), either alone or containing nicotine (nĭk′ō-tĭn) sulphate, works well for many of these insects. What is the source of nicotine? Which of the two methods would work better for grasshoppers? Did you know that the ladybug beetle helps us by devouring scale insects?

A **third** class of insects is the **borers**; these have larvæ with such strong mouth parts that they can cut their way through wood. Often they can be heard at work inside the tree.

349. How Can Flies Be Destroyed? — What are our greatest pests among insects? Without doubt, flies and mosquitoes. Both of these go through several changes before they are full grown (see § 346).

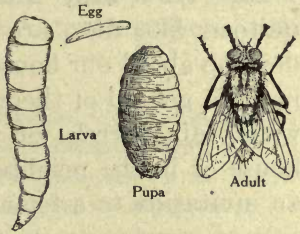


FIG. 260. — Stages in the development of a housefly.

The female fly (see Fig. 260) lays her eggs in **decaying** matter, such as manure or kitchen garbage, and they soon hatch out as white, crawling larvæ, called **maggots**. After feeding rapidly for about a week, the maggot grows a thin case, or shell, about itself, in which it undergoes its change to a fly. What do we call the creature in this stage? See § 346. In about another week it comes out of the shell, an adult fly.

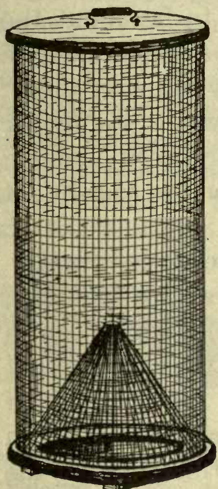


FIG. 261. — A fly-trap, which will catch an enormous number of our household pests. The bait is placed under the trap. When the fly has eaten, it flies upward through the small hole in the cone of wire gauze, and is caught.

The housefly is a dirty creature; it is also directly harmful; for it can spread such diseases as *typhoid fever* (see § 309), by carrying the germs of the disease to our food when crawling over it. We should **screen** our houses carefully against flies, and no food should be left where flies can get at it. It is also important for us to kill all the flies we can. This is especially true in early spring, before the flies have had an opportunity to multiply. **Flytraps** are also very useful for catching flies in summer (Fig. 261).

350. How May Mosquitoes Be Destroyed? — Mosquitoes, like flies, are "home products," that is, they develop about our houses, if we give them a place to breed in. To get rid of them, we must not allow open cisterns, wells, rain barrels, or watering troughs to be about the house or in the neighborhood. Ditches and puddles are an invitation to a female mosquito to lay her eggs there; so is a sagging eaves trough in which water stands for several days after a rain, or broken crockery and tin cans in the back yard, or in the alley or the vacant lot near by.

The female mosquito (Fig. 262) lays her eggs in **water**. Inside of a day they hatch to form larvæ (we call them **wigglers**), which swim about in the water. What we call the "tail" of the wiggler is an organ of breathing, and the wiggler must come to the surface every little while for air. We can kill the wiggler by putting a film of **kerosene** upon the water, as this cuts off the creature's air supply. The wiggler feeds upon what it finds in the water; then it **moults**, or sheds its skin, several times, and is changed into an entirely different form, the **pupa** (see § 346). This has two breathing tubes, which it keeps out of the water most of the time.

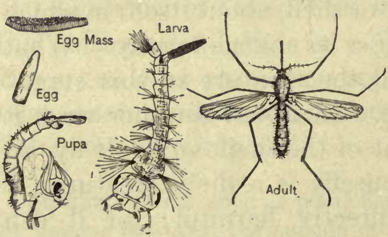


FIG. 262. — Stages in the development of the mosquito.

How would a film of kerosene probably affect it? After three days the flying mosquito comes out of the pupa skin. We can free ponds of mosquito wigglers by putting a film of kerosene upon them, or by stocking them with **fish**, which will eat the wigglers.

The mosquito is a nuisance because it makes life so disagreeable for us out of doors in summer; but it is also a **disease-bearer**, like the fly. One kind of mosquito carries **malaria**; another carries **yellow fever**. If the malaria-carrying mosquito inserts its sharp snout, or **proboscis** (prō-bŏs′ĭs), into a blood vessel of a person who has the disease, the germs of malaria pass into the mosquito's body with the blood which it consumes. There they multiply, and when the mosquito bites another person, the germs enter that person's blood, and give him the malaria.

The yellow fever of Cuba and the Panama Canal Zone was almost entirely driven out, when the breeding places of mosquitoes were destroyed, and when the persons who were sick with the disease were screened off with great care, so that mosquitoes could not bite them and get germs to carry to other persons.

351. Exercises. — 1. Give all the proofs you can think of to show that other animals as a class are harmful to man; then give all the evidence you have to prove that they are helpful.

2. Out of what material does the spider spin its web? The silkworm its cocoon?

3. What animal skins have been used as bottles? As substitutes for paper? As book coverings? As clothing?

4. What is the meaning of "pecuniary"? It comes from the Latin word *pecunia*, meaning cattle; how do you suppose this came about?

5. Can you think why the polar bear and many other polar animals are white? What is meant by "protective coloring"?

6. Name some of the valuable breeds of dairy cows. What part of the milk is present in cheese? In butter?

7. Name some of the common breeds of chickens, and describe them.

8. Do you know of any insects which have a shape or color that make them hard to find in the surroundings in which they live?

9. What are the harmful insects which you know are living in your locality? What is being done to control or destroy them?

Summary. — **Zoology** is the science of animals.

The **domestication** of animals and plants was important for man in his efforts toward civilization.

The Eastern Hemisphere had better **beasts of burden** than the Western.

Man's food supply has been changed greatly by **cold storage** and rapid **transportation.**

Milk is a valuable food, because it has almost every kind of material for supporting life. It must be handled and preserved with **care** to keep it from becoming a breeding place for harmful bacteria.

Leather is the connective tissue of the true skin changed by tanning.

Domestic birds are valuable as food and for their eggs and feathers.

Song birds should be protected because of their songs, their beauty of color and form, their highly developed care for their young, and their destruction of harmful insects.

Fish form the chief animal food of a large portion of the human race.

Insects form the largest class of animals, and are probably man's greatest enemies in his effort to raise and preserve plant food.

Ants, bees, and **wasps** have developed wonderful groups, or **societies.**

Flies and **mosquitoes** often cause the spread of disease and should be destroyed.

PART VII

OUR BODIES AND HOW TO CARE FOR THEM

CHAPTER XXXV

THE STRUCTURE OF THE BODY

352. What is the Plan of the Body? — As you look at a beautiful automobile, with its engine, steering gear, lighting system, and its graceful lines, can you possibly think that it was put together out of any pieces of iron, wood, brass, copper, or aluminum that happened to be lying about? No; you know that it must have been built according to a **plan**, and that each piece of its wonderful mechanism was carefully made, and given just the right size, shape, and strength. The same thing is true of a locomotive, an airplane, a yacht, a sewing machine, or a watch. Is it also true of that most wonderful machine, the **human body?** Is there a plan of the body?

What are the things which impress you most about a machine like the automobile? One of them is its **power**, is it not? But almost at the same instant you think of its **delicate** parts, and of how easily it is harmed, or put out of order. Are not the same things true of man's body? It is powerful, alert, and graceful, but it is easily injured. What is true of man is true of all living things. So, in giving living things their form, nature has had two ideas to work out:

(1) How can the body of the living organism be given the most power, and the ability to care for itself?

(2) How can it be protected from things which hurt it? These two ideas of nature have been worked out in **two kinds** of bodies. In one of them the soft parts of the body are inclosed in a **shell** or case of some kind. The soft organs inside are attached to, and protected by, the strong, outer covering. In what animals is this true? You think at once of clams and oysters, do you not? How about starfishes, crayfishes, spiders, beetles, and butterflies?

What is the plan of the body of a fish? As you know very well, the fish has a bony framework, or **skeleton**, which supports the other organs of the body. The same is true of snakes, alligators, frogs, birds, and all the higher animals, as well as of our own bodies. Some of these animals have outer coverings, such as scales, hair, or feathers, which have developed from the skin, but the real framework is inside. We call those animals with an inside framework **vertebrates** (vĕr′tē-brātz); while those without the framework we call **invertebrates**. To which class does the earthworm belong? The jellyfish? The fly? The dog? The horse?

353. What are Living Cells Like? — Do you remember that after studying about the wonderful organs of a flowering plant like the sweet pea, or the garden bean, we learned that there are plants so simple that instead of having root, stem, leaves, flowers, and seeds, they have just a **single cell?** See § 309. Usually each cell is so small that it is invisible without a microscope. Did you know that there are one-celled animals, just as there are one-celled plants? The **ameba** (ă-mē′ba) is one of them. It is a tiny, jelly-like creature found in muddy pools (Fig. 263).

The ameba has no organs for motion, such as feet. When it wishes to move, it extends the wall of the cell out on one side, forming a **false foot**. The contents of the cell then flow into the false foot, and the creature has moved. The ameba has no mouth; in order to feed itself, it extends two or more false feet about the food, draws away the cell wall, and so gets the food inside the cell. It throws away waste food by simply moving away from it.

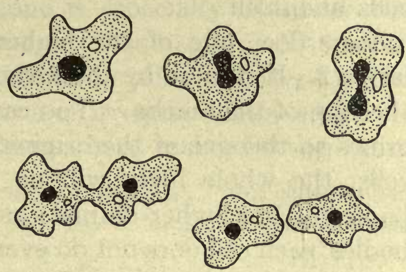


FIG. 263. — The ameba. The figure shows some of the stages of the division of one creature into two.

The ameba carries out **reproduction** in a very simple way. Its **nucleus** (nū'klē-ŭs), or grainy, central part, **divides** into two parts; about half of the material of each cell gathers about each part; the two parts separate; and there are now two amebas instead of one.

The higher plants and animals are composed of cells, too, but there are many millions of them. How can such tiny cells make up the plant or animal body? We sometimes compare the cells of our bodies with the cells of a **honeycomb**, but the cells of the honeycomb are very much larger. Then, too, the honeycomb cells are all alike, and all have the same use, that is, to hold the honey; while in our bodies, and in those of most plants and animals, there are **many kinds** of cells, of different sizes, shapes, and uses. These cells do their work, and wear out; but they produce new cells to carry on the work, so that the **body** lives on.

354. What Are Cells Made Of? — How is the material of a cell different from that of a stone, or of a crystal of salt, or of a honeycomb? The difference is that the cell is **living matter**; we call it *protoplasm*. The cell wall is living; so are the nucleus and the other contents of the cell. The living cell differs from a stone in that it can take material out of food and make it a **part** of itself, and it can carry out reproduction, thus forming other living cells like itself.

How does one of the higher plants or animals grow **larger?** It does so by the **division** of its cells, much as in the case of the ameba. You can see that if each new cell grows to the size of the original cell, and there are more cells, the whole body will be larger. However, in the bodies of the higher animals and plants, and in our own bodies, each cell does not do **every** kind of work, as the one cell of the ameba does. Instead, we have a **division of labor**; that is, some kinds of cells do one sort of work for the body, and other kinds of cells do different work. Thus the red cells, or **corpuscles** (kawr′pŭsls; see § 375), of the blood carry **oxygen** to all the other cells (see § 46), so that the others can remain where they are. The cells in the stomach and intestines **digest** food for the other cells (see §§ 368 and 370); while the **bone** cells build up a strong framework to support the other body cells. What does the group of cells in the lungs do for the other cells?

We call a group of cells of **one kind**, doing one kind of work, a **tissue**. Thus we have lung tissue, muscle tissue, bone tissue, and others.

355. What are Bones Like? — Have you ever looked at the collection of bones left after a chicken, or turkey, or rabbit, has been eaten, and thought of the many different kinds of bones there are, and that each kind is useful for some particular purpose? There are many different kinds in our own bodies also. We find long bones, short bones, flat bones, round bones, and bones of irregular shape. Why do we find this difference of shape and size? Each bone is especially fitted for the work it is to do, and the support it is to give. The bones of the leg are long to enable us to take long steps. The bones of the head are pieces of irregular shape which fit tightly together, so as to form a hard casing for the brain.

Clean thoroughly the leg bone or "wishbone" of a chicken, boil it for a few minutes in water, and soak it for 3 or 4 days in dilute hydrochloric acid (see §§ 176 and 191). If the action is complete, you will find that the bone has become pliable, and may even be tied in a knot! Why is this? The bone is composed of branching, interlacing cells of **connective tissue** (see §§ 195 and 341, and Fig. 264), stiffened with **minerals.** These minerals make up about ⅔ of the weight of the bone. The acid acts upon the minerals, so that they dissolve, leaving the connective tissue, which is easily bent. If a bone is burned, the connective tissue is destroyed, and only the mineral matter is left behind; the bone is then very **brittle**. What quality does the mineral matter give to the bone? The connective tissue?

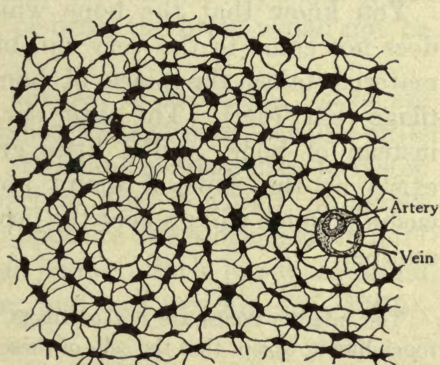


FIG. 264. — Bone cells with canals, or tubes, for the nerves and blood vessels.

Around the bone there is a tough covering of connective material, and the bone tissue itself is very compact and firm. Generally the bones have **tubes**, or "canals," through which the blood circulates; **nerves** (see § 395) are found there too. Why are the larger bones of flying birds hollow, do you suppose?

356. How Do Bones Grow? — Can a very young baby walk? Of course it cannot. We say that its legs are not strong enough to support its body. What are the reasons for this? One is that the baby's **muscles** are not strong enough to permit it to *balance* its body properly; but another important reason is that the bones of its legs are not **stiff** enough. In fact, its legs easily become permanently bent if used too soon.

You know that the bone which supports your nose does not come to the very tip, but that a tough, elastic material takes the place of bone. This is called **cartilage** (kărt'ĭ-lĕj). The outer ear contains cartilage, too, instead of bone, and a little growth of thin cartilage exists at the ends of many bones, so as to make a cushion which will prevent the jarring of one bone against another.

The infant's bones are not cartilage, but they are of a material much **like** it, except that the cells of these soft bones of the infant have the power to produce a stiffening of **minerals**, and so harden the bones. The bones of an infant "knit," or grow together, easily if broken. The bones of an old person are stiff, but they are also brittle. When they are broken, their cells do not grow easily and join the broken pieces together; so that a fall is often very serious.

The bones of a child need **growth materials**, such as are found in milk, so that they may harden properly. Review § 191.

357. Why Do We Have Joints? — Men have distinguished 200 bones in the body. Why are there so many? Why cannot the framework of the body be all in one piece, or at any rate in a few pieces? Such an arrangement would hold the body upright, perhaps; but the body needs to **bend**, as well as to be held upright. This is the reason for **flexible** joints. The joints at the elbow, and in the wrist and fingers, are flexible.

In the case of some other joints the bones simply need to be lashed together firmly; this is true in the skull. Such joints are said to be **inflexible**. If there were no flexible joints, the muscles could not move the body, the body could not bend, and we could not hold anything in our hands. But, on the other hand, if the bones of the skull were easily moved, or bent, the **brain** would not be well protected.

How many kinds of flexible, or movable, joints are there? One of them is called a **hinge** joint, because of its resemblance to a hinge. Examine a hinge used to fasten a door to a door frame; how does it work? It allows the door to swing in two **opposite** directions, does it not? The same is true of hinge joints. Such joints are found in the elbow, knee, fingers, and toes (see Fig. 205, § 276).

Swing your arm about in a circle. Do you think your shoulder has a hinge joint? No, the joint here is of a different sort; we call it a **ball-and-socket** joint. This is a more complicated joint than the hinge joint. On one bone there is a round end, or **ball**, which fits into a hollow place, or **socket**, in the other bone. The ball can turn in its socket in many directions, and so gives great freedom of motion. The joint at the hip is also of the ball-and-socket type (Fig. 265).

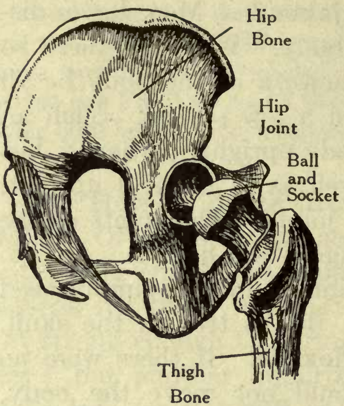


FIG. 265. — The ball-and-socket joint at the hip.

In a third kind of joints the bones slide over one another; these are called **gliding** joints. The small bones of the ankle and wrist are good examples of such joints.

How are bones held together at the movable joints? Partly by the muscles which are attached to the bones, but chiefly by tough cords, called **ligaments**. Thus, ligaments hold the ball of the shoulder joint in place in its socket, except when an accident causes the shoulder to be thrown "out of place."

358. What is the Skeleton Like? — If you examine the framework of the body of a bird or cat, or of any vertebrate animal (Fig. 266), you will be struck by the fact that the bones which make up the framework are planned for **lightness** as well as for strength, and that they are beautifully fitted together. In serving

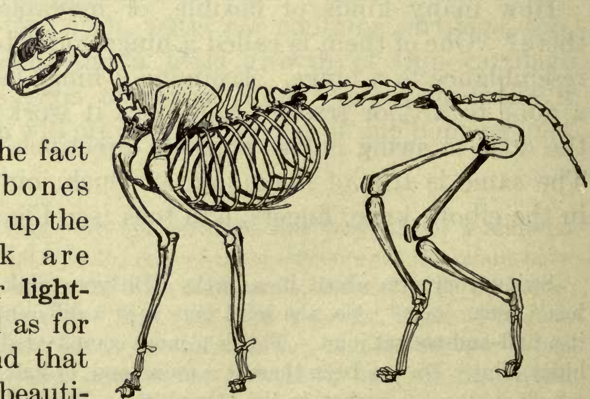


FIG. 266. — Skeleton of a cat. Note that the "heel" is some distance from the ground, and that the cat walks on its toes.

as a framework the bones support not only the soft organs inside the skeleton, but also the muscles, fat, and skin which cover the skeleton and give the body its outer form. The same is true of man's skeleton.

The bones of man's **head** form a very strong case for the brain, and at the same time provide sockets for the eyes, and protecting hollows for the nose, tongue, teeth, and ears, as well as the proper kind of bone for the skull to rest upon, at the top of the backbone, or **spinal column** (Fig. 267).

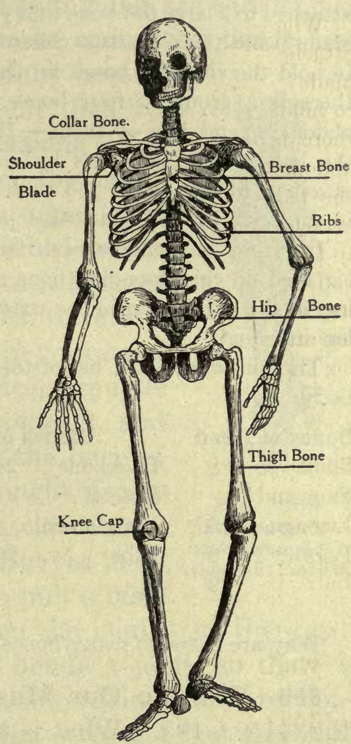


FIG. 267. — The human skeleton.

The **chest**, or thorax, consists of a box, or case, for the lungs and heart, and for the attachment of a strong muscle, the **diaphragm** (dī′ă-frăm), which separates the chest from the abdomen. There are slender, but strong **ribs** attached to the backbone. Seven pairs of these are joined in front to the **breastbone**; three more pairs are joined to the lowest pair of the true ribs (those attached to the breastbone); while two pairs of ribs are called **floating** ribs, because in front they are not attached. How many pairs of ribs are there in all?

What are the bones of our **limbs**? The bone of the upper arm is attached to a large flat bone that you can feel in your back (the **shoulder blade**), and there are two **collar bones** which act as braces, or props, to hold the shoulder bones in place. At the bottom of the backbone there is a group of four bones. These support the weight of the abdomen, and two of them — the **hip bones** — have the sockets of the ball-and-socket joints by which the upper bone of each leg is attached to the body. So both the legs and the arms are attached to the body by ball-and-socket joints. Why?

Our four limbs have each 30 bones. There is a **kneecap** in the leg, and no corresponding bone at the elbow; but there is one bone less in the ankle than in the wrist, so the numbers in the arm and the leg are equal.

The following is the list of the bones in the different regions of the body:

Bones of Head		**Bones of Trunk**				**Bones of Limbs**	
Skull .	8	Backbone .	24	Breastbone .	1	Arms	60
Face and tongue	15	Base of abdomen	4	Collar bones	2	Legs	60
Ears . .	6	Ribs . .	24	Shoulder blades .	2		120
	29				57		
				Total number of bones . .			206

Why are there so many bones in the hands and feet?

359. How Do Our Muscles Work? — Look back at Fig. 115, § 195. What is the steak shown in the figure? It is a piece of a large muscle, is it not? What is the duty, or work, of muscles? They are the organs that **move** the bones, and make it possible for the body to change its position. The bones make the strong framework of the body, but the muscles, stretched over the bones, and sliding over one another, give movement to the body.

The cells in the muscles are long, and gathered together in **bundles** of muscle fiber. The bundles are surrounded by a white, skin-like membrane of **connective tissue** (see § 195). Muscles do their work by becoming shorter, or **contracting**, and then by growing longer again, or **relaxing** (Fig. 268). Consider, for example, the large, **biceps** (bī'sĕps) muscle of the upper arm. One end of the muscle is attached to the shoulder, and the other end to a bone of the forearm. Suppose you wish to raise a weight which you are holding in your hand (see Fig. 205, § 276). The biceps muscle contracts, that is, its **cells** contract, and becomes shorter. As a result the bone of the forearm is raised and brought nearer the shoulder. When the muscle relaxes, or lets go, the forearm falls. But the body cannot depend upon **gravity** to pull a bone back in place and so straighten the joint. As there is a muscle which by contracting **bends** a joint, so there is usually another muscle at the same joint which by contracting makes the joint **straight**. We say that these are **opposing** muscles. What does this mean? Feel of the thick biceps muscle on the inner side of your upper arm, when you draw your forearm up. On the outer side there is a muscle called the **triceps**, which has the duty of making the elbow joint straight.

FIG. 268.—Muscles, tendons, and ligament in the right forearm.

360. What is the Use of Tendons? — Clench your right fist, and with your left hand feel the drawn-up muscles of your right forearm. Also feel the tough **cords** on the inside of your wrist. Are these muscles? Then feel the cords on the inside of your elbow joint. Are these muscles, too?

Suppose that all the muscles which move the hand (there are about 30) were in the hand itself. What a clumsy affair the hand would be, and how unable to do fine, delicate work! But nature has put into the forearm the strong muscles that move the hand; in the forearm their thickness does not matter. What passes into the hand is not these large muscles, but long, slender, very strong *extensions* of them; thus the hand may remain small and skillful. The extensions of the muscles are called **tendons**. They are the extensions of the connective tissue (see §§ 195 and 359) of the muscles, and attach a muscle to the bone it is to move, even when the bone is some distance away. There are also many strong tendons passing from the lower limbs through the **ankles**; these tendons move the bones of the feet.

How can tendons be kept in place at such important joints as those of the wrist and ankle? Encircle your right wrist with the thumb and forefinger of your left hand, as if your left hand were a bracelet. There are "bracelets," or bands, of tough, strong tissue under the skin. These are called **ligaments**. They keep the tendons at the wrist and the ankle from slipping out of place. Usually they do their work properly, but sometimes they are strained or torn.

361. Is Care of the Body Worth While? — Does it matter what position you take when you walk, stand, or sit? Why do some people "carry themselves" gracefully, while others are so awkward in their movements? Part of the difference, at least, comes from the way in which people learn to use their bones and muscles. A correct carriage of the body is a matter of **health** as well as of looks. If the body is not carried erect, round shoulders are the result, and the chest is likely to be too small for the lungs and heart inside it. **Slumping** down into a chair throws the organs of the abdomen out of place. Our bodies are beautifully built machines, but they are delicate, and grow easily in any position in which we hold them. We should help them to become erect and graceful by carrying ourselves correctly (see § 262).

Have we any duty to our **muscles**? Two things are absolutely necessary for a healthful body; they are **rest** and **exercise** in the proper proportions. If the body is not allowed to rest long enough, and if the hours of sleep are too short, the whole body becomes worn out. The muscles become sore, and one feels as if he were not strong enough to walk briskly, or even to hold his body erect when he is sitting in a chair. Just as important as rest, however, is exercise. Exercise is best when it is carried on **out of doors**. No amount of indoor work can take its place. Why? The clothing should always be sufficient for protection in stormy weather. Brisk exercise is needed every day, and the person who neglects it will suffer by having weak muscles, a poor digestion, or some other form of bodily weakness or discomfort.

362. Exercises. — 1. Between the vertebræ (vĕr′tē-brē), or separate bones of the backbone, there are pads of cartilage. How will they affect the jarring of the body in walking? The ability of the back to bend?

2. Do you think you are taller at night, or in the morning? Why?

3. From the way in which you can move your fingers and thumb, what kinds of joints do you think they have?

4. How has the shape and structure of man's hands made his advancement possible?

5. What is the effect of high heels upon the way in which the wearer walks?

6. What is meant by the division of labor? How is the body like a village of people?

7. Name some of the kinds of cells in the body, and the part they take in keeping the body alive.

8. Of what advantage is it to man that he can walk upright?

Summary. — **Vertebrates** are animals with an interior bony framework for the support of the body.

The **cell** is the unit of living matter. It consists of **protoplasm.**

When the cells of a **many-celled** animal divide, they remain attached, and the animal grows in **size.**

A group of cells of the same kind, and doing one kind of work, is called a **tissue.**

Bones consist mainly of **connective tissue** and of **mineral matter.**

A **child's** bones become stiff because the bone cells secrete mineral matter from its food.

The joints of the body are **flexible** and **inflexible** joints.

The three kinds of flexible joints are **hinge, ball-and-socket,** and **gliding** joints.

The bones of the head and trunk are chiefly for **protection**; those of the limbs for **movement.**

Muscles are organs that have the duty of producing movement in the parts of the body. They do their work because their cells have the power to **contract** and then to **relax.**

Tendons are extensions of the connective tissue of muscles.

Ligaments are bands and cords that hold tendons and bones in place.

The body needs proper amounts of **exercise** and **rest.**

CHAPTER XXXVI

HOW FOOD IS DIGESTED

363. What Organs Digest Our Food? — If someone were to ask you what organs digest food, would you answer: "The stomach"? Do you realize that the organs of digestion form a long tube about 30 feet long, and that the stomach does only a part of the work? This long tube is called the **digestive tract.** When food is taken into the mouth, it is not in a condition to be used by the body. The digestive tract consists of organs that act upon the foods and change them, so that they can be used. As the food is mostly insoluble, it has to be put into such form that it can **dissolve.** The digestive tract is lined throughout with a continuation of the skin which covers the outside of the body. This interior skin is called **mucous** (mūk′ŭs) **membrane.** The mucous membrane begins with the lips, where it shows a thin pink covering. The network of blood vessels under it causes the color. The surface of the mucous membrane is made up of flat cells. In many places these cells are **folded in**; thus **glands** are formed (Fig. 269).

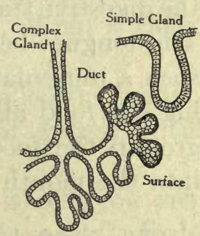


FIG. 269. — A simple gland is made by a fold in the mucous membrane. In a complex gland the many folds pour their secretion out through one tube, or duct.

The glands take certain liquids from the blood, and store them in pockets from which they are poured out upon the foods that pass by. We say that the glands **secrete** these liquids. The liquid secreted is called a **secretion** (sē-krē′shŭn).

364. How Does the Mouth Help Digestion? — The mouth is the first part of the digestive tract. The nerves of **taste** are located on the tongue, and the nerves of **smell** are just above the mouth, in the nose; so that the sentinels of taste and smell can pass upon the food, and tell us whether we ought to eat it or not. Many people gauge the **amount** of food to be eaten by its attractiveness. Such habits often result in overeating. Overeating gives the digestive tract too much to do, and puts it out of order. The **tongue**, besides containing the nerves of taste, is of such a muscular structure that it is very skillful in pushing the food about in the mouth. After the **teeth** have ground the food thoroughly, the tongue pushes it back into the mouth, so that it may be swallowed.

When you are hungry and smell cooking food, your mouth "waters." The "water" in the mouth is called **saliva** (să-lī′vă). Three pairs of glands in the lining of the mouth secrete this liquid. Besides softening and moistening the food, the saliva acts upon it to change its nature. Saliva is like a **base** (see § 177), and has an **alkaline** reaction. What does this mean? It also contains a substance called **ptyalin** (ty′ă-lĭn), which is a **ferment** and simply by its presence brings about a partial change of the starch into **sugar**. Hence a cracker becomes sweet when chewed. Try it.

365. What is the Work of the Teeth? — How many teeth have you? When you are a "grown-up," or an adult, you should have 16 teeth in the upper jaw and 16 in the lower jaw. These teeth are of 4 different kinds, according to the work which each is fitted to do (Fig. 270). There are 4 **incisors** (ĭn-sī′sẽrs) in each jaw. These are flat, sharp teeth for biting and tearing pieces of food. Next to the incisors, on each side, are the **canine** (kā′nīn), or "dog," teeth. In the dog these are greatly developed for the tearing of food.

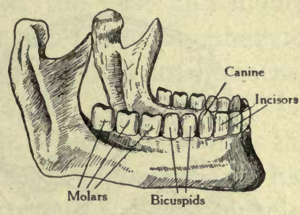


Fig. 270. — The teeth.

Back of the canine teeth, on each side, are two **bicuspid** (bī-kŭs′pĭd) teeth. Each of these has two points, or cusps. The bicuspid teeth, together with the three **molar** teeth back of them make up the **grinders.** What is their work?

A child has a **temporary** set of 20 teeth called the "milk teeth." The first permanent teeth do not appear until the child is six or seven years old.

A tooth consists of: (1) the **crown**, which you see covered with a hard, white enamel; (2) the **neck**, which is in the gum; (3) **roots.** The neck and roots are made of a material called **dentine** (dĕn′tĭn), and the roots are covered with "cement." The inside of the tooth contains blood vessels and nerves and is called the **pulp.**

Since our teeth are so strongly made, people are likely to neglect them, and so cause them to be injured or lost. If our teeth are not **brushed** thoroughly every day, bacteria and decaying food act upon them and **rot** them. If we break the **enamel** by biting threads, nuts, or brittle candy, the decay of the teeth will be very rapid. Every one should have a dentist examine his teeth every six months or so, in order that the small cavities may be found and "filled," before bacteria have entered to break and destroy the whole tooth. Did you know that many diseases of other parts of the body have been traced to bad teeth?

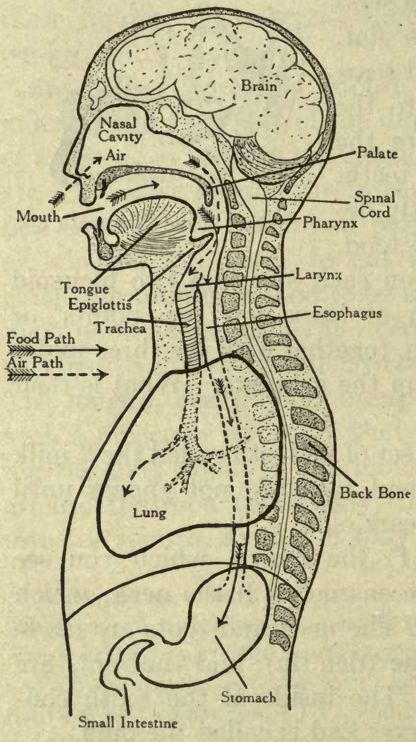


FIG. 271. — Course of food and air as they enter the body.

366. How Do We Swallow? — Perhaps we should ask: How do **you** swallow? Do you wash your food down with water, or gulp it down in a hurry? Swallowing of the food, if properly done, is **unconsciously** done. What does this mean? When the food is softened and mixed with saliva, until it is in the proper condition, the **tongue** pushes it to the back of the mouth, so that it enters the throat, or **pharynx** (făr′ĭnks; Fig. 271). This is a muscular tube about 4 inches long. It has many openings. At the top there are two openings into the **nose**; two lead to the **ear**. One opening is into the **windpipe**, and the food has to pass over it.

The upper part of the windpipe is covered by a **lid** which keeps the windpipe closed until the food has passed over it (see § 386). When we swallow, the nose and mouth openings close also, and the upper muscles of the pharynx contract above the food and force it down into another tube called the **esophagus** (ē-sŏf′ă-gŭs), or gullet. This is a tube about 9 inches in length, which opens into the stomach. It is lined with mucous membrane and has muscles which go around it in a **circle**. These muscles contract rapidly, one after another, above the food, so that the food is forced into the stomach. How can this be? Suppose that a tube like the esophagus has lengthwise muscles, and that these contract, what is the effect? The tube becomes **shorter**, does it not? Suppose that muscles pass around the tube, what happens when they contract? They make the tube **smaller** in diameter, do they not?

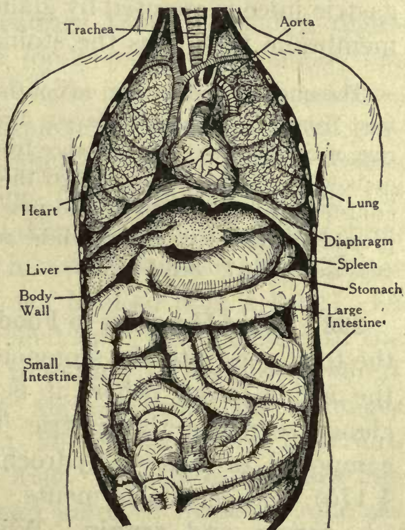


FIG. 272. — The principal organs of the body.

367. What is the Structure of the Stomach? — Have you noticed that when you eat or drink something very hot or very cold, you have a feeling of hot or cold down your **back?** The esophagus lies against the backbone and passes through the chest into the abdomen. There it widens into what we call the **stomach** (Fig. 272). The stomach is an organ about 1 foot in length and 4 inches in diameter. Like the esophagus, it has lengthwise and circular muscles, but it has also a third set of muscles running in an **oblique** direction. These three kinds of muscles, by a series of contractions, " churn " the food in the stomach during digestion. The churning aids in mixing a liquid, the **gastric juice**, with the food. The gastric juice is secreted by glands which are in the mucous membrane that lines the stomach.

The smaller, or receiving, end of the stomach is always open, so that food from the esophagus passes directly into the stomach. But a ring of muscle closes the entrance from the stomach to the **intestines**, or bowels. This opening, called the **pylorus** (pī-lō′rŭs), is so nicely adjusted that it permits food to pass only when the food has become properly mixed with gastric juice, and has an **acid reaction**. What does this mean? See § 178.

368. What Happens to Food in the Stomach? — When the food goes into the stomach, it is deposited all around the inside lining, where it is in close contact with the glands secreting the gastric juice. The gastric juice is composed of water, hydrochloric (muriatic) acid (see § 175), and certain ferments. The chief of the ferments are **pepsin** and **rennin**. What is the ferment in the mouth? By the presence of these ferments, the **proteids**, or nitrogen foods (see § 188), are partly changed. Pepsin causes them to break down into more simple substances. While proteids cannot be dissolved in water, these simple compounds are soluble. Of course everything has to be in a dissolved form, or a very finely divided form, before it can be taken into the blood. Rennin acts upon milk, causing it to form " clots," such as we see in sour milk.

The hydrochloric acid is of value in several ways. Saliva is alkaline (a base; see § 177), and makes the food alkaline. Pepsin works better in an acid solution. The acid also destroys many harmful bacteria which are taken into the body with the food. However, hydrochloric acid will not kill such harmful bacteria as thóse of typhoid fever. After the food has been acted upon in the stomach, it is changed to a milky substance called **chyme** (kīm).

369. What are the Intestines Like? — So far, digestion has changed starchy foods partly into sugar, has partly broken down the proteids into simpler substances that are soluble, and has broken the food into small particles, and mixed it with much liquid. These processes must be **finished.** Leaving the stomach through the pylorus, the food is next taken into the **small intestine.** This is a tube about one inch in diameter and about 22 feet long. How can the abdomen hold so long a tube? Of course the tube must be coiled up. Connected with the small intestine is the **large intestine.** This tube is about 6 feet long. Herb-eating animals have much longer intestines even than man. The grown ox has intestines measuring about 150 feet long. The intestines are like the esophagus in having two kinds of muscles: one set running **lengthwise**, and a circular set running **around** the intestines. How does each set push the food along? The mucous lining of the intestines contains **glands** which secrete the **juices** needed in digestion just as the stomach secretes gastric juices. Small **elevations** in the mucous tissue are important organs of the intestines. They are called **villi** (vĭl′ī), and their work is to take up, or absorb, food from the digestive tract and to assist in transferring it to the blood. The advantage of the villi lies in the fact that they project into the intestines and so increase the absorbing surface 7 or 8 times. The large intestine has no villi, as its chief concern is not to absorb digested food, but to remove solid wastes from the body.

370. What Happens to Food in the Intestines? — Immediately after the chyme enters the intestines, a secretion from the **pancreas** (păn′krē-ăs) is poured upon it. The pancreas is a small gland lying behind the stomach. It is connected with the intestines by means of a short tube and pours, on the average, $1\frac{1}{2}$ pints of liquid into the intestines every day. Another gland of great importance — it is the largest gland in the body — is the **liver.**

The tube from the pancreas and that from the liver join before opening into the intestines, so the liver pours its secretion — the **bile** — through the same tube. The digestion of foods is completed in the small intestine, and there, for the first time, the **fats** are acted upon and made soluble, or changed into a milky **emulsion** (see § 184). Three important ferments in the secretion of the pancreas are: (1) the **starch-digesting** ferment, which completes the digestion of starch; (2) the ferment which digests **fats**; and (3) the ferment which completes the digestion of the **proteids**, or the nitrogenous foods, such as lean meat and eggs.

The liquid in the intestines is called **chyle** (kīl). Is it not wonderful that our bodies are provided with all these ferments, so that each class of food has its own ferment, which is ready to digest that one food and no other?

The liver not only secretes the bile, but has two other important duties. One of these is to store a **starch-like** substance which can easily be changed to **sugar** whenever the body needs food. The liver also helps to remove from the blood the waste nitrogen compounds formed by the destruction of the cells (see § 383).

371. What Should Our Diet Be? — How and what should we eat? As we have learned before (see § 188), the body needs certain qualities and quantities of food. Just as the automobile will not run smoothly on a low grade of gasoline, so the body will not thrive on poor food. The study of the diet is a science called **dietetics.** Experts in this science plan "balanced rations," so that every element of food is present in the proper amounts. Every housewife should know something of this science, too; otherwise she will have hard work in keeping her family well and in the most efficient condition (see § 213). The digestive tract is well adapted to the digestion of good food taken in the proper amount, but it is not built to digest everything we may give it, and it cannot work all the time and retain its power. When we have **indigestion**, it is usually because we have been careless about **what** we ate, or **when** we ate, or because we have eaten **too much.** Ought we to blame our digestive organs for the result?

372. Is Alcohol a Food? — What is a food? Science says it is a substance which can be oxidized in our bodies so as to give us energy, and which at the same time does not **injure** our body cells. Are all of these facts true of alcohol?

A little alcohol, it is true, can be oxidized in the body, and in that case gives us energy, but this is not true of the amount of alcohol which men consume when they drink alcoholic liquors. The quantity of alcohol present, even in those liquors which are supposed to have only a small amount, such as light wine and beer, is **too much** for the safety of the men who drink these liquors. The drinker's **cells** are injured, even if he is only a "moderate" drinker, especially the delicate **nerve** cells, which direct the organs of the body. Would you think it wise to injure the engineer of a train, or the captain of a ship? No, because upon his efficiency and wisdom the safety of all the passengers depends. Yet alcohol injures the organs that **direct** the body, the brain, and other nerve centers. So alcohol cannot be called a food, for it injures our body cells.

Do you think the drinker really wants alcoholic liquors for their food value? Or is it because the taste and effect of liquor have become a strong habit with him?

Did you know that many **patent medicines** contain a great deal of **alcohol**, and that we are in danger of alcoholic effects if we take them?

373. Exercises. — 1. Why do foods have to go through the great length of the digestive tract? Why can they not be absorbed at once?

2. Why is a cow's digestive tract longer than a man's?

3. Is the digestion of any kind of food completed in the stomach? Might the stomach of a person be removed, and the rest of the digestive tract digest all the food?

4. Why should a child's first teeth be cared for, even if the second set is soon to take their place?

5. Is it a good thing to chill the teeth suddenly with very cold ice cream?

6. Is it a good thing to try to bite hard candy or nuts with the teeth? Why?

7. Where are the fats of our food digested? The starch? The proteids?

8. What is the value of a vegetable salad in a dinner?

9. Why can we not consider alcohol a food?

Summary. — The **digestive tract** is a tube about 30 feet long in an adult. It is lined with **mucous membrane**.

Glands take digestive liquids from the blood and store them for the digestion of the food.

In the **mouth** food is broken into small fragments and mixed with the **saliva**.

The " milk teeth " are 20 in number; the permanent teeth, 32.

Food is **swallowed** by the contraction of muscles of the **throat** and **esophagus**. Three sets of muscles act upon food in the **stomach**.

The glands of the stomach secrete the **gastric juice**; this has an **acid reaction**, and contains the ferments **pepsin** and **rennin**.

Food leaves the stomach through the **pylorus**, the gateway into the **small intestine**. In the small intestine the digestion of all three classes of foods: **carbohydrates**, **fats**, and **proteids**, is completed. A special **ferment** is provided for each. The juices containing these ferments are secreted by the **liver** and **pancreas**. Digestion in the intestine takes place under **alkaline** conditions.

The digested food of the small intestine is **absorbed** through the **villi**, and then poured into the blood for transportation to the cells.

Dietetics is the science of the diet. The body needs food of the right **quality** and in the right **quantity**.

Alcohol cannot be called a food, because it has the effects of a **poison**. If **patent medicines** contain alcohol, they are as bad as liquors themselves.

CHAPTER XXXVII

HOW THE BLOOD IS CIRCULATED

374. What is the Use of Blood? — What have we learned thus far about the body? We have learned its general **plan**, have we not, and that it has a bony **framework**, to which its muscles and its soft organs are attached, and by which they are protected? We have also learned that all the living material of the body is composed of **cells**, and that the cells work together, each doing its share for the good of all. Then, finally, we have learned how our food is prepared for the use of the cells by the process of **digestion**. But how can the food get to the cells? Can the cells of the brain, or the lungs, or the muscles, go to the digestive tract for their food? Of course not; only when the food is actually inside the blood channels can it get to the cells. We have learned how the villi of the small intestine absorb the digested food, so that it can be transferred to the blood. Can you see now that what we call the "circulation of the blood" is also the "circulation of the food"? The taking up of the food by the cells is the last operation of digestion; we call it **assimilation**.

There is another use of the blood system. What can the cells do with their **waste products**, the materials they have no further use for, and must get rid of? They turn these materials over to the blood. So the blood is also the great **sewer** of the body.

Is there a **third** need of the blood system? Do the cells in the **skin** remain as warm as the cells inside the body? You know they do not; in cold weather they become much colder, and need heat from the inside of the body. They get this heat from the warm blood that bathes them. The blood thus **regulates** the body's temperature, so that the outside cells are kept warm; it also sees to it that the inside cells do not get too warm.

The blood is carried throughout the body in **tubes**; these tubes, with the heart and the blood itself, make up the **circulatory system.** About $\frac{1}{13}$ of the **weight** of the body is blood. How much does your blood weigh? If we examine the blood with a microscope, we learn that the blood is made up of flat disks which are red, and are called **red corpuscles**, of colorless, round bodies called **white corpuscles** (see § 353), and of a liquid called the **plasma.**

375. What are Red Corpuscles For? — The red corpuscles (Fig. 273) make up about 45% of the weight of the blood. What is the weight of the red corpuscles in your body? Each corpuscle, when it is examined under the microscope, is found to be a rounded **plate**, somewhat like a coin with rounded edges. The center of the plate is thinner than the edges. Each corpuscle, looked at alone, has a **yellow** color; but as they are usually in groups, one over another like coins in a stack, the group appears to be red. Each tiny plate contains a substance called **hemoglobin**

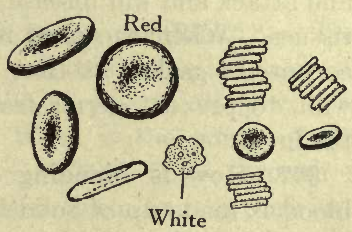


Fig. 273. — Corpuscles of the blood, greatly magnified. The white corpuscles are the larger, and resemble the ameba.

(hē′mō-glōb′ĭn). This is a very active substance, and unites easily with oxygen to form a new substance called **oxyhemoglobin.** How is this word made? The red corpuscle is then carried along in the blood stream to the cells of the body, and gives up its oxygen to the **cells.** Thus the cells get their oxygen in convenient packages without having to go to the lungs for it. After the red corpuscle loses its oxygen it appears dark red or purplish. Bright red blood is rich in **oxygen.**

376. What is the Work of White Corpuscles? — White corpuscles are not as numerous as the red, but they are much larger. They are one-celled bodies much like the ameba (see § 353), and have the power to move about much as the ameba has. They can go **through the walls** of the small blood vessels, and so get between the body's cells. They are the body's policemen, or soldiers, and attack and kill disease germs in the blood and in the tissues. When the **skin** is broken by an injury, white corpuscles gather at that point, and form a protecting wall, to prevent germs from entering the body through the break.

377. How is Bleeding Stopped? — We see that the blood is made up of solid bodies floating in a liquid, the plasma. As we should expect, most of the plasma is **water.** However, it contains, in solution, mineral matter and nutritive substances which go out into the tissues to feed the cells. The plasma is slightly **alkaline** (basic) in reaction (what does this mean?) and salty in taste. The **carbon dioxide** given off by the cells is dissolved in it, and then given off in the lungs (see § 387). Suppose that when you cut your finger, there was no way of stopping the flow of blood before a large quantity of the precious fluid leaked away. But, fortunately, when blood is exposed to the air, it forms **clots**, which close the wound, and prevent a great loss of blood. Of course if a large blood vessel is cut, the blood flows out too rapidly to form a clot, and other means must be used to stop the loss of blood.

How does the blood form a clot? There is in it a wonderful substance called **fibrinogen** (fī-brĭn'ō-jĕn), meaning "fibrin-former." This becomes solid when exposed to the air and forms interlacing strings, or fibers, of **fibrin**. The blood is caught in the meshes of the fibrin, so that the corpuscles are able to hold on. The process by which a clot is formed is called **coagulation** (cō'ăg-ū-lā'shŭn) of the blood. We can help coagulation along by placing a little absorbent **cotton** in a wound; the fibers of the cotton hasten the formation of the fibrin and help to hold the clot in place.

378. How Does the Heart Pump the Blood? — The blood is interesting enough, if you think of it only at rest, but it is more interesting still, if you think how it is pumped through the body. What is the **pump** of the blood? The **heart**, of course. Blood flows through a system of tubes which are called, according to their size and the direction they are going (that is, whether **toward**, or **from**, the heart), **capillaries**, **veins**, and **arteries**. Which of these are the smallest? To enable the blood to flow freely through these tubes to every part of the body, **force** must be exerted. The heart, although only the size of your **fist**, is made of powerful muscles which can furnish the required force. A *protective membrane* surrounds the heart; this has two walls, between which there is a liquid that makes the **friction** of the heart in its movements as small as possible. Why? (See § 281). Inside the strong muscular walls of the heart, there are **four cavities.** These cavities are called the **right ventricle, right auricle, left ventricle,** and **left auricle** (see Fig. 274).

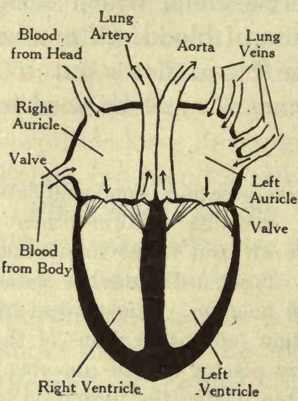


FIG. 274. — The heart and its four chambers. Note that blood is brought in by veins. Note also the **valves** opening from the auricles into the ventricles, but not the reverse, and from ventricles into arteries.

How can the heart keep the blood flowing in **one** direction? In the first place, the right and left cavities of the heart are absolutely **separate**, and there is no opening that allows blood from one side to enter the other side. Blood coming back from a circuit of the body enters the **right auricle**, from which it goes into the **right ventricle**. A **valve** then closes the opening between the auricle and the ventricle, so that the blood stream cannot "back up." By the contraction of the right ventricle, the blood is forced into tubes which carry it to the **lungs** to be oxidized. The blood coming back from the lungs enters the **left auricle**, and then goes into the **left ventricle**. Here again there is a valve which keeps the blood from flowing back into the auricle. From the **left ventricle** the blood is forced out into tubes which distribute it throughout the body (Fig. 275).

The **heart** lies in the chest, almost surrounded by the lungs. The smaller end is to the left of the breast bone. The beating of the heart is caused by the contracting of its muscular walls. When these contract, the blood is sent out with a **pressure** that forces it forward; when they relax, another quantity of blood flows in, and fills the heart.

Remember that the heart must keep up this steady beating all of our lives. The heart of an infant beats about 120 times each minute; a child 14 years of age has about 85 heart beats per minute; the adult has 70 or 80.

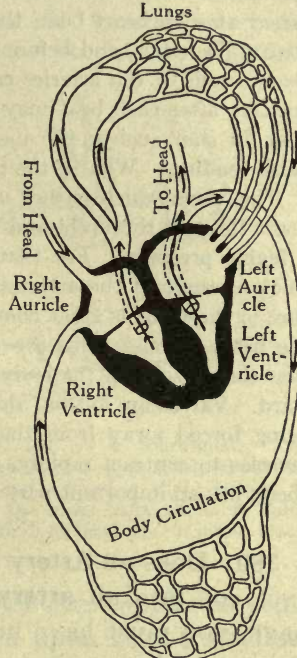


FIG. 275. — Diagram showing the course of the blood to the body, first **from** the heart, and then back again **to** the heart.

379. How Do Arteries Differ from Veins? — The tubes carrying blood **from** the heart are called arteries. The large artery going from the right ventricle to the lungs is the **lung artery**. It carries **dark** blood which needs to be oxidized. The blood comes back from the lungs bright-red in color. It is carried back by the lung vein. All tubes bringing blood **into** the heart are called **veins**.

A large artery leaves the left ventricle (see Fig. 274); it is called the **aorta** (ā-ŏr′tă). It branches soon after leaving the heart. One branch goes to the head, and supplies the cells there; the other branch furnishes the trunk and legs with blood. After the large branches have divided many times, and the blood has passed through the smallest blood vessels, the **capillaries**, it is collected in the veins, and enters the right auricle in two large veins: one from the head, and one from the lower parts of the body.

Because the arteries carry outgoing blood, which is **forced** out with pressure, their walls have to be **strong**. They are made of **three layers**, the middle one of which is muscular. As the liquid is forced into the artery at each heart beat, the walls of the artery **stretch**. After the stream decreases, and before another heart beat can take place, these elastic walls of the arteries **contract** again. This expansion and contraction after each beat may be felt as the **pulse**. Arteries which lie near the skin, such as the one at the **wrist**, are convenient for taking a **pulse reading**. What is the rate at which your pulse beats?

The veins which gather up the blood after it has gone from the heart through the body and lungs contain blood which is under only a **feeble pressure**. For that reason the walls do not need to be so thick as those of the arteries. They are also less elastic. The pressure in the veins is great enough, however, to **force** the blood back to the heart. Some veins are aided in their work by being placed so that the **muscles** of the body compress them, and force the blood forward. **Valves** are located along such veins, to prevent the blood from being forced away from the heart. Exercise, which causes certain muscles to contract rapidly, and thus to press against the veins near them, has an important part in helping the circulation.

380. Does an Artery Bleed Like a Vein? — Have you ever cut into an **artery** in your hand or foot? If you have, you must have noticed that the blood **spurts** from the wound in jets, instead of bleeding in a steady stream. Why? How can you stop the bleeding, so as to give the blood time to form a protecting clot? Remember that in an artery the blood is coming **from** the heart. You must, therefore, force the walls of the blood vessel together somewhere **between** the wound and the heart.

Suppose it is a vein that is bleeding badly, where ought you to pinch it? Since the vein is carrying blood **to** the heart, the proper thing to do is to close the vein **before** the blood reaches the wound, that is, on the side of the wound which is **farther** from the heart.

Do you know how to prepare the " first aid " bandage for a badly bleeding wound? It is called a **tourniquet** (tŭr′nĭ-kĕt; Fig. 276). Every boy scout learns to use his handkerchief for this purpose. Fold the handkerchief diagonally, and tie a knot in the middle of the handkerchief. Then tie the ends firmly together around the arm, leaving a loose loop, put the middle **knot** over the blood vessel, and put a small stick in the loop. By turning the stick in a circle, twist the loop of the handkerchief, until the knot presses hard against the blood vessel, and closes it. Someone should close the blood vessel with his fingers while the handkerchief is being prepared.

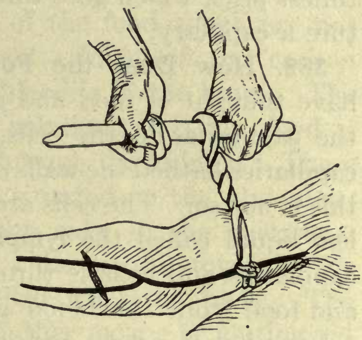


FIG. 276. — A tourniquet. The handkerchief is tied loosely about the arm, and a lever (a stick) is used to twist the loose loop, so as to force the **knot** against the injured blood vessel.

381. What are the Capillaries? — Are capillaries veins or arteries? They may be looked upon as the **smallest** veins and also as the smallest arteries. The walls of the arteries, while well developed for their use, are too thick to permit the food and gases to pass through into the tissues. The arteries divide again and again, forming a network of tiny " capillary " tubes about $\frac{1}{2600}$ of an inch in diameter. The **walls** of these tubes are **thin**. In the lungs, **carbon dioxide** can pass through the walls of the capillaries into the lung cells, and oxygen from the lungs passes into the capillaries. Along the digestive tract **food** passes into the capillaries, and the **glands** take the juices they need from capillaries. The **white corpuscles** and food leave the capillaries to enter the tissues. Capillaries are found everywhere in the body. Even the tiniest prick which goes through the outer skin will puncture a capillary.

382. How Does the Food Get to the Cells? — We have thought of food and gases as passing **directly** from the capillaries to the cells, as though the blood of the capillaries bathed the walls of the cells. Strictly speaking, this is not so. The cells are really surrounded by a colorless liquid called the **lymph**, and the exchange between capillaries and cells is through this liquid. The oxygen and food from the blood go into the lymph. The cell takes what it needs, and gives back carbon dioxide and waste material. Then the capillaries receive these things from the lymph.

Is this lymph another kind of **blood**? It is made up of the plasma and white corpuscles, and water, which have left the blood vessels. After circulating about among the cells, the lymph collects in tubes and is poured back into the blood. So you see it is really a part of the blood, without the red corpuscles.

There is no **pumping** organ for the lymph system; it depends upon the pressure of the body organs and muscles, much as some of the veins do. As a result it circulates very slowly.

383. How Does the Blood Get Rid of Cell Wastes? — When glands take certain things from the blood, and pour them into the digestive tract to aid digestion, they are said to **secrete** these things (see § 363). When glands and cells give off something which should be removed from the body, the process is called **excretion**. The cells *excrete* carbon dioxide and certain minerals, as well as compounds called **uric** (yū′rĭk) acid and **urea** (yū′rē-ă). These are the main excretions of the body, with the exception of the solid particles of the food which are not digested in the digestive tract. Most of the carbon dioxide is removed when the blood is in the lungs. The other waste materials are in **solution**, and the blood is freed from them as it passes through the **kidneys**. These are two bean-shaped organs, situated in the abdomen; they are attached, one on each side, to the backbone. The wastes collected by the kidneys are stored in the **bladder**, until they are expelled from the body. The **skin** (see §§ 71 and 392) is another means of getting rid of the waste material of the cells.

384. Exercises. — 1. Why do we divide the circulation into body circulation and lung circulation? What happens in each?

2. What part of the heart pumps the blood to each kind of circulation? What part of the heart receives the blood from each?

3. Why does the heart beat more rapidly when we are exercising the muscles? Do the contracting muscles help in the circulation of the blood? How?

4. Suppose that the heart had only one compartment, and that it had the power of contracting and relaxing as now, could there be a circulation of the blood? Would it be rapid? Would the blood travel in any one direction?

5. Review § 135, especially the valves of the force pump. Does the heart have valves corresponding to the "cylinder valve" and the "discharge valve"? How do these help the blood to go in one direction?

6. How does a dog cool itself when it is hot? Explain.

7. Which class of blood vessels has the thickest walls? Which compartments of the heart, the auricles, or the ventricles, need the thickest walls? Why?

8. When a boy or girl is growing very rapidly, the heart may not grow in proportion. What effect do you think too severe exercise will have upon the heart at such a time?

9. What bodies in the blood carry oxygen to the cells? Do they carry it as gas bubbles, or dissolved in the water of the blood, or combined with some substance in the blood?

Summary. — The **blood** is the circulating liquid of the body. It carries **oxygen** and **food** to the cells, and waste materials **away** from the cells. It also regulates the temperature of the body.

Blood consists of a colorless liquid (**plasma**) with solid bodies (**corpuscles**) floating in it. It coagulates, or **clots**, on exposure to the air.

The **organs of circulation** are the heart, arteries, veins, capillaries, and lymph spaces.

The **heart** has 2 **auricles** and 2 **ventricles**.

Auricles receive blood into the heart; **ventricles** force blood **away** from the heart.

Veins carry blood **to** the heart; **arteries** carry blood **away** from the heart. **Capillaries** carry blood from the arteries, through the tissues, and back to the veins.

When an **artery** is cut, the bleeding should be stopped by a **tourniquet** placed between the wound and the heart. In the case of a **vein** the tourniquet should be on the side of the wound **away** from the heart.

The cells are bathed in a liquid — the **lymph** — which is much like blood, but has no red corpuscles.

The **waste materials** of the cells are removed from the blood (excreted) by the **skin** and the **kidneys**.

CHAPTER XXXVIII

RESPIRATION

385. How Do Animals Breathe? — Do plants breathe? Review § 300 to recall the way in which the green cells of the leaf are open to the air which enters through the stomata. Do any animals breathe **without** lungs? As you think of the question, you will decide that if such lowly creatures as the ameba and the simpler animals breathe at all, they must get oxygen through their **cell walls**, and not in a special breathing apparatus. Even in an animal so complex as the **earthworm**, there is no special organ for breathing, but respiration is carried on only through the cells of the **skin**. In most higher animals, particularly water animals, the skin is still used as a **help** in respiration, although there are breathing organs (gills or lungs) to do most of the work (see § 46). There must be some way of putting oxygen into the circulating fluid, and of taking carbon dioxide out of it.

Do you know the two **gill coverings** at the sides of the head of our ordinary fishes, and the "arches" with pink "fringe" that make up the **gills** (Fig. 277)? In the **tadpole**, or *polliwog*, stage of the frog, the gills are easy to see; but as the tadpole becomes an adult frog, it develops **lungs**, and must come to the water's surface every little while for air. Do you remember that the mosquito wiggler has **breathing tubes**, and must come to the water surface? See § 350. The adult mosquito and other **insects** also get their air supply through breathing tubes.

What is the difference between gills and lungs? One difference is that gills are really **outside** of the body cavity, and are bathed in the water in which the creature lives. The gills take up some of the oxygen that is **dissolved** in the water, and give off the waste carbon dioxide **to** the water. In lungs we have a large surface of breathing cells in a cavity **inside** the body and the air enters only as a **gas**. But the air must be moist, or the delicate lung cells will be injured (see § 52).

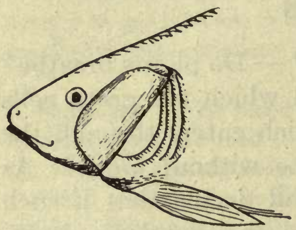


FIG. 277. — The gills of a fish, with the gill cover removed.

In Chapter VII we learned something of **how we breathe**. We take in air, because the muscles of the chest relax, and the chest cavity becomes larger. As the cavity grows larger, the air pressure in the lungs is **less** than it is outside of the body; therefore air rushes in from outside, and we say we have **inspired**, or **inhaled**.

386. How Does Inhaled Air Get to the Lungs? — Through what passage must the air go first on its way to the lungs? Of course through the **nose**. Like all the other tubes through which the air goes, the nostrils are lined with **mucous membrane** (see § 363). Because of the length of the nose passage, there is a large surface of membrane. The membrane always has on it a considerable amount of liquid **mucus**. This moistens the passage, and catches dust particles, preventing them from going to the lungs. **Cilia** (sĭl′ĭ-ă), small, thread-like extensions of the cells, are found in all the tubes of the breathing organs. They act like tiny **brushes**, and protect the lungs by **sweeping back** the dust particles.

A **second** reason for nose breathing is that the air we inhale is warmed in passing through the nose. Ought we, then, to breathe through our mouths?

Trace the passage of air from the nose to the lungs. The nose passages open into the **pharynx**, or throat, the same compartment into which food passes from the mouth. But while the food goes into the **esophagus**, the air goes through the **larynx** (lăr′ĭŋks), or voice box, into the windpipe, or **trachea** (trāk′ē-ă). The lid which covers the larynx while food is being swallowed is called the **epiglottis** (ep′ĭ-glŏt′ĭs). The epiglottis does not go up and down like a real box lid, but it remains in its place, and the larynx is **drawn up** against it to close the passage into the windpipe. When swallowing is over, the larynx **drops down** a little way, and allows breathing to go on. Feel the larynx, or "**Adam's apple,**" in your throat rise when you swallow.

If the **larynx** could not be closed, food would enter the windpipe, and cause us to choke. Does this ever happen? What do we mean by saying that food has gone down our "Sunday throat"? The larynx is a box made of pieces of **cartilage**.

The **trachea**, or windpipe, is a tube about 4½ inches long, and about 1 inch in diamteer. It is composed of about 20 pieces of cartilage, bent around in the shape of a letter **C**. The pieces are held together by tough **connective tissue**. At its lower end the trachea is divided into two tubes, called **bronchi** (brŏn′kī). One of them goes to each lung. The bronchi divide and subdivide a countless number of times to form **bronchial tubes**. The smallest of these tubes end in the **air cells** of the lungs.

387. What are the Lungs Like? — Have you ever seen the lungs of a chicken? They are two organs of pink, spongy tissue. The tissue is a mass of **air sacs** and

air tubes. It is pink from the network of capillaries, through which the blood flows. Our lungs are much like the chicken's, except that they are larger (Fig. 278).

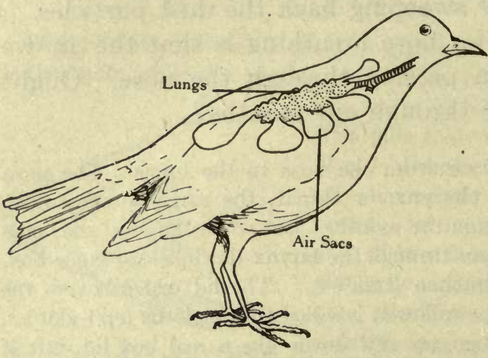


FIG. 278. — Lungs and air sacs of a bird.

Each lung is surrounded by a sac of connective tissue to **protect** it. If the sac becomes inflamed, the disease is called **pleurisy** (plūr′ĭ-sĭ). The **heart** lies between the two lung sacs (see § 378). The lungs, as we should expect, are **elastic**, like a sponge. While they are compressed when we **exhale** air, they expand rapidly when we **inhale** it.

The lungs are the **meeting place** of air and blood. The total surface of their air sacs and tubes is probably 2000 square feet in a grown person, so that a great deal of blood is furnished with oxygen at one time. A room 20 feet wide would need to be how many feet long to have a floor area of 2000 square feet?

Did you know that the breathing organs of flying birds are even **larger** in proportion than our own? The birds have air sacs in various parts of the body, and even inside of some of the hollow **bones**. How does this help the exchange of oxygen and carbon dioxide? How do the hollow bones, filled with air, affect the density of the bird's body? Such birds breathe much more rapidly than we do, and their heart beats more rapidly, too. Their body temperature may reach 110° F. What is ours?

388. What is the Voice? — We have learned that the boxlike organ, through which the air passes in going from the throat to the windpipe, is called the larynx. It contains the organs of the voice, the **vocal cords** (see § 265). These cords are two strips of tough connective tissue (Fig. 279), stretched between the cartilage of the larynx. They leave a V-shaped opening between them when they are at rest, but they have **muscles**, which draw them closer together, and stretch them, when we speak or sing. **Air**, passing these tight cords as it goes through the larynx, makes them **vibrate** like tuning forks or other sounding bodies (see § 265). The vibrations produce **sounds**. The **loudness** of the sound depends upon the **amount** of air you force past the vocal cords. When you shout, what kind of breath do you take?

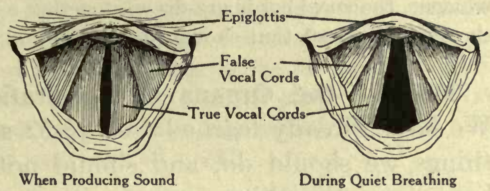


FIG. 279. — The vocal cords in two positions: for producing a sound, and for quiet breathing.

The highness, or lowness (**pitch**), of a vocal sound depends upon the length and thickness of the cords. The more tightly the cords are drawn, the **shorter** they become. Short cords can vibrate a greater number of times per minute than the long cords. Thus, when the cords are short, the pitch is **high**. When the cords are long, the pitch is low. As a man has a larger larynx than a woman, his cords are longer and larger than hers. Therefore he cannot make his cords as short as she can hers. As a result, he has a lower voice than a woman has (see § 268).

The **quality** of a voice, which enables us to distinguish one person from another, is due to the peculiar way in which each person uses his air passages, as well as the shape of the air passages themselves (see § 269). We form the **sounds** of **letters** by changing the **shape** or **position** of the mouth, tongue, and lips. **Vowels** (a, e, i, o, u, and y) are the sounds which are more purely **vocal**, or voice, sounds, and are less changed by the lips and mouth than the **consonants**. When we **whisper**, the vocal cords are drawn together as for sounds made with the voice, but not taut enough to vibrate and produce voice.

389. Do the Organs of Respiration Need Care? — We have already learned (see §§ 52 and 54) some of the things we should do, and should not do, if we wish to keep our breathing organs in good condition. The harmful **germs** of the air reach us chiefly through the breathing organs. If these organs are in good health, so that fresh air can reach every part of them, they are usually able to protect themselves and the body; but if they are not strong, or are weakened by neglect and abuse, serious diseases may attack us. When you recall (see § 204) how easily molds and bacteria **multiply** in warm, moist food, you will understand that the breathing passages and lungs, which are also warm and moist, may be good breeding places for germs of certain diseases. We should see to it that we always have fresh, clean, moist air to breathe, and that the lungs get sufficient **exercise**.

If we ought to breathe air free from dust, and containing as little as possible of gases that are not in pure air, what do you think of the practice of **smoking** tobacco? Will the inhaled smoke and the gases produced by the slowly burning tobacco be likely to help, or injure, the delicate tissues of the throat and lungs?

Physicians tell us that the habit of drinking **alcoholic liquors** weakens the lungs; so that the drinker is more likely to catch lung diseases than one who abstains from liquor.

What do you think of the practice of wearing **tight clothing** and a tight belt? Do you think that a person can breathe correctly, if the abdomen is compressed, and its organs, and those of the chest, are forced out of place?

Do you think that a **cold** is only a harmless discomfort, and does not need any special attention? We must remember that colds are **dangerous**, because they lower the power of the throat and lungs to resist disease, and make it easy for harmful germs to attack us. Breathing deeply of fresh air, if we have been chilled, will often bring a warm **glow** to the skin, and work off a cold.

390. What is the Structure of the Skin? — Does the **skin** form a part of our respiratory system? Review § 385 for the action of the skin in the lowest animals. Yet even in our own bodies, the skin assists the lungs and kidneys in getting rid of the waste of the cells (see § 383), and it is the regulator, along with the lungs and blood, of the body's temperature (see §§ 71, 374, and 392).

Review § 341 for the description of an **animal** skin. Our own skin has a similar structure (Fig. 280). The

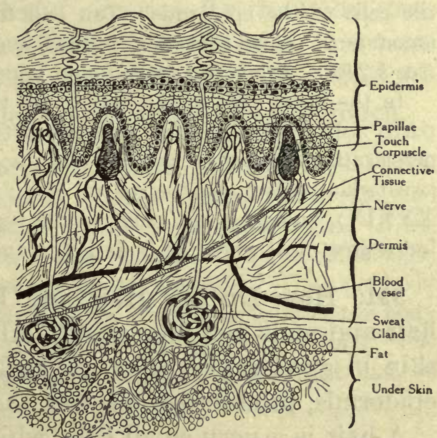


Fig. 280. — The structure of the skin. Note its three layers, especially the complex nature of the dermis, or true skin.

outside layer is the **epidermis**, or *cuticle* (kūt′ĭ-kl). This has neither nerves nor blood vessels, but protects the true skin, or **dermis**, which is beneath it. The outer surface of the epidermis is being worn off constantly (why?); but its **lower** cells are in contact with lymph, and so get food for forming new cells. Where the skin is put to rough use, as in the palms of the hands, a thick layer of epidermis, called a **callus**, is formed.

The **dermis** is thicker than the epidermis, and is made up of strong fibers of **connective tissue**, together with blood vessels and nerves. On its surface are little elevations, some of which contain the bodies that bring about our sense of **touch** and of **temperature** (see § 404).

The **color** of the skin is due partly to the blood, which shows through the capillaries, and partly to the **coloring matter** in the lower layers of the cells of the epidermis. **Tan** and **freckles** are caused by larger amounts of coloring matter, formed by the action of sun and wind (see § 240). A layer of **fat** is found under the dermis.

In the lower part of the dermis are the **sweat glands**. These are partly coiled tubes, which take from the blood the liquid we call **perspiration**, and then pour it out upon the skin (see § 71). The sweat glands are under the control of our **nervous system** (see Chapter XXXIX), and pour out only a little perspiration when we are cool, but a great deal when the body is hot and needs to be cooled.

391. How Do the Hair and Nails Grow? — Do the hair and nails look like skin? Although they differ from skin in appearance, they are really **special forms** of the epidermis, produced to protect the skin (Fig. 281).

A **hair** is a very small tube which grows in a pocket of the dermis. The part projecting from the skin, like the epidermis itself, has neither blood nor nerves. Near each hair there is an **oil gland**, which secretes an oil for the softening of the hair and the skin near it. Do you know what it is that causes "goose flesh" and makes your hair "stand on end"? It is tiny **muscles** in the pockets from which hairs grow.

The **nails** are plates of very tough epidermis. Like the hair, they grow out of the dermis by the constant formation of new cells. Do their outer ends have blood or nerves? What causes their pink color? What are the **roots** of the nails? What is the use of the nails?

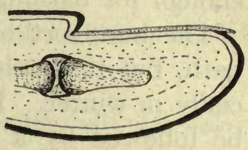


FIG. 281. — A nail, a special form of the epidermis, growing out of the dermis.

392. What is the Work of the Skin? — We have already learned many of the uses of the skin (see §§ 383 and 390). It is a wonderful covering for the body, protecting the cells that are inside from injuries, and from the germs of disease which are in the air. The skin also contains the nerves which give us the sense of **touch**.

The skin acts like a delicate instrument for controlling the temperature of the body. If we are warm, the blood rushes to the skin, and the sweat glands pour out an abundance of the perspiration. If the body becomes cold, the blood vessels near the skin become smaller, and less blood comes near the surface of the body. Thus the body loses less heat. In some forms of fever the temperature of the body is higher than it should be, yet we have **chills**. Why is this? The reason is that the blood vessels near the skin remain closed, and we have the same sensation as if we were in a cold room.

393. What is the Value of Bathing? — Review § 183. Are not the dead skin, the material left by the evaporation of the perspiration, and the dust and smoke and bacteria which attach themselves to our bodies, reasons enough for bathing the skin often?

The best sort of bath for *cleaning* the skin is a hot bath, but it should be taken at night, if possible, especially in winter. If it is taken in the daytime, it should be followed by a cold shower bath, or a dash of cold water, so that we may not "catch" cold. In the morning, especially in cold weather, a **cold** bath is the best. The cold water gives the body a shock, and the blood is driven inward from the skin, by the closing of the blood vessels near the skin. But after a vigorous rubbing with a rough towel, the "reaction" comes, and the skin glows as the blood reënters it. A cold sponge bath is excellent, if one cannot endure the shock of plunging into a tub of cold water. It should be followed by vigorous rubbing with a rough towel.

394. Exercises. — 1. Why must an earthworm come out of the ground in a heavy rain?

2. Trace the course of food to the stomach and of air to the lungs. Where do these paths cross?

3. What two cavities are separated by the diaphragm? Is the diaphragm a muscle? What is its work?

4. What is the scientific reason why you should remain in bed when you have a bad cold?

5. Why does it not cause you pain to cut off a hair? Why does it hurt to pull one out?

6. Do you think that the body can preserve its heat best by having a great deal of blood in the skin, or by withdrawing blood from the skin? Why then is it not best to take a hot bath just before going out on a cold day?

7. What do you think causes the color of hair?

8. What skin structures form our finger prints? Why can they be used to identify a person?

9. Give the reasons why you should breathe through the nose, and not the mouth.

Summary. — **Respiration** brings oxygen to the cells, and takes away the carbon dioxide given off by the cells.

The lowest animals respire through the **cell wall** or through the **skin.**

Water animals breathe through **gills**, by which dissolved oxygen is taken out of the water. **Land animals** have **lungs**, consisting of spongy tissue full of air tubes and air cells, as well as blood capillaries.

The **air passages** are the nasal passages, throat, larynx, windpipe, and bronchial tubes.

The **vocal cords** are in the **larynx**. In speaking and singing we use the throat, teeth, lips, and nose, as well as the vocal cords.

Colds, tobacco, alcohol, and **tight clothing** are likely to injure the air passages or lungs.

The **skin** consists of the epidermis, dermis, and fat. Out of the dermis grow **hair** and **nails**. It has **oil glands** and **sweat glands**, as well as the nerves of touch.

Bathing removes dead skin, waste material brought out by the perspiration, dust, and bacteria.

CHAPTER XXXIX

SENSES AND HABITS

395. How Can Our Organs Work Together? — Is our body like a clock, made up of many interesting parts, and needing only to be wound up from time to time to keep it going? Or is it more like an automobile, which needs constant adjustment of gasoline, air supply, steering gear, brakes, lubricators, and spark plugs, in order that it may run properly? You will agree that it is more like the automobile. But will the automobile run itself? Must there not be a driver in control to make all the adjustments as they are needed? Does the body have a driver, or expert, in control of its delicate mechanism? Of course it does: the **mind**. So the automobile needs a driver, but the driver needs a mind. We cannot tell just where the mind is; we know only the **organs** through which it acts. We ordinarily call the **brain** the organ of the mind. There is a sense in which not merely the brain, but the whole system through which each part of the body knows when to begin acting, and when to stop, is the organ of the mind. This system is called the nerve system, or **nervous system.**

What cells of the body are the **messengers** which tell the mind what is needed by the body, and then carry the proper order back to the body? There is a special kind of cells for this purpose; they are called **nerve cells** (Fig. 282). Do these need to travel to the mind with their message, as the red corpuscles must travel to the cells with oxygen? No, there is a **chain** of cells, and the message leaps from one link to the next, until it is received by that organ of the nervous system which is able to send back the answer.

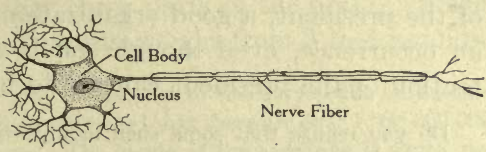


FIG. 282. — A nerve cell. The enlarged part, looking like an ameba, is the cell body; the long, slender part is the nerve fiber.

A nerve cell consists of an enlarged portion, called the **cell body**, and a long, slender portion, which is called the **nerve fiber**. The outside of the cell body is usually **gray**, and the outside of the fiber, **white**. What we call a **nerve** is a bundle of the long, slender nerve fibers belonging to several nerve cells.

396. What is the Work of the Brain? — Suppose you go to a bank employing a large number of men, to make a request or to ask for information; will you go directly to the office of the president? Not if the bank is properly **organized**. You will be met at the door by the doorkeeper or a messenger, and he may be able to answer your question, or to grant your request, without your having to ask anyone else. But he may be obliged to ask a clerk, and the clerk may have to ask the chief clerk, and the chief clerk may need to go to the cashier or vice-president. Possibly he may need to send you to the president himself. Why does the business have such an organization? Is it not because those who are at the head of the business need their time for their special work, and if they were consulted about everything that was brought to the bank, they would have no time left for managing the business? But note this fact: while a great many things can be done without the knowledge of the president, a good organization has ways by which an occurrence, even though small, which needs the attention of the president can get to him *at once.*

Do you realize that some such organization as this exists in the body? At the head of the nerve system is the brain, which is especially the organ of the mind; but the body does so many things that need not go to the mind, that our minds never know of them at all. But if anything unusual happens, or something goes wrong, and the mind needs to know of it, the message can go directly to the highest part of the brain, just as a request made at the door of the bank can, if necessary, go directly to the president himself.

397. What is the Brain Like? We have already learned of the hard case, or **skull**, which protects the brain (see § 358). If you could look at the brain inside your skull (Fig. 283), you would see a rounded mass of grayish material having in it a number of **folds.** There is a deep **dent** from front to back. This upper, rounded part of the brain is called the **cerebrum** (sĕr′ē-brŭm). Back of the cerebrum, and below it, at what we call the "base of the brain," is the **cerebellum** (sĕr′ē-bĕl′ŭm), or "little brain." In front of the cerebellum, and below it, like a large knob at the top of

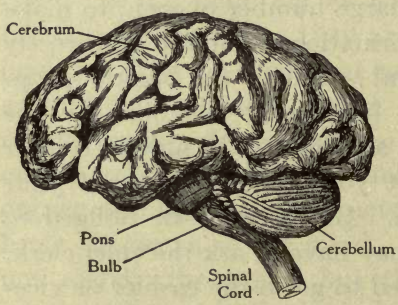


FIG. 283. — Side view of the brain and upper end of the spinal cord.

the spinal cord, is the **bulb**. Another part of the brain, in front of the cerebellum, is called the **pons**, or "bridge." This connects the other three parts of the brain. When a man is full grown his brain weighs from 3 to 4 pounds.

Why is the cerebrum gray? Because of the **nerve cells** on its surface (see § 395). It has been estimated that there are over 1,000,000,000 of them in an adult person. The **inside** of the cerebrum is white, because of the nerve fibers it contains (see § 395). Through the cerebrum we get the sensations of heat, light, sound, touch, taste, and the like, and are able to use our muscles when we wish. Nerves like the nerve of **sight** (see § 252), and the nerve of **hearing** (see § 266), go directly from the organ (that is, the eye and ear, respectively) to the cerebrum and back to the organ, without passing through the other parts of the brain or the spinal cord. A healthy cerebrum is necessary for **intelligence** and **judgment**. Without it we should be likely to starve, even if food were set before us, for we should not know enough to eat.

The cerebellum has special control of our **movements**. It makes the muscles contract properly and in pairs, so that we can move in an orderly way.

398. What is the Spinal Cord Like? — What is the backbone, or **spinal column**, for (review § 358)? It is for the **attachment** of the rest of the body's framework, is it not? But it has also the duty of **protecting** the spinal cord, which is inside it. In an adult the cord passes through the upper 20 of the 24 vertebræ of the spinal column. At its top, the cord is enlarged to form the **bulb**, which is inside the skull, and is a part of the brain. The lower end of the cord branches out into large **nerves** which go to the hips and lower limbs.

The spinal cord is white on the outside, from the covering of the nerve fibers, and gray on the inside. Is this true of the cerebrum? A cutting across the cord would look like capital **H.**

399. How are the Internal Organs Controlled? — How does the stomach get gastric juice when we begin to eat? Does the juice just flow of its own accord, or must it be *ordered* to flow? We have learned that the body is organized, and that its parts are *directed* through the nervous system. The glands that secrete gastric juice must get their orders from some nerve center, such as the spinal cord or bulb, before they can go to work. But the mind need not order the flow of gastric juice, for this can be performed by the lower parts of the nerve system just as well. So the message is turned back in the spinal cord or bulb, and the gastric glands get word to **secrete** the needed juice. But suppose the stomach is injured. Then the messages it sends along the nerves are so unusual that they go right on, past the spinal cord and bulb, to the cerebrum, and we feel **pain.**

We call the brain and spinal cord, with the great nerve groups directly connected with them, the **central nervous system.** The brain and cord act like " Central " of a telephone system. Whenever one organ wishes another to perform its function, it sends the message to the central system. The proper part of this system sends back the message to the muscles or glands that are to do the thing required.

In addition to the central nervous system, the body has a branch which is called the **sympathetic system**, and which aids the central system in controlling the important organs of digestion and respiration. It also controls the skin.

400. What is Voluntary Action? — What does voluntary action mean? It means action that we **will** to do, does it not? When we see an apple hanging from a tree, and decide that we want it, the cerebrum directs the **muscles** of the arm to get it. If this is not enough, the cerebrum directs other muscles to act, so that we stand on tiptoe and stretch the body to its greatest height, in our effort to get the apple. The muscles that can act in this way are called **voluntary** muscles. We cannot stop the muscles in the esophagus from pushing food down into the stomach, nor can we control the muscles of the stomach or the heart by willing to do so; these are **involuntary** muscles, and the movements they produce are involuntary movements. Involuntary action is also called **reflex action.**

What causes **blushing?** Can you control the rushing of blood to your face, so that you will not blush? The skin and the blood vessels that are in it (see § 390) are partly under control of the **sympathetic** system (see § 399). Suppose someone pays you an unexpected compliment (or insult). The **unusual** act so upsets you that your sympathetic system **loses control** of the blood vessels, and the blood rushes into them, until the skin is red and hot. But in a moment the blood vessels are again under control, and grow smaller, so that only the usual amount of blood can go into the skin.

A good illustration of involuntary, or reflex, action is seen when you unexpectedly bring your finger into a **flame**, or against a hot stove. You jerk the finger away **before** you feel pain. Why is this true? In order that your mind may know that an object is too hot, the message of pain must get to the cerebrum; but the **lower part** of the nervous system gets word that something is wrong **before** the brain does, and sends the message to the muscles of your arm to contract. If a fly alights upon a dog that is asleep, does he not try to remove the intruder even in his sleep? Is this voluntary, or reflex, action?

401. Why are So Many Actions Reflex? — Why is it that when we have a cerebrum, through which the mind can work, we do so many things without the order of the brain? All the organs of digestion, respiration, and circulation carry on their usual acts without our knowing it. These are acts *inside* the body. But there are a great many *outside* actions that are reflex, too. Do you have to **make** your eyelids wink? No, this is an act that does not usually need the will. In fact it is hard for you to keep them from winking. The eyes need cleaning, and we might forget to clean them, if the operation were left to our cerebrum to attend to.

You can see why so many acts are reflex. It is so that the brain may be left free from the ordinary duties of the body, and may have time for the **unusual** work which no other part of the nerve system can do. Learning, thinking, remembering belong to the cerebrum alone.

Are there any acts which **once** required the full effort of your mind, but which you **now** do without thinking? Of course there are. How about walking, skating, writing, which were so hard to learn? Or turning down a certain street to your house? After you have done these a great many times, you do them almost, or quite, without thinking. In fact, when you are changed from one room to another in school, you turn involuntarily, unless you " catch " yourself, into the old room the first day or two after the change. Watch your acts, and see how many of them are really reflex. These reflex acts that you learned to do, are called **acquired** reflexes. What does this mean? We also call them **habits**.

402. Can We Make and Break Habits? — You can see that those things we learn to do so well that they become habits with us, like the reflex actions that are entirely natural, are a great **saving** of effort, and spare the cerebrum an enormous amount of work. It is thus left free to learn new things. If we "set our mind" to do an act, we can usually master it, until it becomes almost "second nature," or a habit. So if we have will power, we can *choose* what our habits shall be. Do you see the danger there is in this freedom to choose? We can make **bad** habits, too, can we not, and so break up our good ones? Bad habits, like good ones, become easier and easier; if we do not break them, they master us. It is in this way that man can do so much for his success or failure. Having the **will** always to make a good habit to take the place of a bad one, will help us to forget the bad one, and to be free from it.

403. Why Should We Control Ourselves? — How we admire a person who has **perfect control** of his body; whose eye is clear, whose arm is steady, whose movement is sure, whether on the athletic field, or in running a machine, in sailing a yacht, or in knowing just what to do in an accident! Do we not really admire even more a person who has control over his temper, who looks on the bright side of things, who does not go into tantrums, who does not give up a hard task without a struggle, who thinks twice before he speaks, who is considerate of persons older and weaker than himself?

Do the great athletes have the control over their bodies from their *childhood*, or must they **learn** it? You know how hard men work to train themselves to be "stars" in athletics. Has the person you recognize as a great *musician* risen to his position without effort? No, it is necessary for such a person to work hard to get his wonderful power. So it is with good nerve habits. They are not always easy to learn. Are they not worth the effort?

404. What are Our Senses? — How do we know about the world around us? It is through some of our senses, is it not? We have **eyes** to recognize light and its effect upon objects, **ears** to be set in vibration by the air movements which make up our sounds, delicate **touch cells** in the skin, to enable the mind to judge about the shape, size, temperature, and weight of objects, and along the two channels by which air and food enter the body we have the sentinels of **smell** and **taste**, to help us to distinguish the good from the bad, and so to protect the lungs and the digestive tract from harm.

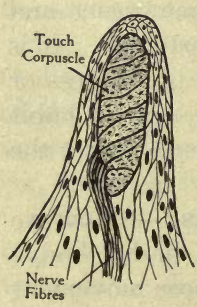


FIG. 284.—A touch corpuscle in the skin, and the nerve fibers which enter it.

We have already learned about the wonderful organs of sight (see § 252) and of hearing (see § 266). The sense of touch is in the **skin** and the **tongue.** Small elevations contain **touch corpuscles** (Fig. 284), which in their turn contain ends of the nerve fibers. When we touch an object, the *change in pressure* excites the nerve fiber to carry a message to the cerebrum. We have to decide by our *judgment* whether the object is smooth or rough, large or small, hot or cold, hard or soft, according to what the cerebrum learns from the nerve cells. Watch a blind person, and see how carefully he examines a new object. Do our **eyes** help our touch corpuscles, if we look at the object, as well as feel of it?

Is the sense of touch equally good *everywhere?* By no means. Some regions of the body have many more touch corpuscles in a given area than others. One way to test how sensitive a given region is, is to use a pair of **dividers**, or two pins stuck through a piece of cardboard. The tongue can feel that there are **two** points, when they are only $\frac{1}{25}$ of an inch apart; the finger tips, when they are $\frac{1}{12}$ inch apart. The touch corpuscles of the back, however, report to the brain that there is only **one** point there, even if the two points are $1\frac{1}{2}$ or 2 inches apart.

405. How Do We Smell and Taste? — In what *condition* must a substance be, in order that we can smell it? You can realize that it must be a **gas**, and must pass into the nose along with the air we inhale. We call the cells having the sensitive ends of the nerves of smell, the **olfactory** (ŏl-făk′tō-rĭ) cells (Fig. 285). You know how acute the sense of smell of dogs is; in cats this sense is much less developed. Wild animals and primitive men can easily recognize friends or foes at a distance, if the wind blows the odor toward them. Civilized man has largely

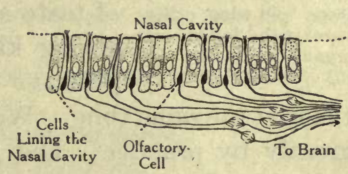


FIG. 285. — The cells of smell, connecting the nasal cavity with the brain.

lost the power to use this sense, except as he smells somc-thing very pleasant or very disagreeable.

Taste is the result of messages carried to the cerebrum by nerves in the tongue (Fig. 286) and back of the mouth. In what condition must a substance be, in order that it may have a taste? It must be in a **liquid** condition. If it is not liquid when we take it into the mouth, the saliva dissolves it. If the saliva cannot dissolve a substance, it has no taste. What is the taste of sand? Of a silver coin?

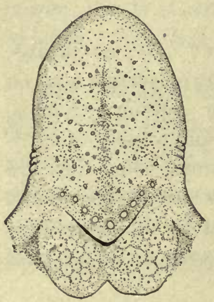


FIG. 286. — The tongue with the structures containing the ends of the nerves of taste. Of what other sense is the tongue an organ?

The **taste cells** can recognize sweet and sour tastes, salty and bitter tastes, and combinations of these. If you hold your nose, and then taste of some strong food, such as cheese or bacon, the taste will seem unnatural; because what we **call** taste is often a **combination** of taste and smell. In fact, some very strong kinds of cheese are said to be pleasant to taste, if we do not smell them at the same time. We can **develop** the sense of taste greatly by practice. Did you know that the quality of a food, coffee, or tea, is often decided by a professional "taster," who has trained his taste cells for the purpose?

406. Exercises. — 1. Why does your mouth "water" when you smell cooking food?

2. Suppose an American baby were brought up in a family speaking only French, what language would it speak? Why?

3. When an accident occurs, and splinters fly toward the eye, we

find that the eyelids close before the splinter reaches them. Is this voluntary action, or reflex action?

4. When a grown person who spoke incorrect English in his youth becomes excited, he often forgets his correct English, and speaks incorrectly. How do you account for this?

5. Why is it that you can recall a fact you thought you had forgotten?

6. What ways have you found successful in controlling your temper?

7. Why can you learn a lesson by going over it several times?

8. How is the nervous system like a telephone system? How unlike it?

9. The image formed on the retina is inverted (see § 246); how do we know that the object is right side up?

10. Telephone poles in a row seem to grow shorter the farther they are away; how do we know they are of the same height?

11. Why does a spark on the end of a stick which is being turned rapidly in a circle look like a ring of light?

Summary. — The parts of the body **work together** because we have a nervous system to **organize** the body's work.

Nerve cells consist of cell bodies and nerve fibers.

The **brain** consists of a large number of nerve cells. Its chief parts are called **cerebrum**, **cerebellum**, **bulb**, and **pons**.

The **spinal cord** is made up of many nerve cells protected by the backbone.

The **sympathetic system** assists the central system.

Voluntary acts are controlled by the cerebrum.

Reflex acts do not require the cerebrum.

Voluntary acts, which have become **involuntary** by being performed often, are called **habits**.

Habits leave the cerebrum free to learn **new** things. They can be made, or broken, by the will.

Our **senses** are hearing, seeing, feeling, smelling, tasting.

Our **judgment** must always decide what the messages from the sense organs mean.

CHAPTER XL

SCIENCE AND THE COMMUNITY

407. What Has Science Taught Us? — Review the preceding chapters, especially Chapter I. We have studied many things about our earth, have we not? In Part II we learned about the **atmosphere** and the phenomena of fire, breathing, and weather, which depend upon it. In Part III we studied **matter** and **energy** as they show themselves in the heavenly bodies, and in the solid and liquid materials which make up our earth. Part IV was a study of the way in which science is applied in our **homes**, in the processes of washing and cleaning, and in the cooking and preserving of food. In Part V we had the story of the wonderful phenomena of **electricity**, **light**, and **sound**, and of simple and complex **machines** by means of which man has harnessed natural forces to do his work. Part VI told about the world of **plants** and **animals**, and the ways in which they help and harm us as we try to get our livelihood. Finally, Part VII was an account of the plan according to which **our bodies** are built, and some of the ways of keeping them in health.

What is the best thing you have gained from the study of science? Has it been the many new **facts** you have learned? Or the story of how man has discovered nature, and made use of the knowledge to help himself to better ways of living? Or the way in which you can keep yourself in **health** and strength? Or a new idea of the **community** in which you live, and what your duty to the community is? Probably you have gained something of each of these.

If you have thought of your lessons seriously, you have realized how many things there are still to learn, and you have probably asked yourself many questions for which you have not yet found the answer. The **important** thing now is what you are going to do with science after you have " passed " in this course. Are you going to **forget** it, or to **use** it daily, and, if you have the opportunity, to study it still more deeply? We learned in Chapter XXXIX that we can make **habits**. One of these is the habit of keeping our minds alert and on the lookout for new knowledge. We call this habit the " power of observation "; it may also be called **open-mindedness**. It is a wonderful habit, for by having it we shall not only learn new facts, but we shall be able to see nature in larger and better ways. This will add enormously to our enjoyment, as well as to our knowledge, for nature is a fascinating teacher.

408. How Can Science Help a Community? — What **interests** do the people of a community have in common? They all need air and sunshine, do they not, and shelter from the weather? They all need food and clothing. They all need to be protected from danger of disease. They all need education for their life work, and recreation to rest them from one period of work, and to prepare them for the next. Because people wish these things for themselves and their children, we have schools, factories, stores, libraries, parks, and other institutions.

Do you see that whether you wish it or not, you are a **member** of the community? The community educates you, and its protection is around you in your home, on your way to and from school, and at play. Its protection makes it possible for your parents to care for you properly. In return the community expects you to obey certain rules of conduct and to give your **best thought** to the good of the community. Is not this fair?

Which person can give **more** to the community, the one who knows science, or the one who does not? Which would do his work better, if he were a mechanic? Which would sell cleaner milk, if he were a milkman? Which would keep house better, the woman who knows the scientific reasons for things, or the one who must do all her work by guess? Which would be the more intelligent in obeying the rules of the Board of Health in the time of an epidemic? Which would vote more intelligently upon the obtaining of a pure water supply, or a needed park, or a sanitary school building?

409. The Community of the Future. — In § 5 we learned some of the ways in which science has made modern civilization possible. It has done this because of the many new tools and **machines** it has given us, and the many new means of **earning** a living it has made possible. But even greater than the machines, and the articles of food, comfort, and culture that have come to us, are the new **ideas** which science has brought. In the light of science we look at ourselves, our work, and our place in the community, in a new way. But this is not all: we also look at history, language, and government in a **new** way. May we not hope that the day will come when the knowledge of scientific truth will reach all the members of all the communities of the earth, both of those we call *backward*, as well as of those we call *progressive?* When it does, we need not fear for the community of the future.

410. Exercises. — 1. If many persons are forced to live in a small tenement house, and they do not observe sanitary care, what will be the effect upon their health and length of life? What is the duty of the community in such a case?

2. How are rats, mice, and flies dangerous to a community?

3. Name some of the ways in which the city might be made more healthful than the country. What would need to be done in the case of the city in which you live?

4. What is the source of the water used in your community? Is the water ever in danger of being contaminated by dangerous bacteria? What is done under such conditions?

5. What is the source of the ice in your city? Is it pure? Is it possible for poor families having children to keep milk cool in summer? Why is this necessary? Review § 340.

6. Which housekeeper makes a better home for her family, the one who wipes up dust with a damp cloth, or the one who uses a feather duster? The one who keeps a great deal of bric-a-brac upon the walls, or the one who keeps little? The one who keeps the foot mat outside the door of the living room, or the one who keeps it inside? The one who uses a carpet sweeper or vacuum cleaner, or the one who uses a broom to remove dirt?

7. What is the method of delivering milk and collecting milk bottles in your city? Is it sanitary? Are all the empty milk bottles washed by the housekeeper before they are collected? Why should this be done, in the interest of the city's health?

8. Watch the way in which garbage is collected in your city. Is it done in the best way? How could it be improved? Could the housekeeper do her part better? What is done with the garbage in your city; that is, is it burned, or buried, or how is it disposed of? What is done with the waste paper of the city? Has this any value?

9. Are any of the bakeries of your city located in cellars? Do you think this is best for the city's health, generally speaking? How is bread handled while it is being taken from the bakery to the store in which it is sold? What is the advantage of a wrapper on bread loaves?

10. Why should the rooms of a house get as much sunshine as possible? In which positions will all the rooms of a house get the more sunshine, if the house faces north, east, south, or west, as is usually the case, or if the house faces northeast, southeast, southwest, or northwest?

11. Does your city have a great deal of smoke? What are the objections to it? Is any effort being made to make the amount of smoke less? Is the effort succeeding?

12. Why is it bad policy for a community to allow clothing to be made in rooms in which people live and then to be taken to stores to be sold?

Summary. — We should make a **habit** of the power of observation we have gained in our study of science.

All the people of a community have **interests** in common, and the person who has a knowledge of science can give more to the community than one who has not.

The **benefits** of science to modern civilization are not only new tools and machines, but also a new **method** and point of view.

APPENDIX

TABLE I. THE METRIC SYSTEM

1. Length. The unit of length is the **meter** (39.37 in.).

10 millimeters (mm.)	=	1 centimeter (cm.).
10 centimeters	=	1 decimeter (dm.).
10 decimeters	=	1 **meter** (m.).
1,000 meters	=	1 kilometer (km.).

Note that the prefix "milli-" means 0.001, as *mill* = 0.001 dollar; "centi-" means 0.01, as *cent* = 0.01 dollar; "deci-" means 0.1 as *dime* = 0.1 dollar. "Kilo-" means 1,000.

2. Square Measure, or **Area.**

100 square millimeters (sq. mm.)	=	1 sq. centimeter (sq. cm.)
100 square centimeters	=	1 sq. decimeter (sq. dm.).
100 square decimeters	=	1 sq. meter (sq. m.).

3. Cubic Measure, or **Volume.** The unit of volume is the **liter,** which is 1 cu. dm., or 1,000 c.c.

1,000 cubic millimeters (cu. mm.)	=	1 cubic centimeter (c.c).
1,000 cubic centimeters	=	1 cubic decimeter (cu. dm.).
1 cubic decimeter	=	1 **liter** (l.)
10 liters	=	1 dekaliter (dl.).
10 dekaliters	=	1 hectoliter (hl.).
10 hectoliters	=	1 kiloliter (kl.).

4. Weight. The **gram** is the weight of 1 c.c. water at 4° C.; 1 liter of water at 4° C. weighs 1 **kilogram.**

10 milligrams (mg.)	=	1 centigram (cg.).
10 centigrams	=	1 decigram (dg.).
10 decigrams	=	1 **gram** (g.).
1,000 grams	=	1 kilogram (kg.).
1,000 kilograms	=	1 metric ton.

TABLE II. EQUIVALENTS

1. Length.

1 centimeter	=0.3937 in.	
1 meter	=39.37 in.	=3.28 ft.
1 kilometer	=1,000 m.	=0.6214 mile.
1 inch	=2.54 cm.	
1 foot	=0.3048 m.	
1 mile	=1.6094 km.	

2. Area.

1 sq. cm.	=0.155 sq. in.			
1 sq. m.	=10.764 sq. ft.	=1.196 sq. yd.		
100 m. square	=10,000 sq. m.	= 1 hectare	= 2.47 acres.	
1 sq. km.	=0.385 sq. mile.			

3. Volume.

1 cu. cm.	=0.061 cu. in.	
1 cu. m.	=35.315 cu. ft.	
1 liter	=1,000 cu. cm.	=1.0567 qt. (U. S.).

4. Weight.

1 gram	=15.4324 grains.	
1 kilogram	=1,000 grams	=2.2046 lb.
1 metric ton	=1,000 kg.	=2 204.6 lb.
1 short, or net ton	=2,000 lb.	
1 long, or gross ton	=2,240 lb.	
1 grain	=0.0648 gram.	
1 ounce (avoirdupois)	=28.35 grams.	
1 ounce (troy)	=31.1 grams.	

TABLE III. DENSITIES OF SOME SUBSTANCES

Acetic acid *	1.053	Magnesium	1.75
Alcohol (ethyl)*	0.794	Marble	2.7
Aluminum	2.67	Mercury (at 0° C.)	13.596
Brass	8.3	Nickel	8.57
Carbolic acid	0.95	Nitric acid (conc.)*	1.42
Carbon (charcoal)	1.6	Oil (cottonseed)	0.926
Carbon (gas)	1.8	Oil (linseed)	0.942
Carbon disulphide *	1.27	Oil (olive)	0.918
Chloroform *	1.5	Oil (turpentine)	0.873
Clay	1.9	Phosphorus (yellow)	1.83
Coal (anthracite)	1.26 to 1.8	Platinum	21.5
Coal (soft)	1.2 to 1.5	Potassium	0.865
Copper	8.9	Sand (dry)	1.4
Cork	0.24	Silver	10.57
Diamond	3.53	Sodium	0.97
Ether *	0.72	Sulphur	2.03
Gasoline	0.67	Sulphuric acid (conc.)	1.854
Glass	2.6 to 3.6	Tin	7.29
Glycerine	1.27	Water at 0° C.	0.999
Gold	19.3	Water at 4° C.	1.000
Hydrochloric acid (conc.)*	1.22	Water at 100° C.	0.958
Ice	0.918	Water (sea)	1.026
Iodine	4.95	Wood (hickory, dry)	1.00
Iron	7.8	Wood (maple, dry)	0.64
Kerosene	0.79	Wood (white oak, dry)	0.86
Lead	11.35	Wood (white pine, dry)	0.42
Limestone	3.2	Zinc	6.9 to 7.2

*At 15°C.

TABLE IV. PERCENTAGE COMPOSITION OF FOOD MATERIALS

Food	Water	Proteid	Fat	Carbo-hydrates	Min-erals	Value of 1 Lb. in Large Calories
Apples	83.2	0.2	0.4	15.9	0.3	315
Beans (dry)	12.6	23.1	2.0	59.2	3.1	1,615
Beef (round)	68.2	20.5	10.1	....	1.2	805
Beef (sirloin)	60.0	18.5	20.5	....	1.0	1,200
Bread	35.3	9.2	1.3	53.1	1.1	1,215
Butter	10.5	1.0	85.0	0.5	3.0	3,410
Candy	3.0	....	....	96.5	0.5	1,785
Cheese	30.2	28.3	35.5	1.8	4.2	2,070
Chicken	72.2	24.4	2.0	....	1.4	540
Cornmeal	15.0	9.2	3.8	70.6	1.4	1,645
Eggs	73.8	14.9	10.5	....	0.8	721
Fish (salmon)	63.6	21.6	13.4	....	1.4	965
Milk	87.0	3.6	4.0	4.7	0.7	325
Mutton (leg)	61.8	18.3	19.0	....	0.9	1,140
Oatmeal	7.6	15.1	7.1	68.2	2.0	1,850
Oysters	87.1	6.0	1.2	3.7	2.0	230
Peanuts	9.2	25.8	38.6	24.4	2.0	2,560
Pork (fresh)	52.0	16.9	30.1	....	1.0	1,600
Potatoes (white)	78.3	2.2	0.1	18.4	1.0	385
Potatoes (sweet)	69.0	1.3	0.6	28.3	0.8	480
Rice	12.0	8.0	2.0	77.0	1.0	1,700
Strawberries	90.4	1.0	0.6	7.4	0.6	180
Sugar	....	....	....	100.0	...	1,850
Tomatoes	95.3	0.8	0.4	3.2	0.3	80
Walnuts (English)	2.8	16.7	64.4	14.8	1.3	3,305
Wheat	10.6	12.2	1.7	73.7	1.8	1,750

GLOSSARY

abdomen (ăb-dō′mĕn)
acetic (ȧ-sēt′ic)
acetylene (ȧ-sĕt′ĭ-lēn)
adenoids (ăd′ē-noid)
aëronaut (ā′ĕr-ō-naut)
aëroplane (ā′ĕr-ō-plān)
albumin (ăl-bū′mĭn)
alga (ăl′gȧ)
alluvial (ăl-lū′vĭ-ăl)
aluminum (ăl-ūm′ĭ-nŭm)
ameba (ȧ-mē′bă)
andiron (ănd′ī′ĕrn)
anemia (ȧ-nē′mĭ-ă)
aniline (ăn′ĭ-lĭn)
antitoxin (ăn′tĭ-tŏx′ĭn)
aorta (ā-ôr′tă)
aqueduct (ăk′wē-dŭkt)
aqueous (āk′wē-ŭs)
armature (är′mä-tiūr)
arsenate (är′sĕn-āt)
artery (är′tĕr-ĭ)
asbestos (ăs-bĕs′tŏs)
assimilation (ăs-ĭm′ĭ-lā′shŭn)
auricle (ör′ĭ-kl)
avoirdupois (ăv′ēr-dŭ-poiz′)
axil (ăx′ĭl)

bacilli (bȧ-sĭl′ī)
bacteria (băk-tē′rĭ-ȧ)
barometer (bȧ-rŏm′ē-tēr)
biceps (bī′sĕps)
bicuspid (bī-kŭs′pĭd)
bisulphite (bī-sŭl′fīt)
bituminous (bĭ-tūm′ĭ-nŭs)
bronchi (brŏn′kī)
bronchial (brŏn′kĭ-ăl)
buoyant (boi′ănt)

cactus (kăk′tŭs)
caisson (kā′sŏn)
calcium (kăl′sĭ-ŭm)
calorie (kăl′ō-rĭ)
calorimeter (kăl′ō-rĭm′ē-tēr)
calyx (kā′lĭx)
canine (kā′nīn)
cañon (kăn′yŏn)
capillary (kăp′ĭl-ā′rĭ)
carat (kăr′ăt)
carbohydrate (kär′bō-hȳ′drāt)
carburetor (kär′bū-rĕt′ĕr)
carnivorous (kär-nĭv′ō-rŭs)
cartilage (kär′tĭ-lāj)
casein (kā′sē-ĭn)
Cassiopeia (kăs′ĭ-ō-pē′yä)
cellulose (sĕl′ū-lōs)
Celsius (sĕl′sĭ-ŭs)
centigrade (sĕn′tĭ-grād)
centimeter (sĕn′tĭ-mē′tēr)
centrifugal (sĕn-trĭf′ū-gal)
cerebellum (sĕr′ē-bĕl′ŭm)
cerebrum (sĕr′ē-brŭm)
chandelier (shăn-dĕ-lēr′)
chloride (klō′rĭd)
chlorine (klō′rĭn)

chlorophyll	(klō′rō-fĭl)
choroid	(kō′roid)
chrysalis	(krĭs′ă-lĭs)
chyle	(kīl)
chyme	(kīm)
cilia	(sĭl′ĭ-ä)
cinquefoil	(sĭŋk′foil)
circuit	(sûr′kĭt)
cirrus	(sĭr′ŭs)
citric	(sĭt′rĭk)
coagulate	(kō-ăg′ū-lāt)
cochineal	(kŏch′ĭ-nēl)
cochlea	(kŏk′lē-ä)
cocoon	(kō-ko͞on′)
cohesion	(kō-hē′shŭn)
composite	(kŏm-pŏz′ĭt)
conduit	(kŏn′dĭt)
conifer	(kō′nĭ-fẽr)
constellation	(kŏn′stĕl-ā′shŭn)
contagious	(kŏn-tā′jŭs)
convection	(kŏn-vĕk′shŭn)
cornea	(kŏr′nē-ă)
corolla	(kō-rŏl′ȧ)
corpuscle	(kôr′pŭs’l)
cotyledon	(kŏt′ĭ-lē′dŭn)
creosote	(krē′ō-sōt)
crescent	(krĕs′ent)
croquette	(krō-kĕt′)
crustacea	(krŭs-tā′shē-ȧ)
crystalline	(krĭs′tăl-ĭn)
cumulus	(kū′mū-lŭs)
cuticle	(kiūt′ĭ-kl)
cyclone	(sī′klōn)
deciduous	(dē-sĭd′ū-ŭs)
decimeter	(dĕs′ĭ-mē′tẽr)
dentine	(dĕn′tĭn)
diameter	(dī-ăm′ē-tẽr)
diaphragm	(dī′ă-frăm)
dietetics	(dī-ĕ-tĕt′ĭks)
dioxide	(dī-ŏx′ĭd)
diphtheria	(dĭf-thē′rĭ-ȧ)
dirigible	(dĭr′ĭ-jĭb’l)
dynamo	(dī′nȧ-mō)
eclipse	(ē-klĭps′)
effervesce	(ĕf-ẽr-vĕs′)
electrolysis	(ē-lĕk-trŏl′ĭ-sĭs)
electron	(ē-lĕk′trŏn)
embryo	(ĕm′brĭ-ō)
emulsion	(ē-mŭl′shŭn)
enamel	(ĕn-ăm′ĕl)
environment	(ĕn-vīr′ŭn-mĕnt)
epidemic	(ĕp′ĭ-dĕm′ĭk)
epidermis	(ĕp′ĭ-dẽr′mĭs)
epiglottis	(ĕp′ĭ-glŏt′ĭs)
esophagus	(ē-sŏf′ȧ-gŭs)
Eustachian	(yūs-tāk′ĭ-ăn)
experiment	(ĕks-pĕr′ĭ-mĕnt)
Faraday	(făr′ă-dā)
fibrinogen	(fī-brĭn′ō-jĕn)
filings	(fīl′ĭŋgs)
formaldehyde	(fôr-măl′dē-hīd)
fossil	(fŏs′ĭl)
fungi	(fŭn′jī)
fungus	(fŭŋ′gŭs)
galaxy	(găl′ăks-ĭ)
galena	(gä-lē′nȧ)
Galileo	(găl′ĭ-lē′ō)
Galvani	(gäl′vä′nē)
galvanize	(găl′văn-īz)
gelatine	(jĕl′ă-tĭn)
germicide	(jẽrm′ĭ-sīd)
glacier	(glā′shẽr)
glycerine	(glĭs′ẽr-ĭn)

hematite (hĕm′ȧ-tīt)
hemoglobin (hē′mō-glō′bĭn)
hemorrhage (hĕm′ō-rāj)
hepatica (hē-păt′ĭ-kȧ)
hibernate (hī′bẽr-nāt)
horizon (hō-rī′zŏn)
hydrochloric (hī′drō-klōr′ĭk)
hydrogen (hī′drō-gĕn)
hydroxide (hī-drŏx′ĭd)
hygiene (hī′jĭ-ēn)

igloo (ĭg′lo͞o)
immune (ĭ-mūn′)
incandescent (ĭn′kăn-dĕs′ĕnt)
incisor (ĭn-sī′sẽr)
incubation (ĭn′kū-bā′shŭn)
inertia (ĭn-ẽr′shĭ-ȧ)
inoculation (ĭn-ŏk′ū-lā′shŭn)
insecticide (ĭn-sekt′ĭ-sīd)
insulator (ĭn′sū-lā′tẽr)
intestine (ĭn-tĕs′tĭn)
iris (ī′rĭs)
isinglass (ī′sĭŋ-glȧs)
isobar (ī′sō-bär)
isolation (ī′sō-lā′shŭn)
isotherm (ī′sō-thẽrm)

kilometer (kĭl′ō-mē′tẽr)
kilowatt (kĭl′ō-wăt)

lactic (lăk′tĭk)
la grippe (lä grĭp′)
larvae (lär′vē)
larynx (lăr′ĭŋks)
leaven (lĕv′ĕn)
legume (lĕg′yūm)
Leyden (lī′dĕn)
lichen (lī′kĕn)
ligament (lĭg′ă-mĕnt)
llama (läh′mä)
lunar (lū′nȧr)
lymph (lĭmf)

magnesium (măg-nēs′ĭ-ŭm)
manganese (măn′găn-ēs)
mercerize (mẽr′cẽr-īz)
meteor (mē′tē-ŏr)
microbe (mī′krōb)
micrococci (mī′krō-kŏk′ī)
millimeter (mĭl′ĭ-mē′tẽr)
monsoon (mŏn-soon′)
mucous (mū′kŭs)
muriatic (mūr′ĭ-ăt′ĭk)

neutralize (nū′trăl-īz)
nicotine (nĭk′ō-tĭn)
nimbus (nĭm′bŭs)
nitrogen (nī′trō-jĕn)
nitrogenous (nī-trŏj′ĕ-nŭs)
nomadic (nō-măd′ĭk)
nucleus (nū′klē-ŭs)

octopus (ŏk′tō-pŭs)
olfactory (ŏl-făk′tō-rĭ)
omnivorous (ŏm-nĭv′ō-rŭs)
opaque (ō-pāk′)
organism (ŏr′găn-ĭsm)
Orion (ō-rī′ŏn)
oxide (ŏx′ĭd)
oxidize (ŏx′ĭd-īz)
oxyhemoglobin (ŏx′ĭ-hē′mō-glōb′ĭn)

palate (păl′āt)
pancreas (păn′krē-ăs)
pancreatic (păn′krē-ăt′ik)
paraffin (păr′ă-fĭn)
Pasteur (pȧs-tûr′)
pendulum (pĕn′dū-lŭm)

penumbra	(pē-nŭm′brȧ)
per capita	(pẽr kăp′ĭ-tȧ)
perennial	(pĕr-ĕn′ĭ-ăl)
periscope	(pĕr′ĭ-skōp)
permanganate	(pẽr-măŋ′găn-āt)
peroxide	(pẽr-ŏx′ĭd)
petiole	(pĕt′ĭ-ōl)
petrify	(pĕt′rĭ-fī)
pharynx	(făr-ĭŋks)
phenomena	(fē-nŏm′ē-nȧ)
phosphate	(fŏs′fāt)
phosphorescence	(fŏs′fōr-ĕs′ĕns)
phosphorus	(fŏs′fōr-ŭs)
Pisa	(pē′zä)
plasma	(plăz′mä)
pleurisy	(plū′rĭ-sĭ)
pleurococcus	(plū′rō-kŏk′ŭs)
plumule	(plo͞o′mūl)
pneumatic	(nū-măt′ik)
Polaris	(pō-lā′rĭs)
polyp	(pŏl′ĭp)
posterior	(pŏs′tē′rĭ-ẽr)
potassium	(pō-tăs′ĭ-ŭm)
proboscis	(prō-bŏs′ĭs)
proteid	(prō′tē-ĭd)
protoplasm	(prō′tō-plăzm)
ptyalin	(tī′ä-lĭn)
pulmonary	(pŭl′mō-nā-rĭ)
pylorus	(pī-lō′rŭs)
pyrometer	(pī-rŏm′ē-tẽr)
python	(pī′thŏn)
quarantine	(kwôr′ăn-tēn)
radiation	(rā′dĭ-ā′shŭn)
refrigerator	(rē-frĭj′ẽr-ā-tẽr)
reservoir	(rĕs′ẽr-vwôr)
respiration	(rĕs′pĭ-rā′shŭn)
retina	(rĕt′ĭ-nä)
retort	(rē-tôrt′)
rotate	(rō′tāt)
sal ammoniac	(săl ăm-ōn′ĭ-ăk)
salicylic	(săl′ĭ-sĭl′ĭk)
saliva	(săl-ī′vȧ)
saprophyte	(săp′rō-fīt)
saturate	(săt′ū-rāt)
sautéing	(sō-tā′ing)
sclerotic	(sklẽr-ŏt′ĭk)
sebaceous	(sē-bā′shŭs)
secrete	(sē-krēt′)
sepal	(sē′păl)
silica	(sĭl′ĭ-kȧ)
Sirius	(sĭ′rĭ-ŭs)
slaked	(slākd)
sodium	(sō′dĭ-ŭm)
solution	(sō-lū′shŭn)
species	(spē′shēz)
spectrum	(spĕk′trŭm)
spinach	(spĭn′ĭj)
spontaneous	(spŏn-tā′nē-ŭs)
stamen	(stā′mĕn)
stipule	(stĭp′ūl)
stomata	(stō′mä-tä)
stratified	(străt′ĭ-fīd)
stratus	(strā′tŭs)
sulphuric	(sŭl-fūr′ĭk)
tangent	(tăn′jĕnt)
tantalum	(tăn′tă-lŭm)
tartaric	(tär-tär′ik)
Taurus	(täw′rŭs)
temperature	(tĕm′pẽr-ȧ-tûr)
thermometer	(thẽr-mŏm′ē-tẽr)
tornado	(tŏr-nā′dō)
Torricelli	(tŏr-rĭ-tchĕl′ē)
tourniquet	(tŭr′nĭ-kĕt)
trachea	(trāk′ē-ä)

tractor	(trăk′tŏr)	**vaccination**	(văk′sĭ-nā′shŭn)
translucent	(trăns-lūs′ĕnt)	**vacuum**	(văk′ū-ŭm)
trichinae	(trĭ-kīn′ē)	**ventricle**	(vĕn′trĭ-kl)
tubercle	(tū′bĕr-kl)	**vertebra**	(vĕr′tē-brȧ)
tuberculosis	(tū-bûr′kū-lōs′ĭs)	**villi**	(vĭl′ī)
tungsten	(tŭng′stn)	**vitamines**	(vīt′ă-mĭns)
turbine	(tŭr′bĭn)	**vitreous**	(vĭt′rē-ŭs)
turpentine	(tûr′pĕn-tīn)	**vitriol**	(vĭt′rĭ-ŏl)
tympanic	(tĭm-păn′ĭk)	**Volta**	(vôl′tä)
Uranus	(yū′rā-nŭs)	**zenith**	(zē′nĭth)
urea	(yū-rē′ä)	**zodiac**	(zō′dĭ-ăk)
uric	(yūr′ĭk)	**zoölogy**	(zō-ŏl′ō-jĭ)

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