JUNIOR SCIENCE

HESSLER

BOOK ONE

JUNIOR SCIENCE

BY

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BOOK ONE

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

J. C. H.

Decatur, Illinois
December, 1919

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PART I

INTRODUCTION

JUNIOR SCIENCE

CHAPTER I

BEGINNINGS OF SCIENCE

1. Some Questions to Think About. — Did you ever wonder why water runs down hill and not upward? Or why a kite flies, why trees shed their leaves, why plants produce seeds, why dew is formed, why milk sours, why yeast raises bread, why the moon grows and wanes, why the sun gives off heat? Did you ever wonder what fire, sound, light, and electricity are, why we have eclipses of the sun and the moon, what lightning is, how soil is formed, why grass is green, how we are nourished by our food?

There seems to be no end to the questions you can ask yourself regarding the objects you see and what happens to them. So far as we know, men have always wondered about the earth and the sky; they seem always to have tried to find the reason for the many things that happen in this world of ours. To be sure, the answers they first gave would probably sound very foolish to us, but gradually men were able to give well-thought-out and common-sense answers to questions regarding nature; their answers are what we study in Science.

2. Old and New Answers. — You have probably read about some of the strange ideas of men of past times. If you had asked, a few centuries ago, what causes an eclipse of the sun, you might have been told that a great beast or spirit moves across the sky and blots out the sun; afterwards men saw that an eclipse of the sun never occurs except at the time of "new moon," that is, when the moon is between the sun and the earth (cf. § 92). So they decided that it is the moon, not a beast or spirit, that sometimes comes exactly between us and the sun.

We have all read how men made fun of Columbus because he believed that the earth is a sphere; the people of his day felt certain that if the earth were round, the people on the other side of it must be standing heads down. Since the days of Columbus we have become used to the idea that we are living on a great, round ball; we see that "down" means toward the earth's center, while "up" means away from it; we are not afraid that we may become dizzy from standing topsy turvy, nor that the earth will in some way lose its grip upon us and let us drop off into space.

Franklin helped us to understand another mystery of nature: the lightning. No doubt many people thought him foolish, on that June day in 1752, to send up a kite (Fig. 1) when a thunderstorm was coming on. But men since that time have honored Franklin, because his experiment showed that lightning is only a great electric spark. So we might go on with stories of how common-sense ideas of nature grew up among men.

3. What is Science? — Columbus and Franklin and other great discoverers and inventors were able to do big things for the world because they learned early to notice common things and to think clearly about them.

If we wish really to know ourselves, our homes, our world, we must do the same. To learn science we, too, must observe the objects about us and the changes that take place in them. We must see them not only with sharp eyes, but with minds sharpened to question why and to work out a sensible answer. We call a change in an object, such as a fire, an eclipse, or the falling of a stone, a **phenomenon**; the plural is **phenomena**.

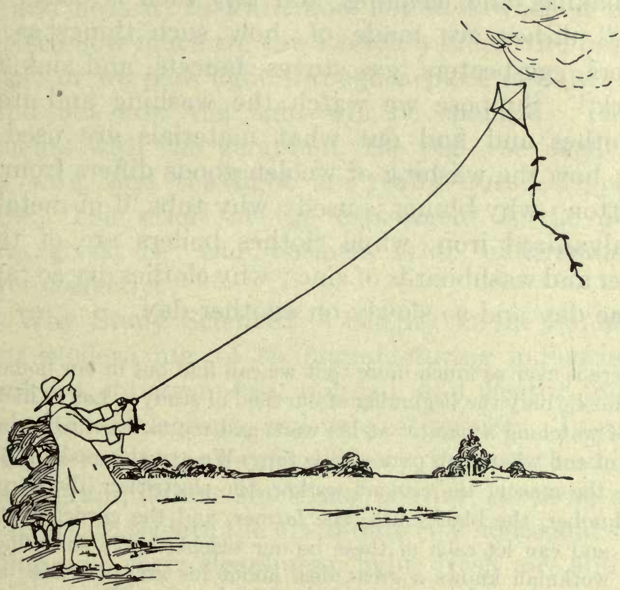

FIG. 1. — Franklin raising his kite.

Think of all we could learn if we would keep our eyes open at home and on our way to and from school! We do not even need to go into the country to learn about trees, shrubs, and weeds, about insects, birds, rocks, clouds, and the wind, or how the ground is washed by the rain. Suppose we really " look into " the kitchen and find out what materials and tools are used in cooking, baking, and cleaning, and *why* each is used; what " tin " dishes are made of; how such things as can-openers, egg-beaters, gas stoves, faucets, and sink traps " work." Suppose we watch the washing and ironing of clothes and find out what materials are used and why; how the washing of woolen goods differs from that of cotton; why bluing is used; why tubs, if of metal, are of galvanized iron, while clothes boilers are of tinned copper and washboards of zinc; why clothes dry so rapidly on one day and so slowly on another day.

There is ever so much more that we can find out in our homes, but let home be only the beginning of our field of study. Let us find some way of watching a painter at his work and try to learn what paint is made of and what each part of it is for. We can also make it a point to see the mason, the cement worker, the electrician, the carpenter, the plumber, the blacksmith, the farmer, and the gardener at their work, and can let each of these be our teacher. We shall find that every workman knows a great deal about his art, or trade; after a while we may be able to learn the *scientific* reasons, that is, the real, common-sense reasons, for what he does.

4. **What is an Experiment?** — You have already seen how much we can learn if we observe common objects and phenomena closely and think clearly about them. In science we also study **by experiment**, that is, we put substances, or plants, or animals, under certain special conditions, so as to find out what happens to them.

Thus, we put a geranium in a dark room, so as to learn how it will grow without light; or we feed different kinds of food to a pig, in order to find out which will fatten it the most rapidly; or we put some sugar into a dish and heat it, to learn how hot it is when it chars; or we see how much we can stretch a brass wire before it breaks; or we pass light through a piece of thick glass, to find out how the light will be changed. The experiments with the geranium, the pig, the sugar, the brass wire, and the light are really questions put to nature. The result of the experiment is the answer nature gives us. Our business is to understand the answer correctly.

5. **Why Study Science?** — Science is the foundation of our modern life, of its manufacturing industries, its agriculture, its steamship, railroad, and electric lines, of its telephone, telegraph, and wireless service. To science the farm owes its modern machinery, its better and larger crops of grain, its fine stock and poultry, its more abundant fruit; to science the up-to-date city house and school building owe their cleanliness, light, fresh air, and conveniences. We should study science, then, not merely to "observe phenomena," but to understand the ways of the community in which we live.

We may think that the comforts we now enjoy have always been here; our great-grandparents, if they were living, could tell a different story. They would tell of a time when such common things as glass and soap were expensive and not easy to get, when houses had no running water, when it was hard to provide heat and light, when cloth was woven at home, and when food canned in " tin " was unknown.

A little further back in time, even the wealthy could not have the commonest of modern comforts. Their houses were full of drafts and were dark and dirty; news came slowly; books were scarce and expensive; traveling was hard and dangerous. The farming of those days was very difficult, for farm tools were crude and farm machinery was unknown (Fig. 2). When we compare this condition of things with our modern ways, with the rapid transportation of people, freight, and news, with cheap books and free libraries, with the care of public health, with scientific agriculture, we get some idea of what science means to the world.

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FIG. 2. — How an Egyptian does his plowing.

But all this study of science will mean little to us unless we apply it to ourselves and to our way of living. We must also learn about these bodies of ours, so that we may know what things will bring us health and power and what will make us weak and useless. No amount of knowledge will help us much, if we do not have proper food and clothing, vigorous exercise, abundant sleep, and strong habits of cleanliness and good conduct. Science shows us, as nothing else can, how to have "a sound mind in a sound body"; we should study it to learn how to live long and useful lives.

6. **What We Have Learned.** — Science begins with common-sense answers to questions regarding nature.

Nature includes objects and phenomena.

Phenomena are changes, or happenings, in objects.

The objects and phenomena we study are: (1) those of nature; (2) those of home industries and the common occupations; (3) those of experiments.

To experiment is to question nature with a purpose.

7. **Exercises.** — 1. What are the proofs that the earth is round, and not flat? Who first sailed around it?

2. What is the diameter of the earth? Of the moon? How far is the moon from the earth? (Consult Chapter XI.)

3. Make a list of some of the great inventions, with their dates and the names of the inventors.

4. Name some of the important scientific discoveries of the last century.

5. Make a list of the tools and apparatus used in your kitchen, for cooking, baking, and cleaning.

6. Make a list of the different substances used in your kitchen and laundry.

7. Give the names and uses of the most important tools and machines used by carpenters; by gardeners; by up-to-date farmers.

8. Make a list of the different kinds of materials used in the building of a house.

9. Name the different methods used for carrying (and lifting) passengers and for sending freight and news.

PART II

THE ATMOSPHERE AND ITS RELATION TO MAN

CHAPTER II

AIR

8. What is Air Like? — One of the hard things for man to understand was the air. It fanned his cheek, turned his windmills, and drove his ships, but he could not find out much about it until a little over a hundred years ago. We can see why this was true. Air is invisible to us, except when we see its quivering motion over a hot stove or on a hot day in summer. What man could not see, he found it hard to handle and to understand. Thus, when he used up some of the air, he did not know that he had done so, because more air rushed in from all sides to fill the empty space. Observe how the surrounding water rushes in when we dip some of it out of a tub or pail; air would rush in in the same way. When men grew used to this idea, they did not try to study all the air at once, but they took vessels of air, such as tanks or bottles, stoppered them in some way, and then studied this *enclosed portion* of air by itself. In this way they learned a great deal more about the air.

9. Does Air Take Up Room? — Have you ever thought, as you filled a glass with water from a pitcher or faucet, whether anything was flowing out of the glass while the water flowed in? Have you ever poured water out of a small-mouth bottle? Try it and see whether anything happens which shows that something goes into the bottle as water flows out.

Suppose we push a glass, held upside down, into a deep dish of water; does the water rise up to fill the glass? Why?

Fig. 3. — Will the water run into this bottle in a stream, or by spurts?

Let us perform the following **experiment** (Fig. 3):

Put a funnel stem loosely into a small-mouth bottle, such as a ketchup or vinegar bottle, and quickly fill the funnel with water. Does the water run in as a stream, or by spurts? Now fit the funnel stem tightly into the mouth of the bottle. You can use a one-hole stopper for this purpose, or you can wind around the stem a strip of wet muslin, about an inch wide, until the joint is tight. Finally, fill the funnel rapidly with water. How does the water run in now? Why?

Carry out another **experiment** (Fig. 4):

Fill a bottle with water and close the mouth of the bottle tightly with your hand; then turn the bottle upside down in a pan of water. If the mouth of the bottle is under water, you can remove your hand without the water falling out. If you then blow air into the bottle through a bent tube, you can collect the air in the bottle; for as the air bubbles rise into the bottle, they push the water out. In this way we can collect a gas "over water."

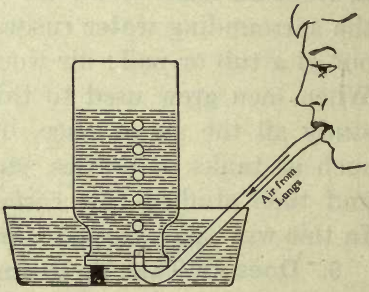


Fig. 4. — Collecting the air of your breath "over water."

From these experiments we can see that air takes up room, or occupies space, just as water does. If we want to pour water into a vessel, we must give the air a way of getting out; if we want to pour the water out of a vessel, we must let the air go in to take its place.

10. Does Air Have Weight? — When we have grown used to the idea that air fills vessels that we think of as "empty," we are ready to believe that air has weight. How can we find out if this is true?

If we wish to get the weight of a cupful of water (Fig. 5), we first weigh the "empty" cup; then we fill the cup with water and get the weight of the cup and water together. By subtracting the weight of the cup from the weight of the cup and water, we get the weight of the water alone. We write down the results in this way:

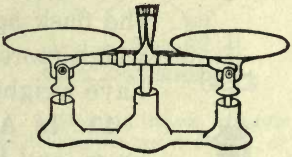


FIG. 5. — Scales for laboratory weighing.

Weight of cup and water = ... ounces.
Weight of cup alone = ... ounces.
Weight of water alone = ... ounces.

You may have seen this method used when you have bought butter in a crock or honey in a pail. The weight of the butter or honey alone is spoken of as the "net" weight, while the weight of the material and the container together is the "gross" weight.

When we weigh an "empty" cup, crock, or pail, we make no account of the air which it contains. But when we try to find out whether or not air has weight, we must first get the weight of a vessel which is really empty, that is, without even air in it. One way to do this is to attach the vessel, such as a flask (Fig. 6), by means of rubber tubing, to an air pump and then to remove all the air we possibly can. Then, while the flask is still attached to the air pump, we close the stopper in the glass tubing. We can now weigh the flask really empty; then we open the stopper, let air enter, and weigh the flask again. The flask and air together weigh more than the empty flask, so air must have weight.

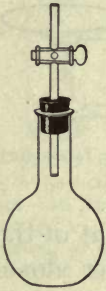


FIG. 6. — A flask from which we can remove the air.

11. Is Air Matter? — Since air takes up room and has weight, it is a form of matter, or a substance, just as water and sugar are substances.

One cubic foot of air ordinarily weighs about $1\frac{1}{4}$ ounces; how can we find out how much the air of your schoolroom weighs?

Suppose that the room is 24 feet long, 20 feet wide, and 10 feet high. The volume, in cubic feet, will be 24×20×10, or 4800 cubic feet. Since 1 cubic foot of air weighs about $1\frac{1}{4}$ ounces, the air of the room must weigh about $4800 \times 1\frac{1}{4}$, or 6000 ounces. To get the weight in pounds we divide 6000 ounces by 16. So the schoolroom holds about 375 pounds of air.

Measure the living-room of your house and find the volume and weight of the air it holds.

12. How Do Heating and Cooling Affect Air? — Suppose we set an "empty" flask upside down in a shallow dish of water (Fig. 7) and carefully heat the flask with a burner, or pour hot water over it; what happens? We can also try warming the flask by means of our hands.

As the air in the flask is warmed, it expands, so that its volume is too great for the flask, and some of it escapes through the water. If we pour cold water over a second flask of air, the air contracts in volume. Since the outside air cannot get into the flask, water is forced up instead. Think of some cases you have seen in which air expands and contracts.

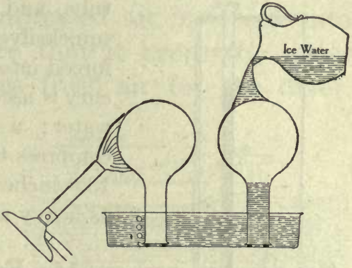


FIG. 7. — Heating the air expands it, while cooling makes it shrink, or contract.

13. Can Air Be Compressed? — We saw in the last section that if air is cooled, it shrinks in volume. This is the same as saying that it occupies a smaller space. We can also force air to occupy a smaller space if we increase the pressure upon it. Thus, a **popgun** is a tube having one end closed by a cork and the other end closed by a piston. As we force the piston into the tube, we compress the air inside. Finally its pressure becomes great enough to force the cork out with a "pop."

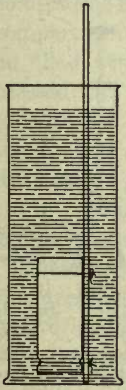


FIG. 8. — The air in the vial is compressed by the pressure of the water in the jar.

We can see how the pressure of water compresses air, if we put a glass of air, upside down, under water. The deeper the water, the smaller the volume of the air will become. We can see this better if we fasten a glass vial or flask (Fig. 8) to a rod of glass or metal and put it into a deep vessel of water.

The apparatus of Fig. 9 also shows how, by increasing the pressure, we decrease the volume of a gas. If we begin with a certain volume of air in the closed, shorter arm of the bent tube, and add portions of water or mercury (quicksilver) to the longer arm, the air will be forced into a smaller and smaller space. Mercury is used because it is so much heavier than water; a column of mercury 1 inch high will compress the air as much as a column of water 13.6 inches high, because mercury is 13.6 times as heavy as water.

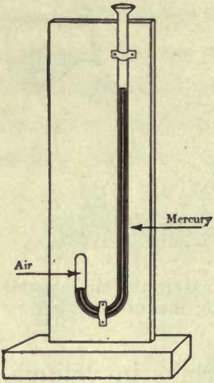


FIG. 9. — The air in the closed arm of the tube is compressed by the weight of the mercury in the longer arm.

14. For What Can Compressed Air Be Used?

— Have you ever thought of some of the important uses man has made of compressed air? To pack air into a smaller space we commonly use a **compression pump.** The bicycle and automobile pumps (Fig. 10) are the most common of the compression pumps; they are used to crowd a great deal of air into the tire. The compressed air, as well as the rubber tire, acts as an elastic cushion and protects the car from jolts. We can also use a bicycle pump to crowd air into a basketball or football.

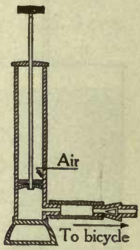


FIG. 10. — The bicycle pump compresses a great deal of air into the tire.

How do you suppose men lay the foundations of bridges in the bottom of a river, or do other work under water? We learned in the last section that if a vessel of air is pushed, mouth downward, under water, the pressure of the water compresses the air. If we are to keep the vessel *entirely full* of air, we must force a supply of air into the vessel. This is what is done in the **diving bell** (Fig. 11), in which men work *under water.* Compressed air is forced into the "bell" at such a pressure that it keeps the water from rushing in and furnishes fresh air for the diver. The air is kept flowing, so that it bubbles out around the edge of the bell.

A **caisson** is a diving bell which men use in placing the foundations of large buildings, when water rushes into the excavations (cf. § 133).

You would not think that a **submarine boat** is a device for using compressed air, yet this is so. It has compartments, or spaces, which can be filled with either water or compressed air. When water is allowed to push the air out of these spaces, the boat as a whole is heavier and sinks under water; when compressed air is used to force the water out of the spaces, the boat rises to the surface. The compressed air apparatus also keeps the sailors supplied with air for breathing.

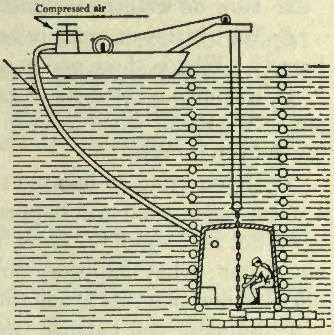


FIG. 11. — Air is kept flowing through the bell, so that the workman can lay a foundation upon the bottom.

There are many other inventions that use compressed air. Have you ever heard the rapid pounding of the **pneumatic hammer** on a steel bridge or building? It is used to rivet together large pieces of steel, and increases greatly the speed with which steel structures can be built.

The **air brake**, invented by George Westinghouse, is another important piece of apparatus that uses compressed air. It sets the brakes against the wheels of railroad cars and stops the train. The air is compressed and stored in the locomotive.

A **sand blast** is a current of air set free from pressure and carrying sharp sand with great speed. It is used to roughen the surface of glass, producing "ground glass." The sand particles chip the surface. The wind of a sandy desert is a natural sand blast; it not only roughens window glass, but wears away the surface of rocks (cf. § 151).

15. Exercises. — 1. Is it easy to get ketchup out of a small-mouth bottle? How do you do it? Why?

2. How do we get machine oil out of its can? Why?

3. Why is there a vent, or hole, near the top of a vinegar or kerosene barrel? Why is there one in a steam radiator?

4. Examine a kerosene or gasoline can. How does the liquid come out of the spout when the top of the can is closed? How, when the top is open? Why?

5. If you bring an inflated toy balloon from the cold, outer air into a warm room, what will happen to it? Why?

6. Set an "empty" glass, mouth down, into a saucer or basin of hot water; what happens, and why? Have you ever noticed any phenomenon like this in the rinsing of dishes with hot water?

7. Suppose you balance two dry, "empty" flasks or tomato cans on the two pans of the scales, and then heat one of the flasks, or cans, and put it back on the scales; what will happen, and why?

8. Do you think the gas in an inflated toy balloon is under pressure? Why?

9. Suppose that the inside space of a basketball holds $\frac{1}{5}$ of a cubic foot. How much does this volume of air weigh? Suppose that three times this volume of air is packed into the ball, what does the air in the ball weigh?

CHAPTER III

PRESSURE OF THE ATMOSPHERE

16. Does the Atmosphere Have Pressure? — If we were living at the bottom of an ocean of water, the weight of the water above us would cause a great pressure upon our bodies and upon all the objects in the water. Is the same true of an ocean of air? Let us perform a few experiments to find out.

(*a*) Look back at § 9, Fig. 4. Why does not the water fall out of the bottle that is set, upside down, in the pan of water?

(*b*) Fill a drinking glass or a large-mouth bottle completely with water, close the mouth of the vessel entirely with a wet piece of cardboard or stiff paper; a stiff envelope will do. Now hold the covering in place with your hand, turn the vessel upside down, and remove your hand. Why does not the water fall out? In what direction does the atmosphere exert pressure in this case?

(*c*) Hold a clean glass vial or other small-mouth bottle between your lips and remove as much as possible of the air by suction. Then, before the air reënters, close the mouth of the vial or bottle with your tongue or the inside of your lips or cheek. What evidence do you get of the pressure of the atmosphere? What happens when you pull the bottle away?

(*d*) Over the mouth of a clay pipe tie tightly a piece of thin sheet rubber and then, by suction through the stem, remove some of the air. Explain what happens. Does this show anything of air pressure?

If your laboratory has an air pump, perform the same experiment as shown in Fig. 12.

(*e*) Blow a paper bag full of air.

The pressure of the air inside and outside the bag will then be the same. Now make the mouth of the bag small and remove the air by suction. Why does the bag collapse?

Can you tell why you can drink lemonade or soda water through a straw?

Do any of these experiments show that the atmosphere's pressure pushes upwards? Downwards? Sidewise?

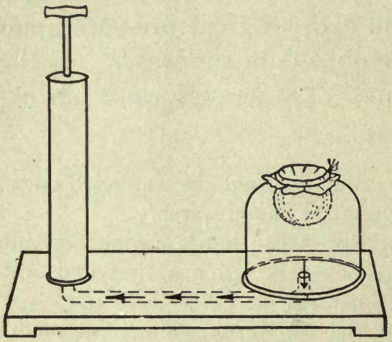


FIG. 12. — As the air is removed from the bell-shaped jar by the air pump, the pressure of the outside air forces the sheet rubber into the jar.

17. Can the Atmosphere's Pressure Be Measured? — Suppose that you had a tube or pipe 10, 20, 30, or 40 feet long and that your lungs were strong enough, could you, by suction, raise a liquid, such as water or lemonade, up to your mouth? Your lungs are not strong enough, but you could use a suction, or lift, pump for the purpose. This is just what we usually do when we pump water from a well or cistern.

Nearly 300 years ago a landowner in Italy was trying to raise water from a well. No pump he could get would raise the water more than about 34 feet. He asked the scientist Galileo (pronounced Găl-ĭ-lē′ō) to tell him why; but Galileo did not know. Torricelli (pronounced Tŏr-rĭ-tchĕll′y), a pupil of Galileo, gave the answer in 1643. He believed that water rose into a pump because the atmosphere's pressure forced it up. He said to himself that if the pressure of the atmosphere was just great enough to push up a column of water 34 feet, it could not push up a heavier liquid to so great a height. He decided to try mercury, which is 13.6 times as heavy as water. If Torricelli's guess was correct, the air ought to be able to hold up a column of mercury only 34 ÷ 13.6, or about 2.5 feet high. This would be about 30 inches.

18. The Barometer. — To test his guess, Torricelli used a straight glass tube about 3 feet long (Fig. 13) and closed at one end. He filled the tube entirely with mercury, closed the open end with his finger, and turned the tube upside down, so that its open end was below the surface of some mercury in a dish. When he removed his finger, some of the mercury ran down into the dish, but not all. It stopped when the column was about 30 inches high. So Torricelli's guess was correct. The space above the mercury did not contain air; we call it a **vacuum**, which means *empty space*. Torricelli's apparatus is called a **barometer**.

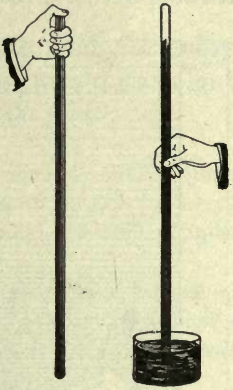


FIG. 13. — A barometer. The pressure of the atmosphere holds up the column of mercury.

If the opening of a barometer tube has an area of 1 square inch, the mercury column 30 inches high weighs **14.7** pounds. This is the reason why we say that the air pressure on every square inch of surface is about 15 pounds.

19. Is the Atmosphere's Pressure Always the Same? — If we examine a barometer frequently, we shall find that the height of the mercury column is not always the same; it varies from day to day and sometimes even from hour to hour. These changes in the "barometer height," as it is called, are caused by changes in the atmosphere's pressure. A study of these changes is of great importance to the weather observer, for they help him to foretell changes of weather. How he does this we shall learn later (cf. § 81).

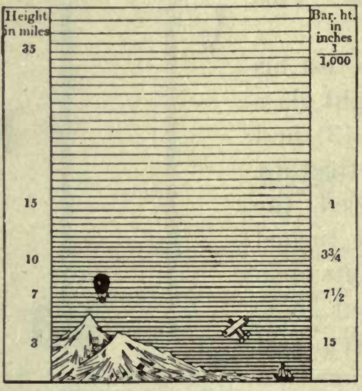


Fig. 14. — The balloon and the airplane are still in the lower part of the ocean of air.

What do you think would be the effect of carrying a barometer down into a deep mine or up a mountain? At the bottom of a haystack the hay is more compact than at the middle or the top, because all the hay above is pressing upon that at the bottom. The same would be true of a pile of sofa pillows or of any other material that is easily compressed. Is this true of air? If it is, then the pressure should become greater if we go down into a mine, and should grow less if we go to the top of a high building, or up a mountain. This has been found to be true (Fig. 14). At the height of 4 miles above sea level the barometer height is about 15 inches; at about

7 miles some aëronauts found it to be only 7 inches. They had thus left $\frac{3}{4}$ of the air behind them.

The pressure of the blood in our bodies is about 17 pounds to the square inch; hence there is danger of *hemorrhage*, or bursting of the blood vessels, when the atmosphere's pressure suddenly becomes too small. So it happens that many persons have nosebleed when they are carried quickly up a mountain.

The barometer column falls about an inch for every 900 feet we ascend above sea level; what would its height be at an elevation of 1800 feet? Of 4500 feet?

20. Exercises. — 1. If your body has an area of 2000 square inches and the atmosphere's pressure upon it is 15 pounds for every square inch, your body must support a pressure of 30,000 pounds. Why do you not feel so great a pressure?

2. When the cover of a Mason jar is hard to remove, we sometimes push a knife blade under the edge of the cover until we hear a hissing noise. What causes the noise? Why is it easier afterwards to remove the cover?

3. Alcohol is only $\frac{4}{5}$ as heavy as water; would a barometer column consisting of alcohol be higher or lower than one made of water?

4. Why is mercury used in the barometer instead of water or alcohol or any other liquid?

5. How could a barometer be used to tell the height of a mountain top above sea level?

6. Can you think of any reason why the atmosphere's pressure should vary from day to day?

7. Could you prove, by the use of a clay pipe with sheet rubber tied over the bowl, that the air presses in all directions? Try it.

CHAPTER IV

FIRE

21. What Does Fire Mean to Us? — What a number of pictures come to our minds as we hear the word "Fire"! Perhaps you think first of the fire that destroys some house, of the uncontrolled prairie fire and forest fire, of the destructive fires in coal mines and petroleum wells, of the great conflagrations that have swept over cities like Rome, London, Moscow, Chicago, Boston, and San Francisco. We ought also to think of the quiet fires of the home: a burning match, burning wood or coal in the open fireplace or in the stove, the gas jet and gas stove, the flame of a candle, the kerosene lamp, the furnace fire. We think, too, of the great fires of industry and commerce: the blast furnace, that gives us iron; the copper, zinc, and lead smelters in which, by the aid of fire, these metals are prepared for our use; the furnace fires that produce the steam of the locomotive and steamship. Then, too, we think of the joyous bonfire of our celebrations and of the camp fire over which we cook our picnic meal.

It is true that fire destroys many precious lives every year and enormous sums in property, yet without it man would be poor indeed. A proverb says: "Fire is a good servant, but a bad master." The poet has the same idea when he says:

> "How kindly is the fire's might,
> When tamed by man and watched aright."

What is fire and how did man come to use it?

22. How Are Fires Started? — How do you suppose man ever learned to start a fire? Nowadays we do this in a very matter-of-fact way. We strike a match; its tip bursts into flame; then the match stick burns and we use its flame to kindle our fire. But suppose we were off in the woods or the mountains, without matches; how could we kindle a fire then?

Fig. 15. — Kindling fire by means of a flint-and-steel.

A hundred years ago there were no matches; men lighted their fires by means of a **flint-and-steel.** That is, they struck a piece of *flint* (a kind of rock) with a short bar of steel and produced hot *sparks*. They caught the sparks in some *tinder* and thus set the tinder on fire. We often see such sparks when a horse's hoofs strike a stone pavement. The tinder consisted of dried moss, bark, pitch, or some other substance that was easily set on fire.

Our forefathers did not use the flint-and-steel every time they wanted a fire, but saved the hot coals each evening for the next day's fire. If the coals "went out," as they sometimes did, some one (usually a child) had to go out in the frosty morning to "borrow fire" of a neighbor. The glowing coals were carried in little covered iron pails or kettles.

But the flint-and-steel was not the earliest way of making fire. At a still earlier time men started their fires by rubbing one piece of wood against another, until the wood, or some tinder placed near it, was heated to the kindling temperature. Some barbarous peoples do this today (see Fig. 16).


(*Copyright, 1912, by Frederick Starr.*)

FIG. 16. — How a Batua of the Congo Free State kindles his fire by turning a drill rapidly between his hands.

23. How Does a Fire Burn? — Watch a fire and see how the flame or glow *travels* from one part of the burning body to another. We see this in the burning of an incense stick, a match, or a stick of wood, as well as in the burning of a house or a city block. The part already afire heats up the part next to it to the "point of burning," or **kindling temperature.**

A number of other things happen in a fire. There is usually a **flame,** which gives off **light.** We use lamps for the light of their flames. Lincoln learned to read by the light of a burning pine knot. A third thing about a fire is that it gives off **heat**; a fourth, that there is usually some **smoke.** A fifth thing is that after *solid* fuels, like coal and wood, no longer burn with a flame, they burn with a **glow**. Finally, when the coal or wood is entirely through burning, gray **ashes** remain. Many substances do not seem to burn at all; such are the iron of a stove and the bricks of a fireplace. Why does not the nail in a stick of wood burn up with the wood?

24. Experiments with Burning.—In order to find out more about burning, or fire, let us carry out a few experiments. First we must have a bottle and a cork to close it, also a pine splinter that can be fastened into the under side of the cork (Fig. 17). Let us light the splinter and hold it in the bottle, and press the stopper into the bottle's mouth. At first the flame burns brightly, then faintly; finally it "goes out." Suppose we remove the cork, relight the splinter, and thrust the splinter once more into the bottle. The splinter will not burn. Except, possibly, for a little smoke, the inside of the bottle looks just as it did before we burned the wood in it.

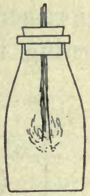


FIG. 17.—A lighted splinter burns for a time in the inclosed air of the bottle and then "goes out."

Let us remove the splinter, fill the bottle entirely with water, pour out the water, and put the burning splinter back into the bottle. What happens? The splinter burns once more. What did the water force out of the bottle? The used, spent air. What entered the bottle when we poured the water out? Fresh air. The experiment shows that burning wood spoils the air for further burning and that we must provide fresh supplies of air, if burning is to go on. The same is true of all ordinary burning.

We can perform the same experiment with a burning **candle**. The candle should be a short one and fastened by means of a stiff wire to the cork, so that the candle may be held upright in the bottle.

We can also carry out the experiment with burning **sulphur** held in a long-handled spoon (combustion spoon). The handle is put through the cork. After burning for a little while, the sulphur flame "goes out" and the bottle has in it a gas with a sharp odor. If we now put into the bottle a burning splinter, or a candle, it will not continue to burn.

25. How Much of the Air Supports Burning? — The experiments we have already performed show us that a burning body needs air. Let us now try to find out whether all, or only a part, of the air takes part in the burning.

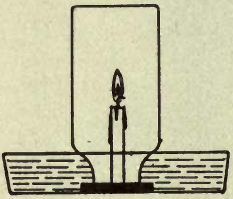


FIG. 18. — As the candle burns, it uses up part of the air of the bottle.

We can use a short candle, such as a "birthday" candle (Fig. 18). Soften the bottom of the candle by warming it and then press it against a piece of tin, such as a jelly-glass cover, until it sticks. Now set the candle upright in a basin containing water to the depth of about one inch, and light the candle. When it is burning briskly, put over it, and into the water, a bottle of fresh air. At first the candle flame burns just as it does in the outer air, but soon it dies down and goes out. When the flame goes out and the gas left in the jar becomes cool, water rises into the bottle. What does this mean? It means that there is less air in the jar after the candle has burned than there was before. The water rises to take the place of that part of the air which has been used up.

Another material that helps us in our study of burning is **phosphorus**, but the experiment must be performed by the teacher, since phosphorus burns with great fierceness. There are two kinds of phosphorus: one is a red powder and the other a yellow, waxy solid that comes in sticks which look like lemon stick candy. The red is much safer to handle and to keep. If the yellow is used, it must be kept under water and cut under water, or it may take fire of itself and cause serious burns. For this reason, the piece cut off for use must be handled with forceps or tongs, never with the fingers. You would never guess that such an active substance could be a part of our bones and of the rock phosphate that is put upon soil, but it is so.

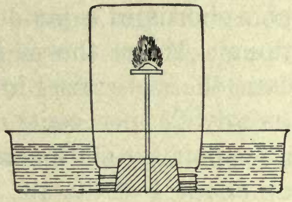


FIG. 19. — The phosphorus burns until it has used up that part of the air which permits burning to go on.

Let the teacher set up the apparatus of Fig. 19. The vessels needed are a pint fruit jar and a shallow pan containing water. The phosphorus is put on a holder that reaches about halfway up the jar. The holder may be a strip of "tin" with a horizontal top about the size of a 25-cent piece, or it may be a small cork fastened to a wire and covered with a disk of "tin." The lower end of the strip or wire is put through a hole or a narrow slit in a piece of sheet lead or into a rubber stopper, so that the phosphorus holder will stand upright. A floating support for the phosphorus is often used; it may be made out of a thin, flat cork with a disk of tin laid upon it to protect it. When the support is ready, we set the phosphorus on fire, put the jar of air over it, and press the jar against the bottom of the pan.

The phosphorus will burn for a time, forming a dense, white smoke; then, although there is still some phosphorus left, it stops burning. Finally the smoke dissolves in the water, leaving the gas in the jar quite clear and transparent, like the air itself. But long before the smoke disappears, water will rise into the jar.

Let us examine the bottle in which the candle has burned, or the jar in which phosphorus has burned.

What fraction of its volume is filled with water? Is it $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, or what? To find out, we can close the mouth of the bottle or jar, under water, with a card and then remove the jar from the water and set it upright on the table. If we put a burning splinter or candle into the jar, we find that the gas in the jar is inactive and does not allow burning to go on.

26. Is Air a Mixture? — By burning a candle or some phosphorus in a jar of air we find out a very wonderful thing. When the experiment is carried out with great care, the water rises into the jar until it fills about $\frac{1}{5}$ of it (nearly 21 per cent). Many other burning substances act upon air in this way; that is, after they have used up about $\frac{1}{5}$ of the air, they do not act further. How can we explain this fact? The explanation is that the air consists of at least **two different gases**: one that permits burning to go on and another that does not. The active gas, which unites with substances when they burn, is called **oxygen**. The inactive gas, making up about $\frac{4}{5}$ of the air, is **nitrogen** (mixed with small amounts of some other gases). The air is oxygen *diluted* with nitrogen, much as lemonade is lemon juice diluted with water.

27. How Can We Explain Burning? — We can now understand what the strange phenomenon called **burning**, or **fire**, really is. Burning is the *uniting of a body with the oxygen* of the air. The burning body and the oxygen rush together so vigorously that heat and light are produced. The burning body sometimes disappears, as far as we can tell by our senses, but if we have the skill and the patience, we can prove that it has merely united with oxygen, and we can collect the invisible materials that are formed. The white smoke formed when phosphorus burns contains both the phosphorus that was used up in burning and the oxygen that united with it.

Another name for burning is **combustion.** A substance like wood, coal, or fuel gas, which burns in the air is a "combustible substance," or, simply, a *combustible.*

28. What is a Flame? — Have you ever asked yourself, as you watched the flame of a bonfire leap high into the air, what a flame really is, and how it can reach out so far from the burning body? And have you noticed that a jet of gas, or a candle, or a piece of wood burns with a flame, while a piece of burning charcoal or coke merely *glows?* Why is this?

To find out the reason, let us study the quiet, little flame of a lighted candle. A candle consists of wax, or tallow, and a wick. When the wick is set on fire, some of the wax is melted, and the liquid wax rises through the wick into the flame, where it is burned. In a kerosene or alcohol lamp the liquid rises through the wick in the same way.

If we look at the flame carefully, we see that it consists of a dark, central part surrounding the wick, and a burning, outer part that gives the light. How can we find out what is taking place in the central part? One way is to hold one end of a small tube in it, as shown in Fig. 20. If we then bring a burning match near the upper end of the tube, we can get a flame there, too. What does this mean? It means that an *invisible, combustible gas* is formed in the dark, central part of the flame and passes up through the tube. On the wick and in the central part of the flame the wax is being turned into this gas. Why does not the gas burn on the inside of the flame? Because the air gets at the gas only on the outside. So the candle flame really consists of a burning, outer region surrounding a central region of unburned gas; *a flame is a burning gas.*

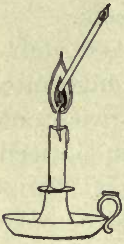


FIG. 20. — In the center of a candle flame there is a combustible gas that can be drawn off through the glass tube and burned.

We can show in other ways that flames are burning gases. Suppose we "blow out" a candle flame, and at once hold a burning match just above the wick. By making several trials we shall find that, even with the match quite a distance above the wick, we can still relight the candle. What is it that passes from the wick into the air and is set on fire by the match? The invisible gas formed out of the wax. If we give the wick time to cool, it can no longer turn the wax into a gas; then we cannot relight the candle without heating the wick up to its *kindling temperature.* We can carry out the same experiment with a kerosene lamp.

If we watch a burning piece of wood, especially a burning log, we see that gas comes out of the wood in little jets that burn with flames; often these can be lighted at some distance from the wood. Soft coal gives off a gas in the same way, and so burns with a flame. Coke and charcoal burn without flames because they have no combustible gases to give off (cf. § 36).

29. Exercises. — 1. Why are paper and wood used in kindling a coal fire?

2. How can a "burning glass" start a fire? Do you think that broken bottles left in the woods might act as burning glasses and cause forest fires?

3. Do you think that the air which passes out through the stovepipe when there is a fire in the stove contains more, or less, oxygen than when it entered the front of the stove? Why?

4. If we wish to put out a fire, what must we keep away from it? How can this be done?

5. Is water a combustible? Is it a supporter of combustion? When water is turned into steam, does the steam burn or support combustion? Try this by putting a burning match into the steam that comes from a teakettle in which water is boiling hard. Tell how these facts explain why water puts out a fire.

6. Why does a blanket or rug put out a fire?

7. If your clothes are set on fire, ought you to run outdoors to get help? Why? What ought you to do?

8. Does an old iron stove ever show any signs of being partly burned up?

CHAPTER V

OXYGEN, THE FIRE GAS

30. How Can We Prepare Oxygen? — You would naturally think that the easiest way to get oxygen unmixed with nitrogen would be to remove the nitrogen of the air. But we must remember that the oxygen is the active gas, and that burning substances, like a candle or phosphorus, always combine with the oxygen and leave the nitrogen. So to get oxygen we must use chemicals that consist partly of oxygen and we must get the oxygen out of these. The most common way to get oxygen is to heat a mixture of two substances called **potassium chlorate** and **manganese dioxide.** The potassium chlorate is a white solid; the manganese dioxide is a black one.

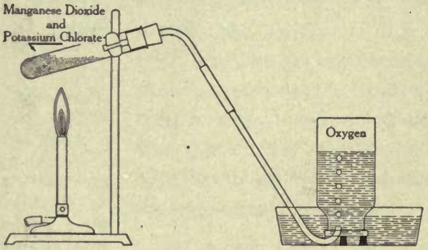


Fig. 21. — When a mixture of powdered potassium chlorate and manganese dioxide is heated, oxygen is given off.

The **apparatus** used is shown in Fig. 21. To fill three or four 8-ounce (250 cc.) bottles with the gas we use about $\frac{1}{4}$ of a test tube of potassium chlorate and about $\frac{1}{8}$ of a test tube of manganese dioxide. Each should be in the form of a fine powder and the two should be mixed carefully on a clean, smooth sheet of paper. By means of a one-hole stopper we connect the test tube containing the mixture with a " delivery tube " that carries the gas to the water pan.

To heat the mixture we use a *very small*, smoky flame (a candle flame will do); bubbles of oxygen will soon escape from the end of the delivery tube. If a bottle full of water is placed, mouth downward, over the end of the delivery tube, the oxygen rises into the bottle and pushes out the water. We thus collect the gas " over water," as we collected air in § 9, Fig. 4.

When a bottle is full of oxygen, we slip under it a piece of cardboard, or of sheet glass, and then set it, right side upward, on the table. We can then fill other bottles with the gas. If the gas is to be kept for a day or two, the bottle should be stoppered tightly. Pint fruit jars with rubber rings and tight covers make excellent storage vessels for gases.

When we have collected enough oxygen, or when all has come off that will, we remove the delivery tube from the water; then, and not until then, should we take away the flame. The reason for this care is that as the gas in the test tube cools, it *contracts* (cf. § 12); if cold water from the water pan is forced into the hot tube, the tube may break.

We shall want to use the bottles of oxygen in the next section and in Chapter VI.

FIG. 22. — When hydrogen peroxide solution is added to manganese dioxide, oxygen is given off.

Another way of getting oxygen is shown in Fig. 22. For this we need only a glass bottle and a loose cover, such as a piece of sheet glass. Into the bottle we put **manganese dioxide** (or, better, *potassium permanganate*) and enough water to just cover the solid; then we add some **hydrogen peroxide** solution. No heating is needed. The mixture bubbles, or foams, as the oxygen rises through the water. The oxygen pushes the air out of the bottle; soon we have the bottle full of oxygen.

31. What is Oxygen Like? — We are now ready to learn some of the *properties*, or qualities, of this interesting gas. We can see, by looking at the bottles of oxygen, especially after they have stood for a few minutes, that oxygen has no more color than air has. Perfectly pure oxygen has neither odor nor taste.

If we light a pine splinter, and put it for an instant into a jar of oxygen, the wood burns much more vigorously than in air. If we blow out the flame, and put the glowing splinter into the bottle, the *glow becomes very intense and the splinter bursts into a flame.* In this way we can tell a bottle of oxygen from one of air.

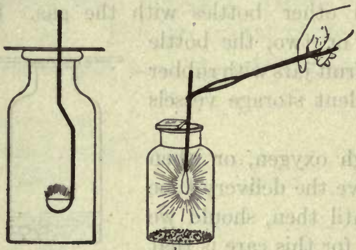


FIG. 23. — *a.* When burning sulphur is put into oxygen, it burns with a brilliant, purple flame. *b.* Iron wire burns in oxygen with a brilliant light and a shower of tiny sparks.

A burning **candle** burns more vigorously when put into oxygen. Try it, if possible. To burn **sulphur** in oxygen, we hold it in a combustion spoon (cf. § 24). We light the sulphur by holding the bowl of the spoon in a flame, and then put the spoon into a bottle of oxygen (Fig. 23, *a*). In the air, sulphur burns with a pale, almost colorless flame, but in oxygen the flame is a brilliant, purple one. By smelling cautiously of the gas formed in the bottle we learn that it has the same sharp odor as the gas formed when sulphur burns in air. We call it *sulphur dioxide.*

We do not see **iron** burn, ordinarily, in air, but in oxygen it burns (Fig. 23, *b*) with a brilliant light and a shower of tiny sparks. The best way to show the burning of iron in oxygen is to use a piece of picture cord made up of fine strands of iron wire and to put on one end of the cord a tip of melted sulphur or the head of a match; we then light the sulphur, or match head, and put the wire at once into the jar of oxygen. The shiny, black lump formed on the end of the wire is made up of iron and oxygen; we call it *iron oxide.*

32. What is Oxidation? — Are you ready now to learn the meaning of some important words? We use the word "oxidation" so often in science and even in our daily life, that we should get some idea of what it means. We see at once that the word comes from "oxide" (pronounced ŏx′ĭd) and that oxide comes from "oxygen." Oxidation means *uniting with oxygen;* the substance that unites with oxygen is said to be **oxidized.** Thus the iron burning in oxygen is *oxidized* to *iron oxide.* When **lead** is heated in air, it is oxidized to *lead oxide.* The white smoke formed when phosphorus burns in air (cf. § 25) is called *phosphorus oxide.* When coal and charcoal, which consist chiefly of **carbon**, are burned, the oxide formed is called *carbon dioxide* (cf. § 37). In this, as in *sulphur dioxide,* the syllable "di," meaning *two,* is put before "oxide."

33. Why Does Paint Harden? — What has paint to do with oxidation? Perform the following **experiment**:

Wet the inside of a test tube with linseed oil and then let most of the oil drain out of the tube. Now set the test tube upside down in a dish of linseed oil (Fig. 24) and leave it for a day or two. The oil will rise part way up the tube and then stop; why? What substance does linseed oil take out of the air?

Common paint consists of linseed (flaxseed) oil and turpentine, mixed with "white lead" or "zinc white" and perhaps a colored substance. White lead and zinc white are used to give the paint "body," or "covering power." The turpentine not only thins the paint, but assists in drying the oil.

When paint dries, its linseed oil is oxidized by the air to a hard gum which does not dissolve in water and so resists the "washing" of the rain; this gum forms a durable coating for the outside of a house as well as for inside woodwork.

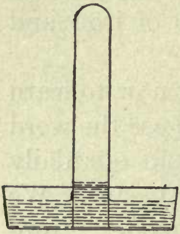


FIG. 24. — Linseed oil unites with the oxygen of the air in the test tube. What gas remains?

Considerable heat is given off as paint dries; hence heaps of painters' cloths sometimes take fire without our knowing why. The phenomenon is called **spontaneous combustion**, or *spontaneous ignition*, because it seems to take place "of itself." But it is a case of oxidation as truly as the burning of a match. Cloths containing linseed oil or paint should never be left about a building except in covered metal boxes or cans.

34. What are Rusting and Decay? — Do you suppose that rusting has anything to do with oxidation? Carry out this **experiment**:

Wet the inside of a test tube with water and drain off most of the water. Then put some iron filings into the moist tube and shake them around in the tube. Pour out the filings that do not stick to the tube. Now set the test tube, mouth downward, into a dish of water and let it stand for a day or two. What happens? The iron rusts and at the same time water rises into the tube. Finally no further change takes place. What does the iron take out of the air of the tube?

Iron rust is *iron oxide;* the rusting of iron is really the *slow oxidation* of iron. Heat is given off, as in the burning of iron, but so slowly that we cannot usually notice it. Many other metals tarnish, or rust, in the air.

Decay. — What becomes of the dead bodies of animals and plants and of dead leaves, wood, and fruit? We say they " decay " or " rot." Decay is another case of *slow oxidation.* Some kinds of the tiny plants we call *bacteria* (cf. § 204) bring about the decay; they use up oxygen in doing so.

Have you ever seen a " hotbed," in which vegetables may be grown during the winter or in early spring? The hotbed is a large, shallow box with a glass cover; the lower part of the box is surrounded by manure. The heat given off by the decay of the manure keeps the ground and air inside the box warm, so that vegetables can be grown there even in freezing weather.

Thus we see that oxygen is not only the supporter of combustion, but the world's great purifier. It turns the remains of former life into harmless substances, so that the life of the present time may have a better opportunity.

35. Exercises. — 1. What names should you give to the substances formed when tin and zinc burn in the air?

2. What substance is used to polish stoves? Why?

3. What metals are used to cover iron to keep it from rusting? What is " galvanized " iron?

4. Why is the soil in some places red?

5. Of what are " tin " dishes made? Test one with a magnet.

6. Examine an old washboard; what is the color of zinc rust? Why is zinc used for washboards instead of iron or copper?

7. Covering wood with an oxide protects it against fire. Why?

8. Let an empty " tin " can rust without losing any material. Does the rusted can weigh less, or more, than the original can? Why?

CHAPTER VI

CARBON AND CARBON DIOXIDE

36. Why Do Some Substances Char? — Have you thought, as we studied about fire and oxidation, how strange it is that the active, colorless gas oxygen is hidden away in the red iron rust and the white potassium chlorate, and is hidden so successfully that we would never guess that it is there, until we study science? Well, the oxygen is no more skillfully hidden than is carbon, the black solid that we see in coal and in the "black lead," or *graphite*, of our pencils. Is it easy for you to believe that the brilliant diamond, the hardest substance known to man, is made up of the same black carbon that is present in coal? Yet this is true; the diamond is nearly pure carbon.

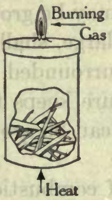


FIG. 25. — The baking-powder box has a hole in its cover. When the box is heated, a combustible gas escapes through the hole; this gas comes from the wood.

But there are more common hiding places for carbon than in diamonds. Light a match or splinter, and after a few seconds blow it out and examine the partly burned end. The end is now a black substance, no longer wood; we call it **charcoal**. Charcoal is a form of **carbon**. If we heat wood in a deep dish, such as a test tube or a baking-powder box (Fig. 25), and apply a burning match to the open end of the dish, we find that the heated wood is giving off a gas that can be set on fire. When the heating is over, charcoal remains. When soft coal is heated in the same way, **coke** remains.

Nearly all plant and animal substances behave like wood: when they are heated, they char, or "turn to carbon." This is a short way of saying that heating breaks up the delicate substances formed by animals and plants; that a large portion of these substances escapes as a gas, but that a part remains behind as solid carbon.

Men make charcoal on a large scale (Fig. 26) by piling wood in heaps, covering the heaps with sod, and setting the wood on fire. Small openings are left to allow a little air to enter and the gases to escape. The part of the wood that burns gives off the heat which is needed to drive off the gases from the wood that is near it. This is exactly what happens in the half-burned match.

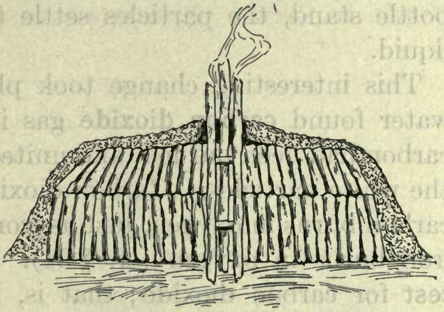


FIG. 26. — Charcoal is made by the heating of covered heaps of wood.

If a ton of wood were "turned into charcoal," would the charcoal weigh more or less than a ton? Why?

37. What Is Formed When Carbon Burns? — We are now ready to see how carbon burns in air or oxygen and to learn what substance is formed. Fasten a piece of charcoal to a wire, or hold it in a combustion spoon (cf. Fig. 23, § 31) and heat the charcoal until it glows. If we then hold it in a bottle of oxygen, the charcoal burns with a brilliant light, much more fiercely than in air. After the charcoal glow has gone out, put about a tablespoonful of clear limewater into the bottle and shake the limewater and gas together. A strange thing happens; the limewater becomes *white*, or "milky." The milky appearance is caused by a multitude of white particles which are formed in the limewater. If we let the bottle stand, the particles settle to the bottom of the liquid.

This interesting change took place because the limewater found **carbon dioxide** gas in the bottle in which carbon had been burned, and united with this gas to form the white particles. Carbon dioxide is formed when the carbon burns in oxygen, just as iron oxide is formed when iron burns in oxygen (cf. § 31). We use limewater to **test** for carbon dioxide; that is, limewater helps us to know if a gas is really carbon dioxide or something else. For the same reason we used a glowing splinter to test for oxygen.

If we burn wood and coal in a bottle of oxygen or air, and make the limewater test, we find that carbon dioxide is formed in these cases also. If we burn a candle in air or in oxygen, the same thing is true. Men have even burned diamonds in oxygen and have proved that they produce carbon dioxide.

38. How Can We Make Carbon Dioxide? — We have already had one answer to this question: we can make carbon dioxide by burning carbon in oxygen. But if we want to use several bottles of it, we can get the gas more easily by putting some **marble** in a bottle and adding to it some dilute **hydrochloric acid.** The marble froths as the acid acts. The frothing is caused by the gas rising in tiny bubbles through the liquid, just as we have white-caps on the lakes or ocean from the air rising through the waves.

The apparatus is shown in Fig. 27, *b*. The long, upright tube with the rounded funnel at the top is called a " thistle-tube " or " safety-tube." Through it we pour the acid upon the marble. We collect the gas over water (cf. § 30).

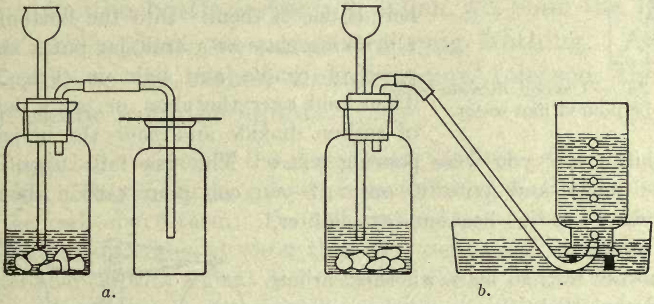


FIG. 27. — *a*. Carbon dioxide pushes the air out of the collecting bottle. *b*. Carbon dioxide may be collected over water, as oxygen was.

Instead of letting the gas collect over water, we can **let it fall** into the bottom of a bottle; it pushes the air upward and out of the bottle (Fig. 27, *a*).

In place of marble we can use **baking soda** or **washing soda**, and in place of the hydrochloric acid we can use **vinegar** or **lemon juice.** We do not need the stopper, thistle-tube, and delivery tube at all; but we can use a bottle with a glass cover (Fig. 22, § 30). If we put marble (or soda) into the bottle, and add the acid, the carbon dioxide that is formed pushes all the air out of the bottle.

39. What is Carbon Dioxide Like? — Carbon dioxide is colorless, like air and oxygen. But when we put into the gas a burning match, it acts differently from air and oxygen. The burning match is put out *instantly*. If we put some limewater into a bottle of carbon dioxide, the limewater becomes milky. If we let the gas bubble through limewater, the same change takes place.

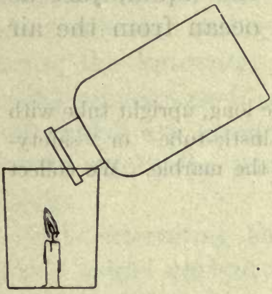


FIG. 28. — Carbon dioxide can be poured like water.

We can perform a number of very interesting **experiments** with carbon dioxide; here is one of them. Into the bottom of a drinking glass or a fruit jar put a short piece of candle and light it (Fig. 28). Then hold over the glass, or jar, a bottle of carbon dioxide and *pour* the invisible gas, just as if you were pouring water. The gas falls upon the candle flame and puts it out. If you can pour carbon dioxide downward, is it heavier, or lighter, than air?

Another way to learn whether carbon dioxide is a light gas or a heavy one, is shown in Fig. 29. If we balance an empty tin can or paper bag upon the scales and then pour carbon dioxide into it, the can (or bag) sinks; this proves that the carbon dioxide is heavier than air. If we turn the vessel upside down, the gas falls out, and the scales become balanced once more.

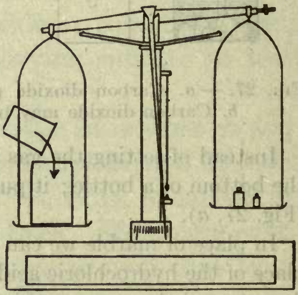


FIG. 29. — A vessel filled with carbon dioxide weighs more than when full of air.

40. Why Does Soda Water Foam, or Effervesce? — Suppose we make an imitation of soda water. Let us put into a pop-bottle, or some other kind of bottle that we can stopper tightly, a tablespoonful of baking soda, enough water to half fill the bottle, and three or four teaspoons of lemon juice, or vinegar, or dilute hydrochloric acid. We must stopper the bottle at once after adding the acid.

At first the liquid froths, or *effervesces*, as the carbon dioxide bubbles through it. But in a short time the frothing stops almost entirely. The carbon dioxide cannot escape, and is therefore compressed; in this compressed state it dissolves more easily in the liquid. But when we open the bottle, especially when we pour the liquid out into a glass, we notice a strong frothing. As the pressure on the carbon dioxide is now released, the gas can escape from the liquid.

Beneath the surface of the ground there are both water and carbon dioxide. They are under greater pressure than at the surface, because of the rock above them. For this reason more carbon dioxide can dissolve in underground water than in water at the surface. When water charged with a great deal of carbon dioxide reaches the surface, as in some springs, it effervesces like soda water. We call such springs " carbonated " springs.

41. How Does Carbon Dioxide Put Out Fires?— When you saw that carbon dioxide could be poured upon a burning candle, did the idea come to you that we might use this gas to put out a fire? Men had this idea years ago and have used it in fire extinguishers. In the ordinary " chemical " fire engine, such as is used to protect a school building or a factory (Fig. 30), the carbon dioxide is formed from the action of baking soda with an acid. The baking soda is dissolved in water and the solution is kept in a metal tank. A bottle of sulphuric acid is fastened in the upper part of the tank. When we turn the tank upside down, the acid is spilled out of the bottle and acts with the soda, forming carbon dioxide. The pressure of the carbon dioxide forces out some of the water and carbon dioxide; these two put out the fire.

A mixture of baking soda and dry sawdust is also used to put out fires, especially gasoline fires. The burning substance heats the soda and it gives off a large amount of carbon dioxide. The invisible carbon dioxide covers the burning body like a blanket and keeps the oxygen away; hence burning cannot go on.

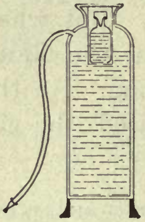


FIG. 30. — A fire extinguisher. The liquid in the tank is a solution of soda. The bottle at the top contains sulphuric acid.

42. How Does Carbon Dioxide Get into the Air? — Do you need any proof that there is carbon dioxide in the air? Then set a shallow dish of limewater in the air in your schoolroom and watch it for an hour or two. It will become covered with a white crust, or scum, which consists of the solid that makes limewater milky. The chemist calls this **calcium carbonate**; *limestone* and *marble* are natural forms of it.

How does carbon dioxide get into the air? We have learned that when charcoal burns in oxygen, carbon dioxide is formed. When wood, coal, paper, a candle, gasoline, or any other substance that contains carbon, is burned in air or in oxygen, carbon dioxide is formed. So we see that an enormous amount of carbon dioxide must get into the air from all ordinary **burning**.

Carbon dioxide gets into the air not only from burning, but also from the **breathing**, or respiration, of animals and plants. You can readily prove that you yourself breathe out a great deal of carbon dioxide, by blowing your breath through limewater (Fig. 31). The limewater will become very milky.

A third way in which carbon dioxide gets into the air is by the **decay** of such things as wood, leaves, and fruit, and the bodies of dead animals (cf. § 34). The carbon of the decaying substances is changed chiefly to carbon dioxide, which enters the air just as if the substance had been burned.

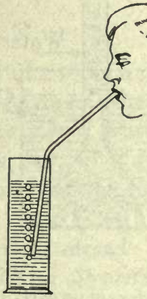


FIG. 31. — Blow your breath through limewater; the limewater becomes "milky" from the carbon dioxide you exhale.

43. How Is Carbon Dioxide Removed from the Air? — What becomes of all the carbon dioxide that is poured into the air? It is given off by every living creature, by every fire, and by all decay. Why does not carbon dioxide become so plentiful that fires will no longer burn and that animals and plants will not be able to live? Can we answer this question by an experiment? The experiment (Fig. 32) is to let *green plants*, in the presence of *sunlight*, act upon water containing carbon dioxide.

First make some carbon dioxide, as in § 38, from marble chips and an acid. Half fill a large, small-mouthed bottle with water and drive out the air that remains by passing carbon dioxide into the bottle (the bottle to be mouth upward). Then stopper the bottle and shake the water and carbon dioxide vigorously together. In this way you can make a great deal of carbon dioxide dissolve in the water.

Into a deep glass jar (" battery jar ") place, upside down, a large funnel filled with spinach or parsley; then almost fill the jar with the carbonated water. The stem of the funnel must be entirely under water. Now fill a test tube with water, close its mouth with your thumb, set the test tube mouth downward into the battery jar, and slip it carefully over the stem of the funnel. Then set the whole apparatus in bright sunlight for an hour or two.

If you watch carefully, you will find that bubbles of gas rise into the test tube. When enough gas has been collected, remove the test tube carefully from the funnel, close the tube, under water, with your thumb, and then turn the tube right side up. Now find out what the gas is by putting into it a splinter with a glowing tip. The gas is **oxygen.**

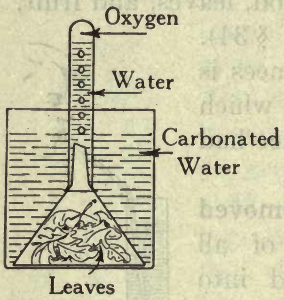


FIG. 32. — When green leaves act on carbonated water in the sunlight, they break up the carbon dioxide and set oxygen free.

Does this experiment help us to answer our question as to how carbon dioxide is removed from the air? The answer is that green plants use up carbon dioxide and give back oxygen to the air. Thus, in spite of all the ways in which oxygen is used up, we still have it in the air.

How is the carbon dioxide removed in winter? Does all the earth have winter at the same time?

44. How Do Plants Help Animals? — In thinking of the ways in which plants help animals, we must consider that plants are not only the food of animals, but that they prepare and purify the air for the use of the animals, as we have just learned. This careful balance between the action of plants, which remove carbon dioxide from the air and give back oxygen, and the action of the animals, which do the opposite, is one of the most interesting facts man has discovered. You can study this balance in an aquarium. If you have some small animals, such as goldfish, in the aquarium, and the right quantity of water plants, the water will not grow stale, but the plants will use up the carbon dioxide given off by the animals and will return the oxygen to the animals for their future use.

45. Exercises. — 1. How may a stove make the air of a room unfit to breathe? Is there any danger in sleeping in a room having a stove?

2. When soda is put with tomatoes, a foaming takes place; why?

3. If a candle is lowered into an old well and goes out, what gas may be in the well? How did it get there? Should a man go into such a well?

4. Is there any soda in soda water? What causes its frothing?

5. Name six white substances which are partly made up of carbon. Name two transparent ones.

6. Coal and diamonds are each largely carbon; why the great difference in their values?

7. If you have a bottle of oxygen and one of carbon dioxide and neither bottle has a label, how can you tell which is which?

8. Would a carbon dioxide fire extinguisher work better with a fire near the floor or with one near the ceiling?

CHAPTER VII

THE AIR WE BREATHE

46. Why Do We Breathe? — Have you ever thought of the interesting act we call **breathing** and asked yourself how and why we breathe? Of course all of us know what breathing is. It is the taking of outside air into the lungs and then expelling the used air from the lungs. Is air changed by breathing? To answer this question, carry out the following experiment:

Provide a bottle with a cardboard cover and make a hole in the cover. Put a glass tube or lemonade "straw" through the hole and into the bottom of the bottle. Hold your breath as long as possible and then blow it through the tube into the bottle. Now test the air in the bottle with a burning stick. Does the stick continue to burn? What has the air lost? What has it gained?

Men have found that while the air which rushes into the lungs is more than one-fifth oxygen and contains very little carbon dioxide, the air which leaves the lungs has lost a part of its oxygen and has gained carbon dioxide. Thus we see that not only in supporting fire is oxygen used and carbon dioxide formed, but also in supporting life.

Why then do we breathe? The answer seems to be to get oxygen into the body and to remove carbon dioxide from the body. We must remember, too, that the oxygen we breathe does not stop in the lungs, but passes through the walls of the lungs into the blood vessels; it is then carried by the blood to all parts of the body. The whole process by which oxygen gets to the cells of the body is called **respiration.**

A grown man takes into his lungs about 350 cubic feet of air in a day. How much of this is oxygen? "Why," you will ask, "do we need to take in so much oxygen?" The answer is that we need oxygen to *oxidize the food* we eat. The digested food, like the oxygen, is carried by the blood to all parts of the body. The oxidation of our food is a change somewhat like the burning of coal in a stove; at any rate, it produces heat, and carbon dioxide is formed, just as when a candle burns in a bottle of air (cf. § 24). It is only by the oxidation of our food that we get the power to move and to do work. The heat produced by this same oxidation keeps our bodies at about 98.6° Fahrenheit, winter and summer, as long as we are well.

Water animals need oxygen to oxidize their food and make movement possible, just as land animals do. Such creatures as fishes, clams, and tadpoles depend upon the oxygen dissolved in the water in which they live. Their gills act in place of our lungs in taking up oxygen and giving off carbon dioxide.

47. Why Do We Need Ventilation? — Do you know what ventilation means? It comes from a word meaning "wind," and means the bringing of fresh air into our houses and the taking out of the used air. Do you realize how bad it is to breathe the same air over and over again? Doctors know that people who have good health in warm weather, when they keep their doors and windows open, have colds and other troubles of the nose, throat, and lungs almost as soon as cold weather comes and their houses are tightly closed. The sealing up of the openings keeps the fresh air out and the foul air in. This is especially true when storm windows and weather strips are used to " keep out the cold."

It has been calculated that in one hour a healthy man makes about 4000 cubic feet of air unfit to breathe. This means that if one man were put into a perfectly tight room 20 feet square and 10 feet high, he alone would make the air bad in one hour. Of course rooms are not air-tight and so a good deal of fresh air gets in through cracks around doors and windows, even when we do not try to ventilate. Schoolrooms, since they have a large number of persons in a small place, need special care to make them safe. According to a Massachusetts law, each pupil should get at least 1800 cubic feet of air every hour. If a person coming in from out of doors notices that the room has an odor, the air has been breathed too often. The class work in such a room is probably dull and slow.

48. Fresh Air and Tuberculosis. — Most of us probably know some one who has, or has had, *tuberculosis*, or " consumption." It is called the " Great White Plague," because it causes the death of so many people. Persons suffering from this disease are now generally given the fresh-air treatment. They live in tents in the open air, winter and summer, day and night. Of course they must be warmly clothed and must have very nourishing food. Nearly all who begin the fresh-air treatment when they are first attacked by the disease are able to cure themselves. Many healthy persons keep themselves well by sleeping out of doors winter and summer. This "sleeping-out" gives the lungs every chance for fresh air.

49. How Do We Ventilate Our Houses? — Do you want to know how our houses are ventilated naturally? Then carry out this simple **experiment**:

Open the door leading from a warm room into a cold one and hold a lighted match near the top of the doorway. You will find that the match flame is blown *from* the warm room *toward* the cooler one. Now hold the match near the bottom of the doorway; the match flame is blown from the colder toward the warmer room. The flame shows us how the invisible air currents are moving. Cold air flows in at the bottom of the room to take the place of the warmer air which rises and flows out at the top. The reason for this has already been learned (cf. § 12). When air is warmed it expands, so that a cubic foot of warm air will weigh less than a cubic foot of cold air. You have probably all seen the hot-air toy balloons that are sent up in the evening celebration of the Fourth of July. A wick soaked in kerosene is fastened at the bottom of the balloon, which is open. The burning wick heats the air that rises into the balloon and the balloon becomes filled with warm air. As the balloon full of warm air is lighter than if filled with cool air, it rises, just as a cork would, if you were to let go of it under water.

Natural ventilation is, then, the method of ventilating which depends upon the entrance of cold air at the bottom of a room and the leaving of warm air above. You see that natural ventilation must work better in winter than in summer, because in winter there is such a great difference between the temperatures inside and outside the house. Weather strips, storm doors, and storm windows are really used to prevent ventilation and to hold the warm air inside the house.

50. How Can We Ventilate Our Bedrooms? — Not only the living-rooms of the house, but also the bedrooms, need to be ventilated with great care. Rooms used in the daytime are sure to have a good deal of fresh air brought into them by the opening of doors as people go in and out. But there is very little chance for a closed bedroom to get fresh air. So we should have at least one window open every night and the room should be thoroughly aired during the day.

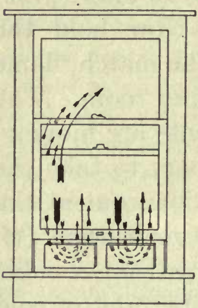


FIG. 33. — A board with boxed holes allows air to enter and leave a room even in stormy weather.

Because a bedroom is kept cold does not mean that the air is pure; cold air, if not changed often, may be just as foul as warm air. It is a good plan, if the weather is too stormy to allow a window to be open from the bottom, to lower the upper sash part way. The opening at the top and the space between the sashes make the two openings needed for the movement of air. If a board with boxed holes (Fig. 33) is put under the lower sash, the air will enter through the holes and pass out between the sashes.

The air of our houses becomes unfit to breathe, not so much because it contains impurities as because it is not *in motion*.

51. How to Ventilate the Schoolroom. — If a schoolroom depends upon natural ventilation, how shall we ventilate it? Shall we have several windows each open a little, or one open a great deal? If we try the results, we shall find that one window opening gives stray currents of air (drafts); while several small openings will give just as much circulation, but no person will feel a draft. The openings should be on the side of the building opposite the wind.

When a stove is used to heat a room, air currents are made by the stove. As the air near the stove is heated, it rises and flows away along the ceiling; at the same time the cold air moves along the floor toward the stove, to be heated in its turn.

If a stove "drum" is used (Fig. 34), it protects the persons near the fire from too great heating and sets up stronger currents than the stove alone. The cold air comes from the farthest corners of the room, is heated, rises, and flows back to the corner from which it came. In this way the room is heated and ventilated evenly.

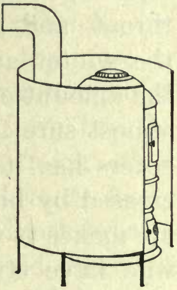


FIG. 34. — Such drums as these were used to help heat and ventilate the barracks of our training camps.

In large school buildings the heating and ventilating are done together by what is called **forced ventilation**. One method is to force fresh air over steam by means of rotating fans in the basement. After the air has been heated, it is forced into the schoolroom. The impure air escapes through openings in the walls or ceiling. Sometimes the impure air is removed from the room by means of rotating fans and warm fresh air is brought in through small holes near the floor. Find out how your school building is ventilated.

52. Do We Need Moisture in the Air? — Do you remember days when the air was "sticky" and the perspiration did not evaporate? If you were to ask a scientist what is the trouble on such days, he would tell you that there is too much moisture in the air. Then, on other days, the moisture of the skin evaporates too rapidly and leaves the skin parched and dry. The reason in this case is that on these days the air holds too little moisture and so takes it up from everything that contains it, including our skin and the linings of the nose, throat, and lungs. When our houses are closed up in the winter and heated to the temperature of summer, the amount of moisture present in the air of the house is almost sure to be too small, because the cold air which enters has its power of taking up moisture greatly increased by being warmed. Breathing of this warm, dry air makes it very easy for us to "catch cold." People who have studied ventilation say that the amount of moisture in a room should be so great that some of it will be deposited as dew and frost on the windows in cold weather. Rooms which are heated by steam or hot water should also have the air moistened by pans full of water near the radiators. Hot-air furnaces have pans for water; these should be kept full.

53. How Do We Breathe? — People often think that in some way we "suck" air into the lungs. This is not true. What happens is that as we allow the muscles of the chest to become loose, or *relaxed*, the lung cavity becomes larger. The pressure of the air in the lungs is then less than the pressure of the air outside; so the outer air rushes into the lungs. When the chest muscles contract, and become shorter, they make the lung space smaller. Part of the air is thus forced out of the lungs. Our regular breathing is caused by the regular contracting and relaxing of the chest muscles. We shall learn more about breathing in Chapter XXXVIII.

54. Proper and Improper Breathing. — We learned in the beginning (cf. § 5) that science should help us to live healthy lives. One way in which it does this is in explaining the importance of fresh air and good methods of breathing. The air goes through the nose, throat, and windpipe before it enters the lungs. If the nose is healthy, the air is filtered from dust and the germs which cling to the dust. It is also warmed. If we breathe through the mouth, the purifying and warming effect of the nose passages is lost and we are much more likely to have diseases of the throat and lungs. Mouth breathing may be just a bad habit; if so, we should overcome it at once. It may be caused by a stoppage of the nose by colds or by inflammation of the nose passages. This should be cured. But mouth breathing may also be caused by growths in the throat ("adenoids"), which partly close the opening from the nose into the throat. These should be removed by a physician, for they may cause not only mouth breathing and badly formed mouths, but also *deafness*. Children having adenoids often seem to be stupid, when they are really ill.

We should all practice full breathing, with head and shoulders erect, so that all parts of the lungs can get fresh air. If we must work indoors for long periods, we should go out of doors or to a window every little while, so as to get deep breaths of fresh air.

55. Exercises. — 1. Watch a person who breathes through his mouth; does such breathing affect his appearance?

2. How do *you* ventilate your sleeping-room? How should it be ventilated?

3. Tell how your schoolroom is ventilated.

4. What should be done with a child that breathes through its mouth?

5. How should people having tuberculosis be treated?

6. What is the real value of breathing exercises?

7. Is there any evidence of a greater amount of moisture in the air of your house on a wash day than on other days? Tell what happens and why.

CHAPTER VIII

HEATING THE AIR OF THE HOUSE

56. How Do We Heat the House? — What do we mean when we say that we "heat" our houses? Is it not that we heat the *air* of our houses and that it is through the heated air that we get heat to the objects of the house? When we say that we "keep in the heat" and "keep out the cold," we mean that we keep in, or keep out, as the case may be, the heated or cold air.

57. Fireplaces. — To heat their dwellings men have used open fires, fireplaces, stoves, hot-air furnaces, and hot-water, steam, and electric heaters. The Indian built a fire on the floor of his wigwam and let the smoke escape through a hole in the top. The Eskimo uses *blubber* (fat obtained from the whale) as the fuel to heat his house, or *igloo*. You may imagine the smoke and odors of these barbarous fires. Civilized man has improved greatly on these methods.

Nowadays we are likely to think of the **fireplace** as merely an ornament, but it is really very useful, no matter how the house is heated. It helps greatly in ventilating a house (cf. §§ 49 and 60), for it carries out the air near the floor and so makes room for fresh air.

In the early days of this country all heating, both for cooking and baking and for heating the house, was done by the fireplace (Fig. 35).

The **andirons** kept the fuel up from the hearth, so that air currents would be drawn through the fire. A **crane** (a swinging frame) could be swung out over the fire. From it, by means of chains, the kettles were hung. Kettles were also mounted on three legs, so that hot coals could be put under them. The **backlog** was a large log placed at the back of the fireplace. The **forestick** was in front, on the andirons; between the backlog and the forestick the smaller fuel of the fire was piled. The backlog sometimes lasted several days. Much of the light as well as the heat for the household came from the open fire (cf. § 23).

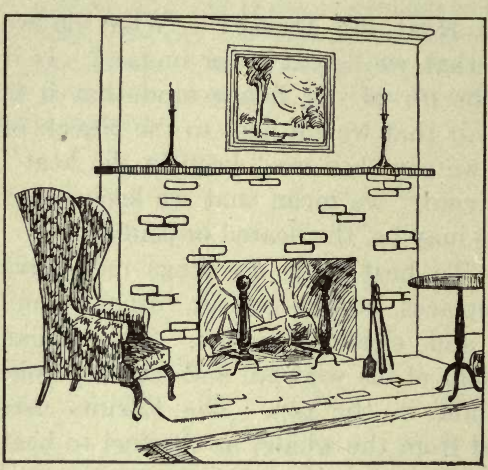


Fig. 35. — Fireplaces are put into modern houses both for beauty and for use.

58. Stoves. — The fireplace is only an open fire, such as a bonfire, surrounded with a flue for the escape of the waste gases. The whole fireplace opening serves for the entrance of fresh air. In a stove the fire is surrounded closely on all sides. There are **dampers** to control the entrance of air and a pipe to carry off the waste gases. In place of the andirons, there is a **grate** to hold the fuel up, so that air may pass through it. In a cookstove both the top of the stove and the oven must be heated, hence the stove has a " back damper " which does not allow the hot, waste gases to escape at once, but compels them first to travel around the oven and thus to heat the oven. Examine a stove and make out the course taken by the air that passes through it.

59. How Does a Fire Warm Us? — Put a flatiron on a hot stove; what happens? The iron becomes hot because the heat of the stove is passed over, or **conducted**, directly to the iron. To touch the handle of the flatiron with your hand would make a painful burn. To prevent this you use a **nonconductor** of heat, such as a pad of cloth or asbestos, or a wooden handle. If you put your hand into warm water, the heat of the water is conducted to your hand. When you put your hand into cold water, your hand gives heat to the water. The colder body or object is warmed **by conduction**. The air that touches a stove is also warmed by conduction.

But suppose you sit before the fire of a fireplace. The currents are all rushing toward the fire, so the air is not bringing heat to you. You are not touching the fireplace. Therefore you are not getting heat by conduction. How does the heat get to you? It would come to you whether you were above the fire, or below it, or on one side, just as the light of a lamp does. We say that the heat of the fire, like the light of a lamp, is **radiated** to you. Radiated is a word coming from *radius*, meaning the spoke of a wheel. The heat of the sun, as well as its light, comes to us by radiation through space. There are, then, two ways in which heat can come to us from a fire: (1) by **conduction**; (2) by **radiation**, in the form of "heat rays."

60. Hot-air Furnace. — Sometimes we speak of the way in which air rises when heated and falls when cooled as a *third* way of distributing heat: **convection** (cf. § 49). You can see that this is really not a new way at all, because in order that there may be warm convection currents in the air, the air must be heated by touching a hot body (conduction) or by means of heat rays (radiation).

The **hot-air furnace** makes use of the principle of convection currents. The air is heated in a tight "drum" which entirely surrounds the firepot of the furnace. When a fire is burning in the firepot, air currents are formed in the drum. As a result, warm air rushes up through the register, rises into the room, is cooled, falls again, and goes into the cold-air register, to be taken back to the drum to be reheated. You can understand the hot-air furnace better if you will study Fig. 36. From time to time fresh, outside air comes through the "cold-air intake" and after being heated is distributed to the house.

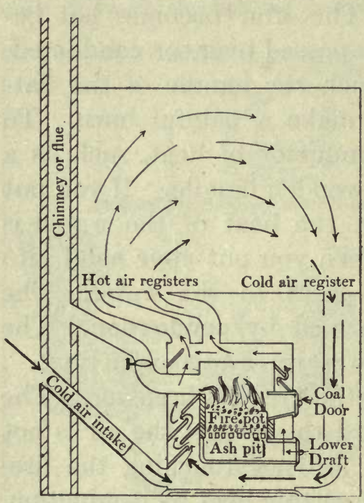


Fig. 36. — A hot-air furnace is a fire pot surrounded by a "drum" in which air currents are formed.

Do you think there are convection currents in a refrigerator? In order to cool the whole refrigerator, where should the ice be placed, near the bottom, or near the top?

61. Heating by Hot Water. — By examining a hot-water heating system, you will find that it consists of radiators in the rooms and a furnace in the basement (Fig. 37). The furnace, instead of being surrounded by air, is surrounded by a "jacket" of water. How is the heated water made to move from the water jacket to the radiators in the rooms above? We can carry out an **experiment** which will help us to understand this process (see Fig. 38).

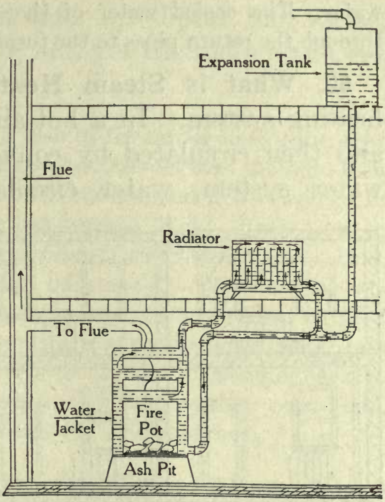


Fig. 37. — A hot-water heating system depends upon the convection currents formed in the water surrounding the firepot.

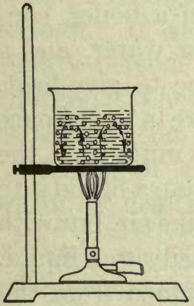


Fig. 38. — The sawdust helps us to see the convection currents in the water that is being heated.

Into a glass dish (beaker or flask) of water put a little sawdust and warm the dish by means of a small flame placed under it. Follow the movements of the sawdust. Are there convection currents in the water? The heated water acts like heated air. It is lighter than water of the ordinary temperature and rises to take the place of the cooler water at the top. Thus you see that the convection currents in water are caused by the rising of warm water and the falling of the cold water. The cooled water of the hot-water heating system flows through the return pipes to the furnace, to be heated over again.

62. What is Steam Heating? — Examine a steam-heating system. In a hot-air furnace, the air is heated and then circulated by convection currents. In a hot-water system, water circulates through radiators by convection. In the case of steam heating a new principle comes into play, although the steam heats the pipes and the heat is *conducted to* the air and *radiated into* the air as before.

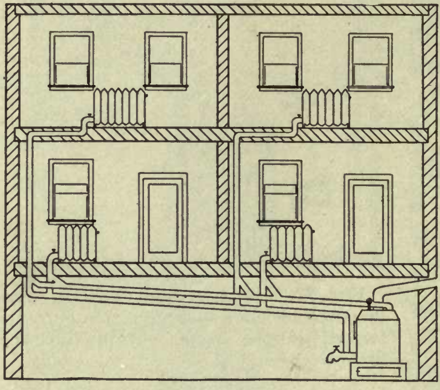


Fig. 39. — Steam-heated houses get their heat by the condensation of steam. The heat stored in the steam is set free when the steam turns into water.

The steam-heating system (Fig. 39) consists of a boiler, containing water, and a furnace to give heat. The fire in the furnace not only heats the water, but heats it so much that the water boils. The water, then, is changed from a liquid into a gas. We call the gas "steam." Steam is like air, but with this difference: the steam can condense easily to a liquid.

The heat used to boil the water is obtained from the burning fuel. This heat is stored away in the steam, but it can be gotten back, if the steam is allowed to turn into water. Does it seem strange that steam, when it condenses, gives off heat?

So steam at 100° C. could enter a radiator, and water, also at 100° C. could leave it, and yet the room could get a great deal of heat.

Perform this **experiment**: In a dish (a tin can or deep cup), heat some water to boiling and hang a thermometer so that the bulb is in the water. Let it boil for 10 or 15 minutes, until a considerable amount has boiled away. What has become of it? From time to time during the heating, notice the reading of the thermometer. Does the temperature change as the water boils away? What has become of all the heat that is added after the temperature ceases to rise? The answer is that this heat is used to change the liquid water into the gas form of water. Now when the steam is changed back to liquid water, as it is in the radiators, this heat appears once more, and by conduction and radiation heats the air of the room.

63. How Can We Know the Temperature of the House? — By the **temperature** of any object we mean its *degree of heat or cold.* Of course the nerves of the skin tell us something of temperature, but not accurately enough. If we want to keep a room warm to please an elderly person, we are likely to get it too warm for the children. The best temperature for the air of a house is said to be 68°–70° F. Americans living in cities, especially in apartments, usually have the rooms too warm for health.

Perform the following **experiment** to see how easily our sense of temperature is deceived: Have some cold water in one basin, some lukewarm water in another, some hot (not scalding) water in another. Put one hand into the cold water and the other into the hot; then put them both together into the lukewarm water. To the cold hand the lukewarm water feels hot, to the warm hand the lukewarm water will seem cold. Yet both are your own hands in the selfsame basin of water. Now put your hands on some oilcloth and on a rug; which is the colder? The oilcloth seems colder, because it conducts heat away from your hand, but it has really the same temperature, since both rug and oilcloth are in the same room and exposed to the same air. To get an accurate temperature, then, we cannot depend upon our feelings, but must use a **thermometer.**

64. How Is a Thermometer Made? — If you were given the problem of making an instrument to tell temperature, how would you set to work? We have learned that heat expands most substances, while cooling contracts them. **Galileo** used a glass bulb filled with air and a small tube partly full of water (Fig. 40). As the air of the bulb became warmer, it expanded and pushed the water downward; if the bulb was cooled, the air shrank and the water went higher up the glass tube. So he could tell whether the temperature rose or fell.

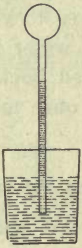


FIG. 40. — Galileo's idea of a thermometer.

Galileo's thermometer was not very accurate, but from it other men got the idea of measuring temperature by expansion and contraction of some substance. **Fahrenheit** used a glass bulb, as Galileo did, but instead of using air in the bulb, he used mercury. This is a liquid metal which expands and contracts, although not as much as air and water do. The tube must be very small as compared with the bulb. Sometimes alcohol, which requires an extremely small tube, is used. When the thermometer is made, the bulb is blown on the end of the tube, and the bulb and a little of the tube are filled with mercury. The bulb is then heated until the mercury fills all the tube. The open end of the tube is finally sealed. Modern thermometers are "graduated," that is, marked in "degrees." First the bulb is put into melting ice (Fig. 41, *a*), and the place at which the mercury in the tube stops is called the **freezing point**, or 32° F. Then the bulb of the thermometer is put into steam that comes off from boiling water (Fig. 41, *b*); this place on the tube is the **boiling point**. It is marked 212° F. Between the freezing point and boiling point 180 equal degrees are marked off (Fig. 42).

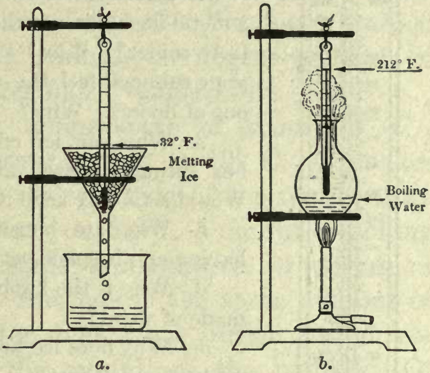


FIG. 41. — *a.* The "freezing point" of a thermometer is obtained by putting the bulb in melting ice. *b.* The "boiling point" is obtained by holding the thermometer in the steam coming off from boiling water.

65. The Two Thermometer Scales. — Some years after Fahrenheit, another scientist, **Celsius** (pronounced Sĕl′sĭ-ŭs), called the freezing point 0° and the boiling point 100° (Fig. 42). His thermometer is called the **Centigrade** thermometer; its abbreviation is **C.** You can see that if the mercury expands and contracts evenly, and if the glass tube has the same bore, or opening, throughout its length, we can mark degrees above 100° and below 0°. Thus, if we make a mark as far *above*

100° as the zero mark is *below* 100°, the new mark will be 200°. In this way we can mark mercury thermometers up to the temperature at which mercury boils and down to that at which it freezes. Why would not water be as good as mercury for a thermometer?

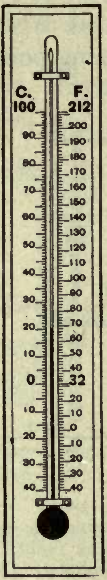


FIG. 42. — In the Centigrade thermometer the freezing point is called 0° C. and the boiling point 100° C.

66. **Exercises.** — 1. Which is really the colder, a metal door knob or the wood of the door? Which feels colder? Why? Do your woolen mittens, or your rubbers, feel the colder, if you have left both out of doors? Why?

2. Why can ice cream be carried in a paper box through heated air and yet melt very little? Would a tin box keep it better? Why?

3. Why are houses built with double walls having an air space between the walls?

4. Why is the knob on the cover of a teakettle made of wood?

5. Why does ice keep through the summer when packed in sawdust?

6. If you put the bowl of a silver spoon into a cup of hot water, the handle becomes hot; explain. Would the handle of a wooden spoon become hot too? Put an iron (" tin ") spoon and a solid silver spoon into a cup of hot water at the same time. Which handle becomes hot the sooner? Explain.

7. What method of heating is used in your house and school? Is anything done to keep the air moist?

8. How could you make an air thermometer?

9. Should steam pipes be put near the floor, or near the ceiling, in order to heat the room? Why? Where should the cold-brine pipes be put in a cold-storage room in order to cool the room? Why?

10. What are some of the advantages and disadvantages of the different heating systems?

CHAPTER IX

MORE ABOUT HEAT

67. Are Heat and Temperature the Same? — What is the **temperature** of any object? We have learned that it is the hotness or coldness, or **degree of heat**, of the object. Boiling water has a temperature of 100° C.; lukewarm water has a temperature of about 40° C.; cold water has a temperature of 0° to 10° C. It makes no difference, when you are speaking of the temperature of water, how much water you have; a cupful of boiling water has exactly the same temperature, or degree of heat, as a pailful has. But has it the same **amount** of heat? If you heat water over a gas burner, which requires longer heating, the cupful, or the pailful? Of course, the pailful takes the longer heating. If you used the water to warm yourself, which would give you the more heat? Of course the pailful would give you the more. In a house heated by hot water, we know that a large room requires a greater amount of hot water, that is, a larger radiator, than a small room does. From all these cases, we say that the amount of heat in a body depends not only upon the *temperature* of the body, but also upon the amount, or weight, of *matter* in the body.

68. Can Heat Be Measured? — If you want to warm some cold water, you can heat it over a fire, or you can put some hot water with it. Is there any way of knowing just how much hot water to use in order to heat the cold water to any given temperature? If you mix a pound of water at 100° C. with a pound of water at 0° C., what will the result be? You will have two pounds at 50° C. If you mix 1 pound at 100° C. with 2 pounds at 0° C., you will get 3 pounds at $33\frac{1}{3}$° C. One pound at 100° C. with 3 pounds at 0° C. will give 4 pounds at 25° C., and so on. The cold water gains the heat which the hot water gives up.

There is a great need for a **unit of heat**, so that we can speak of the quantity, or amount, of heat, just as we speak of the amount of sugar or iron. The amount of heat that is needed to heat a pound of water through one degree, Fahrenheit, as from 32° F. to 33° F., is called a **British Thermal Unit** (B. T. U.). The amount of heat required to heat 1 gram of water through one Centigrade degree, as from 15° C. to 16° C., is called a **calorie**. If you put a piece of hot iron into 1 gram of water and heat the water from 0° to 10° C., the iron adds 10 calories of heat to the water. If 100 grams of water at 10° C. are put into an ice box and cooled to 0° C., the water gives off 1000 calories of heat to the ice box. Since food is used to heat the body and to enable it to do work, we measure the value of food in calories.

69. Is Heat Needed to Melt Ice? — What becomes of the ice in an ice box? It melts. What causes it to melt? Of course the cause is the heat that is given to the ice by the box itself, by the air in the box, and by the food that is put into the box. As these give their heat to the ice, they themselves are cooled. The amount of heat needed to melt 1 gram of ice is able to heat **80** grams of water from 0° C. to 1° C.; that is, **80 calories.** It is because ice takes up so much heat in being changed to water that it cools the air in the box (cf. Fig. 43). People often speak as though we added "cold" to the food. Does ice conduct or radiate "cold"? When we think of the matter, we see that cooling anything is not adding "cold" to it, but taking heat *from* it. The food is cooled because it gives heat to the ice. By losing heat the food becomes cold. If you put enough chipped ice into water, the water is cooled to the melting point of ice, that is, to 0° C. Of course the amount of ice needed depends upon the weight and temperature of the water.

The temperature at which water freezes is the same as the temperature at which ice melts. So we put a thermometer into melting ice (cf. Fig. 41, § 64) to mark the "freezing point" on the thermometer. The temperature of ice and the water it forms by melting remain at 0° C. until all the ice is melted. In the same way, when water freezes, the ice and the water remain at 0° C. until all the water is frozen.

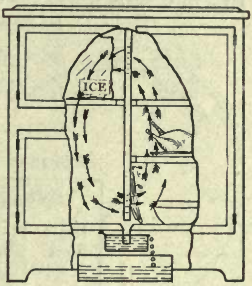


FIG. 43. — A refrigerator is a box in which food gives off heat to air currents and to ice and so becomes cooled. Note the arrows showing the convection currents; also the "trap" for cold air.

70. How Does the Body Keep Its Heat? — First let us ask how the body gets its heat? We learned in § 46 that the heat comes from the oxidation of our food (cf. Fig. 44). The excess of heat produced in some organs is given to the blood. The blood, by circulating through the body, makes the temperature of the body nearly the same everywhere.

Does clothing make us warm or cool? You will see that when you put on clothing in a cold room, the clothing has the same temperature as the room. But it keeps your body warm by preventing the heat of the body from escaping. If you wished to keep a piece of ice from melting, would you wrap it in woolen cloth, or in cotton cloth? Tramps put newspapers inside their coats, instead of putting on overcoats. Why? Clothing for preventing the escape of heat from the body should be of a material which is a **nonconductor** of heat.

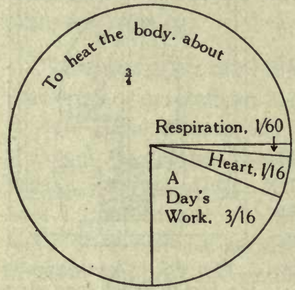


FIG. 44. — What becomes of the heat we obtain from our food?

Wool is the best of our common materials for warm clothing. Woolen goods are made from the natural covering of sheep, animals which live through very cold winters in the open. The feathers of birds keep the birds warm, not because the feathers are nonconductors of heat, but because they are loose. Did you ever see birds fluff out their feathers? By doing so they imprison a great deal of air in the meshes of the feathers. It is this air that is the real nonconductor and keeps the bird warm. Linen and cotton do not hold so much air as wool and are therefore better heat-conductors than wool. They make better clothing for summer than for winter.

71. Why Does Perspiration Cool the Body? — Perform this **experiment**: Wet your hands with water having the temperature of the room, and wave them rapidly to and fro, until the water has evaporated. Do they feel warmer or cooler? Also try the following: Put a few drops of ether or gasoline upon your hand and blow over it gently until the liquid has evaporated. What sensation do you feel?

From these experiments you can see that evaporation of liquids takes heat from bodies touching them and so causes the bodies to be cooled. This is what perspiration does for our bodies. It is constantly evaporating from the skin, even when we do not know it. If we are very hot from exercise, the perspiration is formed more rapidly than it can evaporate and we have "noticeable perspiration," or **sweating.** Heat is needed to produce evaporation of a liquid, just as it is to cause the boiling of a liquid, although evaporation takes place at a lower temperature. The heat which is needed for the evaporation is taken from the body. The liquid is changed into the form of a vapor, or gas, just as in boiling.

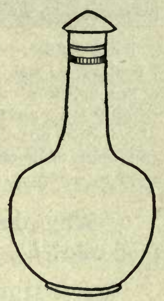


FIG. 45. — As water oozes through the porous jar, it evaporates and cools the water inside the jar.

In tropical countries a porous jar is used to cool water. As the water oozes out through the walls of the jar, it evaporates, and so cools the water that is left in the jar (cf. Fig. 45). Would you say that the jar should be left in a draft, or where the air is quiet? Where does perspiration evaporate most rapidly, in moving air or in a quiet room?

72. Exercises. — 1. Why does the sprinkling of water over a porch floor cool the porch in hot weather?

2. If you have a cup of boiling water, what is the quickest way to cool it? What becomes of the heat?

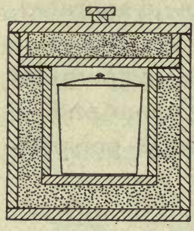


FIG. 46. — A "fireless cooker" is a box made of non-conducting materials; it does not allow the heat of cooking food to escape.

3. Do birds and other animals fluff out their feathers and fur in summer, or in winter? Why?

4. Why do we wear cotton and linen clothing in summer and woolen clothing in winter?

5. Is it correct to say that woolen clothing "keeps out the cold"?

6. Do you suppose that snow and ice evaporate without melting? How do you account for the fact that the sharp edge of a piece of ice becomes rounded, even in very cold weather?

7. How is a fireless cooker constructed? Why? See Fig. 46.

8. Is a fireless cooker also a "heatless" cooker? What is the source of its heat?

9. Why does a thermos bottle keep hot food hot and cold food cold?

CHAPTER X

WEATHER

73. What is the Weather? — All of us know what weather is. It is the temperature of the air outside our houses; the amount of moisture in the air; whether the sky is clear or cloudy; the amount of dew or frost, rain or snow; the direction of the wind and the rate at which it is moving. These are the things which we mean by "the weather." The *average* of the *weather conditions* at any given place makes the **climate** of that place. Inside our houses we try to control the conditions of the air, but outside our houses these largely control us.

The weather would not be so interesting to us if it were always the same, but it is continually changing. One day is fair and the next stormy; one is hot and the next cold; one has a strong wind from one direction, the next has a wind from nearly the opposite direction, and the third has no wind at all. So the expression, "changeable as the weather," is a common one. In thinking about the weather we should remember that we are surrounded on all sides by an ocean of air: the **atmosphere.** This covers the earth with a layer perhaps 200 miles thick. We should remember that the weather at the place where we live is the condition of only a very small part of the atmosphere. When we look at the weather of our country as a whole, we see that the changes that seem to be haphazard and fickle are parts of great air movements and that there is a cause for every change.

74. Of What Is the Atmosphere Composed? — We have already learned what air is like. It has weight and takes up room, like a liquid or solid object; it can be expanded or compressed. We have also learned that it is made up of more than one kind of gas. Its active gas is oxygen, which is used in burning and in respiration; its inactive gas is chiefly nitrogen. Another gas that is present in the atmosphere is **carbon dioxide** (cf. § 42). Besides these gases there is **water** in the form of vapor. Water vapor is taken up by the atmosphere, as the water of rains, lakes, and rivers evaporates. **Dust** is also found in the atmosphere; it contains a multitude of particles, some living and some not living (cf. § 204).

75. What Causes Dew and Frost? — Have you ever seen a pitcher, or glass, of water "sweat" on a hot day? Do you think the drops of water go through the glass? Suppose we perform this **experiment** (Fig. 47): Partly fill a polished metal cup, or small, smooth, metal pail, with water at room temperature and add small pieces of ice to it, one at a time. Add a new one only after the one before has melted. Stir the ice and water with the bulb end of the thermometer, noting carefully when the first moisture is collected on the outside of the metal vessel. Then read the thermometer. The temperature you find is the **dew point** of the air at that time. Find it on a day when the weather is clear, also on a rainy day. It varies according to the amount of moisture in the air. The air that cannot be cooled at all without depositing dew is said to be **saturated** with moisture, or " at the dew point." **Dew** and **frost** are *water* deposited from the vapor of the air upon cold objects, such as grass blades and stones. These objects cool more rapidly than air; so they cool the air near them, causing some of its water to be condensed. If the dew point of air is below 0° C., **frost** is formed instead of dew.

A **clear night** favors the forming of dew and frost, because the earth and the air cool more rapidly in clear weather than when clouds are present. Clouds act as a blanket over the earth and prevent rapid cooling. A **gentle breeze** brings fresh supplies of air to the cool objects and so helps in the formation of dew and frost. A strong wind, however, does not leave the air near the cool object long enough to allow dew or frost to be formed. Orchards and vineyards in hollows are more likely to be injured by frost than those on a hillside or on the hilltop, because the heavier, cold air falls into the hollows and remains there. Should orchards be planted in hollows?

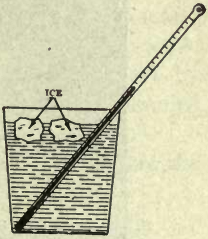
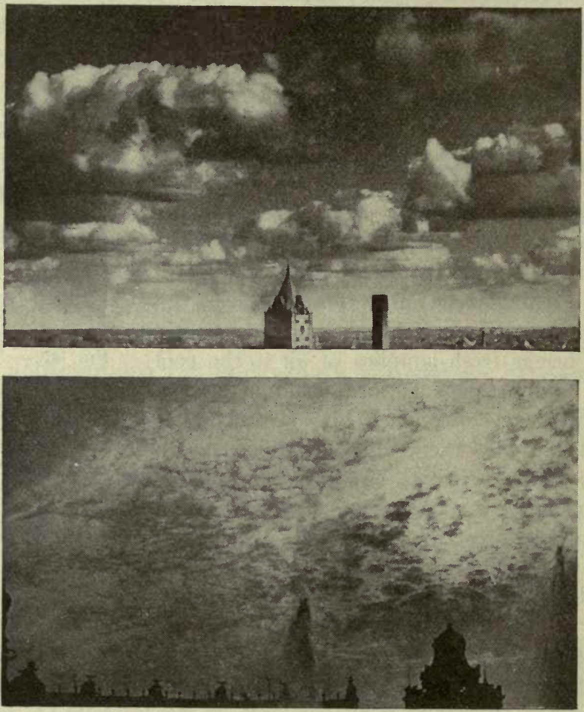


FIG. 47. — The temperature shown by the thermometer when moisture begins to appear on the outside of the metal cup is the "dew point."

76. How Are Clouds Formed? — Some people think that clouds are water vapor floating in the air. Is this true? In the first place, water vapor is an invisible gas, like the air itself. In the second place, the cloud particles are droplets of water and are heavier than the air. Why, then, don't they fall to earth? The answer is that they do fall, but that at a certain level, which forms the bottom of the cloud, they evaporate completely to form the invisible water vapor. It is because droplets are formed at one place and disappear at another that clouds change their forms so rapidly.



(*Copyright by International Stereograph Co.*)

FIG. 48. — *Cumulus* clouds are great, rounded masses; *cirrus* clouds are feathery or streaky.

If the water vapor in the air just above the ground is condensed to droplets, we have a **fog.** If this happens some distance above the earth, we have **clouds.** Clouds are often formed because ascending air currents loaded with water vapor meet cooler currents and are cooled below the dew point. If the sun's heat raises the temperature of the air above the dew point, fogs and clouds evaporate and disappear. Some clouds consist of **ice** particles.

Observe the clouds and see how wonderful they are, and how many different shapes they have. Some are rounded, like heaps of wool; these are called **cumulus** clouds (Fig. 48). They are formed by ascending air currents. "Thunderheads" are one form of cumulus clouds. They are one or more miles high.

Cirrus clouds are feathery, or made of distinct lines. They are the highest: often five miles above the earth (Fig. 48).

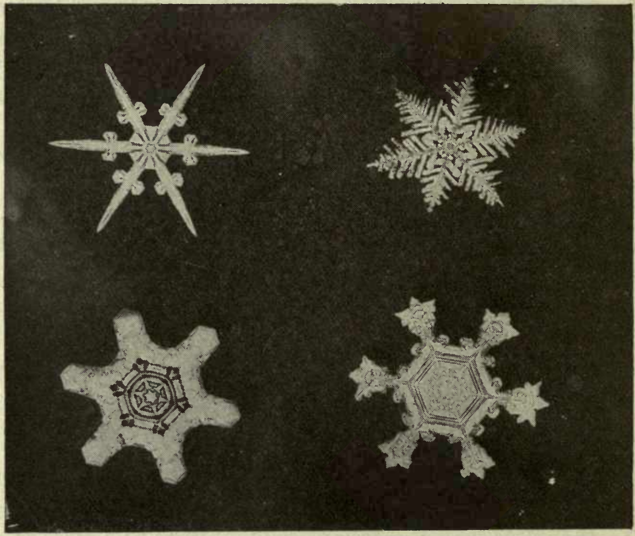
Stratus clouds are in *layers*. They are about $\frac{1}{2}$ to 3 miles high.

Nimbus clouds are like great dark "veils." They are cumulus or stratus clouds depositing rain or snow (Fig. 53, § 80).

77. Why Do We Have Rain, Snow, and Hail? — You know how different rains can be: sometimes the rain falls in tiny drops, at other times in great splashes. Snow is often made up of tiny grains and again of large, fluffy flakes. How large the raindrops shall be depends upon how the *droplets* are condensed. Raindrops are made up of a large number of cloud droplets united. These big drops fall through the air and reach the earth before they can be evaporated. If the condition of the air is right for a rain, but the temperature is below 0° C., we have **snow** (Fig. 49).

Hail is made up of layers of ice and snow. At the center there is probably a frozen raindrop. The frozen drops are carried upward by air currents; then they fall down some distance and are carried up again, until they take on many layers. Finally they are too heavy for the air currents to support, so they fall as hail. Hail does a great deal of damage to window panes, trees, and crops.

78. What is Rainfall? — Rain is so necessary for crops, that its amount is very important to a country. If you examine a rainfall map of our land (Fig. 50), you will find that one region gets less than 10 inches of rain in a year; while another region gets 60 inches, and another even 80 or 100 inches. Before this map could be made, the rainfall had to be measured for many years. Rain is caught in a **rain gauge** (Fig. 51). The opening of the



(Courtesy of the McIntosh Stereopticon Co.)

FIG. 49. — The delicate lines of snowflake and frost.

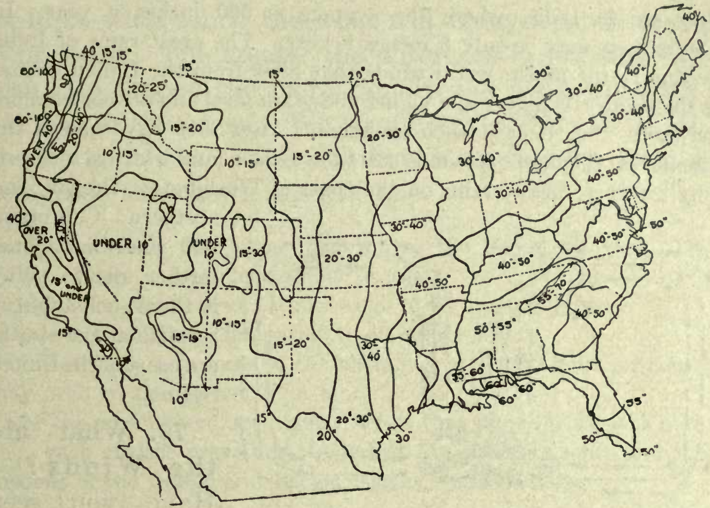


Fig. 50. — The figures show how much rain, on the average, falls each year in different regions of the United States.

funnel is made just 10 times as large as the cross section of the stem, so that $\frac{1}{10}$ of an inch of rain makes a depth of 1 inch in the stem.

Make a simple rain gauge by putting a baking powder can in the yard and measuring the depth of water in it after a hard rain. Keep a record of every rainfall for a month or so.

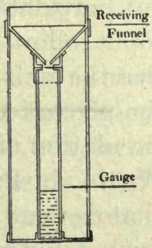


Fig. 51. — A rain gauge. The opening of the funnel is ten times as large as that of the stem.

Snow is measured as rain, the snow being allowed to melt. When we remember that more than half the earth has less than 20 inches of rain in a year and has, therefore, not enough for farming, we see why the rainy regions have been more thickly settled by man. The greatest rains are in India, where the average is **500** inches a year. In deserts there may be only 5 inches a year. The great rains of India are due to the moist, warm winds that blow from the Indian Ocean. As the winds rise higher and higher above sea level and are cooled more and more, they deposit their moisture. After they have passed the Himalayas, they are dry winds and blow over a land which is a desert. Why are there heavy rains on the coast of Washington, Oregon, and northern California, and such light ones farther east? Why is there such a heavy rainfall on the southern coast of the United States?

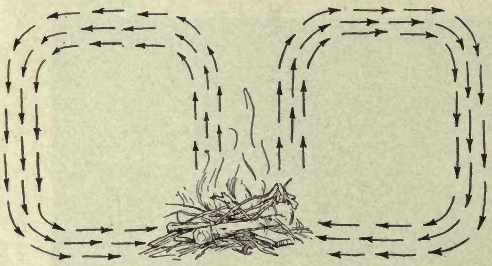


FIG. 52. — Air currents over a fire, or over the heated earth, rise to a certain height, then flow out horizontally, and finally fall again to the earth as they become cooled. Tell why.

79. What are the Winds? — Have you seen the smoke and sparks from a large bonfire on a quiet evening? They rise almost vertically and then move out horizontally before they come down (Fig. 52). If we could follow the currents of air near the fire, we would find that the air is flowing *along the ground* toward the fire, to take the place of that which ascends. Thus we get a complete circulation of air, because some of it is heated by the fire. We do not feel the currents that ascend, nor the currents that descend, but we feel those that flow along the ground. Such *horizontal* air currents are the **winds**. The air is very free to move, and if the air pressure becomes smaller at any given place, the heavier air around that place crowds in from all sides and pushes the lighter air up.

The force with which the wind will blow depends upon the pressure. The greater the difference in pressure between two places, the more rapidly the wind will blow from one to the other. We should expect this to be so, since we know that water will flow more rapidly down a steep grade than down a gentle one.

A **light** wind is one which just moves the leaves of trees. Its velocity, or rate, is 10 miles an hour or less.

A **high** wind sways trees; it moves 25 to 40 miles an hour.

A **gale** is air rushing along at 40 to 60 miles an hour.

In a **hurricane** or a **tornado** the air moves above 60 miles an hour; it may even go as high as 200 or more.

Over the ocean there are regular winds that blow for months at a time; such are the **prevailing westerlies** of temperate zones and the **monsoons** of the Indian and Pacific Oceans.

Carry out the following **experiment**: Fill one saucer with dry, black earth and fill another with water. Let both stand until they come to the temperature of the room; then set them side by side in the sunlight. With a thermometer tell which is warmed the more rapidly.

Land breezes and sea or lake breezes are due to the fact that the earth is heated more by day than the water is, and is cooled more at night. Because of this fact, ascending currents rise over the land during the day and over the water at night. When the heated air current rises over the land, a horizontal current of air flows in from the sea. Thus we have a **sea breeze** during the day. At night the wind blows from the land to the sea (the **land breeze**).

80. What Causes Our Great Storms? — You already know one of the effects of the rotation of the earth on its axis: it causes day and night. It also has a great deal to do with the winds. If the earth were not turning, the winds would blow toward the place having a low pressure, much as they do now, but they would blow **directly** there, in a straight line, just as the spokes of a wheel come together at the hub. But the rotation of the earth on its axis causes the winds to blow toward the "low" region **in a curve**, hence the air at the center is set to whirling. A whirling mass of air doing this on a small scale is called a **whirlwind.**

Fig. 53. — In a lightning discharge the electricity bursts through the air and passes from cloud to cloud or between clouds and the earth.

In a **cyclone** the whirling mass of air may be 1000 miles in diameter and 5 miles high. In the northern hemisphere the air is set whirling in a direction opposite to the movement of the hands of a clock; in the southern hemisphere the whirl is in the direction in which the hands of a clock move. In the northern United States the whole area of low pressure moves easterly at the rate of about 30 miles an hour.

Our cyclones are not *tornadoes*, but the "cold waves" that sweep down upon us more or less regularly in both winter and summer.

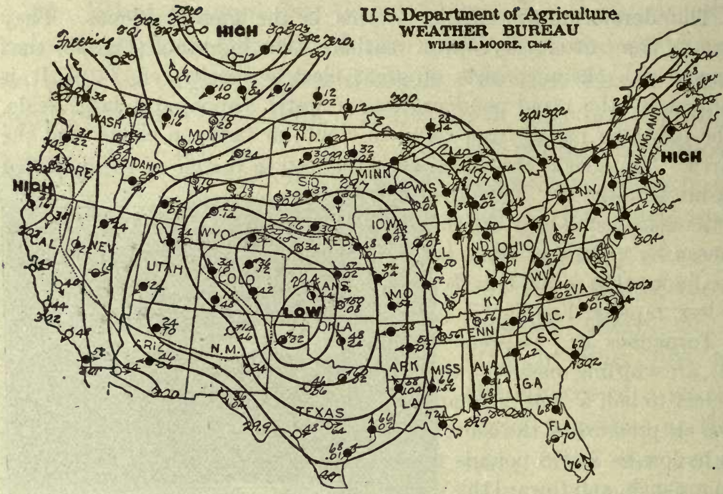
Thunderstorms are smaller storms in the great cyclones. They usually come after very warm weather. The lightning (Fig. 53) that comes with them consists of great electric sparks (cf. § 2). It is formed by the rapid condensation of water vapor on a large scale. The lightning passes from cloud to cloud, or between clouds and the earth. Thunder is the vibrations produced in the air as the lightning flashes through it. From the time it takes for us to hear the thunder caused by a flash of lightning, do you judge that sound travels more, or less, rapidly than light?

Tornadoes, or "twisters" (Fig. 54), are whirling masses of air from 50 feet to half a mile in diameter. The air pressure at the center may be as low as 7 or 8 pounds to the square inch, and toward this center the wind may blow as rapidly as 200 miles an hour. The tornado can pick up bowlders, cut houses in two as a great knife would, and can turn locomotives over. Frail objects, such as straws, may be driven into oak wood.

FIG. 54. — How a Western "twister" looks when it goes into action.

When seen coming, a tornado looks like a heavy cloud shaped like a funnel. The lower end dangles along the ground, touching it here and there. Our tornadoes move northeastward at 25 to 40 miles an hour.

Hurricanes are violent storms that arise in the Atlantic off the northern part of South America. Similar storms in the Indian and Pacific Oceans are called *typhoons*. They are whirling masses with a diameter of 300 miles or more, and having very violent wind and rain. The West India hurricanes move northwest until they reach the southeastern coast of the United States; then they move northeast and finally into the Atlantic. They come in the summer and cause great damage to life and shipping. Not only do they bring wind and rain, but also great storm waves that sweep over the low portions of the coast.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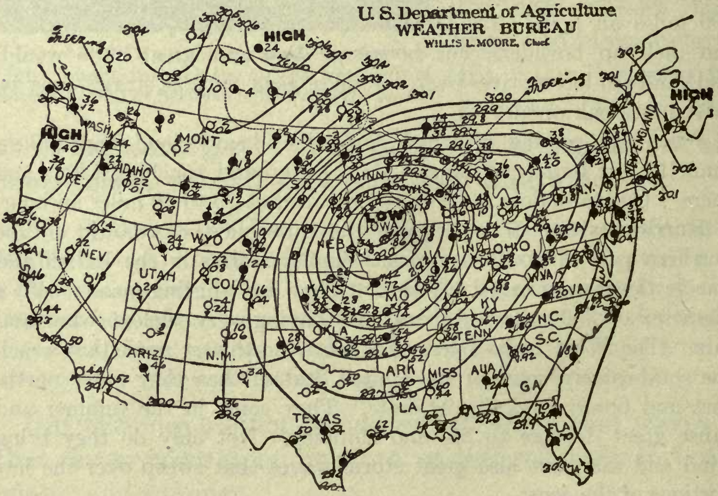
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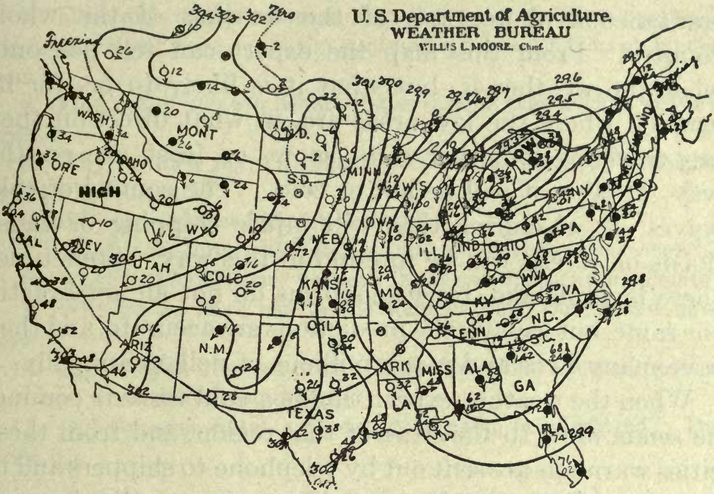


FIG. 55. — Figs. 55, *a*, *b*, and *c*, are weather maps of three successive days. Note the "low" area has moved to the northeast. The arrows show the directions of the wind. The first figures beside the arrows show the temperature; the second figures show the rainfall in inches during the preceding 24 hours; the third figures (if present) show the wind's velocity. Other signs are:

○ clear ; ◉ partly cloudy ; ● cloudy ; Ⓡ rain ; Ⓢ snow ; Ⓜ report missing.

81. What is the Weather Service? — Did you ever visit a weather office? If you did, you found there delicate instruments for recording the direction and velocity of the wind and for measuring the rainfall, the temperature, the atmospheric pressure, and the amount of water vapor in the air. These facts are recorded each day at 8 A.M. on the Atlantic coast and at 5 A.M. on the Pacific coast; they are then telegraphed to Washington. When all the results are put together on a weather map (Fig. 55), they give the expert at Washington an instantaneous photograph of the weather of the whole country. From this map the expert can tell not only what the weather is, but what it is likely to be, for he can tell where the low areas are, in what direction they are traveling, whether rain, snow, or frost are on the way, whether it will be hot or cold. The coming of cold waves, or of storms that will injure shipping or cause floods on rivers, can be foretold in this way. Sometimes there is a mistake, because storms do not all act exactly the same, but usually the predictions are accurate, and they save many lives and many millions of dollars annually.

When the weather expert thinks a cold wave is coming, he sends word to the cities of that region, and from these cities warnings are sent out by telephone to shippers and to farmers. Signs are also placed on trains, so that farmers are warned to do all they can to save crops. In a similar way warnings of coming storms are sent to ship captains.

Weather Maps. — On a weather map you will see heavy solid lines joining places that have the same atmospheric pressure in a given region; these are called **isobars**. We can see from the map that the isobars curve irregularly about the regions of low pressure and high pressure. The "lows" show cyclonic storms. The "highs" bring the sharp, bright weather which follows storms. There are also dotted lines to join places having the same temperature; these are **isotherms**. Generally only the isotherms for freezing and for zero weather are shown. The map shows also the temperature of the weather stations of the country, the direction of the wind, and the amount of rain or snow.

82. Exercises. — 1. Examine weather maps for several successive days. In what general direction do the "lows" move?

2. What is a weather vane? Its shape? Why does it have this shape?

3. Fishermen on the seacoast often sail out at or before daybreak and return about noon. Do the land and sea breezes help or hinder them?

4. Find out, if you can, what are the various flags used as weather signals.

5. Why do men say, "If the wind doesn't 'come up' tonight, we shall have frost"?

6. Why are weather forecasts valuable?

7. What is the force which makes great waves rush up on a beach?

8. What is the difference between the terms weather and climate?

9. Why do we have hail in the summer time, but do not have snow?

10. Suppose you were watching a barometer while a tornado passed near you, what should you observe?

11. Did you ever watch a miniature tornado, or whirlwind? Describe it.

[illegible]

When the weather [illegible]

[illegible] Signs are also placed on trains, so that farmers are warned to do all they can to [illegible]

Weather Maps.—On a weather map you will see heavy solid lines [illegible]

98. **Exercises.**—1. Examine a weather map [illegible] In what general direction [illegible]

What is a weather vane? [illegible]

[illegible]

PART III

MATTER AND ENERGY IN EARTH AND SKY

CHAPTER XI

THE HEAVENLY BODIES

83. What is the Earth Like? — We like to think of our earth as a great, solid floor on which we stand and on which we can depend. We speak of getting down to the firm earth. But if we wish to get a correct idea of what our earth is like, we must imagine ourselves as standing off in space and looking back at the earth. Then we shall see it as a great, round ball turning with dizzy speed from west to east and flying with still dizzier speed in its great path around the sun.

The ancient Greeks knew that the earth is round and that it turns or **rotates.** They had even worked out a way of calculating its size, but their work was afterwards forgotten. So it came about that when Columbus, in the latter part of the fifteenth century, said that our earth is a great ball, the people of his day made fun of him. As we know, the time the earth takes for one rotation is a **day.** The imaginary line, or **axis,** around which the earth spins, passes through the north and south poles.

With a tapeline measure carefully the distance around (the **circumference** of) a round plate, or hoop, or wheel; then measure the distance across it, through the center (the **diameter**). How many times as great as the diameter is the circumference? Then measure the circumference of a tennis ball, or croquet ball, or baseball, and calculate its diameter.

By very careful measurement men have found that the circumference of the earth at the equator is nearly 25,000 miles. What, then, is its diameter?

How rapidly must a spot at the equator be turning? Do you see that it must turn through about 25,000 miles in 24 hours, or at the rate of about 1000 miles an hour?

We may give the earth's rate of rotation in another way:

We know that the distance around a circle may be measured in *degrees*, each complete circle having 360 degrees (written 360°). The distance around a sphere like the earth is measured on a circle that passes around it, and is also stated in degrees. Since the earth spins about on its axis once in every 24 hours, in one hour it goes through 360 ÷ 24, or 15 degrees.

84. What is the Sky? — Have you ever looked along a straight picket fence and observed that the pickets all seem to be at about the same place? Yet our judgment tells us that they are one behind the other. Perhaps you have noticed how hard it is to tell which of a group of mountain peaks are near and which are farther away. All distant objects seem to be at about the same distance from us. So it is with the sky. The sky seems to be a hollow sphere and the heavenly bodies all seem to move across its surface. Yet the truth is that some of these bodies are enormously distant as compared with others. When we see the moon near a certain bright star, their nearness to each other is due to the fact that they are in the same direction from us, one beyond the other. Just in the same way the sun and moon at intervals of about four weeks seem to be almost at the same place in the sky (the time of "new moon"), although the sun is much farther away than the moon.

While it is true that the sky is just a make-believe sphere, we must learn its parts if we want to study the heavenly bodies. The circle in which the sky and earth seem to meet is the **horizon** (Fig. 56). It is the line beyond which we cannot look because the bulging surface of the earth is in the way. The horizon has its four points: north, east, south, and west. The point in the sky exactly above you is the **zenith**.

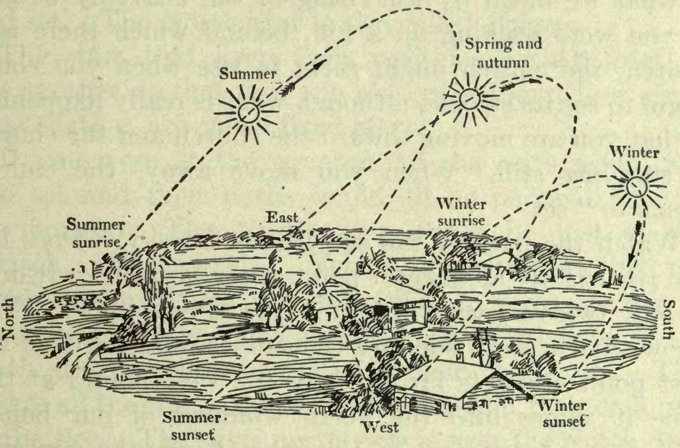


FIG. 56. — The path of the sun across the sky in the four seasons of the year. When is the sun above the horizon for the longest time? The shortest? (Suggested by Todd's Astronomy.)

85. Why Do the Heavenly Bodies Rise and Set? — As you look at the sky, you see that the moon and the stars, like the sun, rise in the east and set in the west.

Men used to suppose that all these bodies turned, or revolved, about the earth, but we now have many proofs that the earth is turning, or rotating, on its axis once every 24 hours, and that it is this rotation of the earth that brings us back each day to such a position that we can again begin to see the same heavenly bodies. This is what we mean by the **rising** of the heavenly bodies. If you were walking up a hill, behind which there is a church, the church might seem to rise when you could begin to see its steeple, although what is really happening is that you are moving toward the church and the church is standing still. When you move away, the church seems to "set."

Watch the path of the sun across the sky. Does the sun rise exactly at the east point of the horizon? It does so only twice a year: in March and in September. You know that in early summer the sun rises far north of the east point and sets far north of the west point; at this time it shines into the north windows of our houses (Fig. 56). In winter, on the other hand, the sun rises far south of the east point and sets far south of the west point.

86. What is the Path of a Star across the Sky? — Are there any stars that do not rise and set, but are always above the horizon? If you look at the northern sky on a bright night, you will see the Big Dipper. This is a group, or **constellation**, of seven principal stars. The two bright stars, which make one side of the bowl of the dipper, point toward the North Star and are known as the "Pointers." If you live in the northern states and watch the position of the Dipper at a given time — say at 8 P.M. — every week or two during several months, you will find that it revolves about the North Star in a complete circle and is always above the horizon. If a star is somewhat farther away from the North Star than the Dipper is, it will be above the horizon part of the time and below it part of the time; that is, it will rise and set. The North Star is also called *Polaris*.

The stars that keep their positions with respect to one another, so that they can always be found in a given constellation, are called **fixed stars.**

If you were at the equator, all the stars would rise and set and their paths would all be perpendicular to the horizon. The North Star would be just at the horizon. Why is this? You must remember that the daily motions which the stars seem to have are due to the turning of the earth and that the north pole of the earth always points to the north pole of the sky. This makes all the stars seem to revolve around the north pole of the sky. The sky's north pole is near the North Star.

87. What are Some Star Groups? — We have already learned of one star group, or constellation, called the Big Dipper. This is part of a larger group called the *Great Bear.* If you try to make out the shape of the Great Bear, you will need a great deal more imagination than to find the Dipper. Many of the constellations received their names centuries ago from the Egyptians, the Greeks, or the Arabs; others are more modern. The stars and constellations made out by the ancients were named after heroes, animals, or events.

The Dipper is only one of several constellations near the North Star. Another one is the *Little Dipper;* this is a part of the Little Bear. The North Star is at the end of the Little Dipper's handle, or at the end of the Little Bear's tail. See the star map (Fig. 57, *a* and *b*) in this chapter.

Let us look for another constellation. Imagine a circle in the northern sky and that the North Star is at its center; also imagine that the circle passes through the Big Dipper Look on the opposite side of the circle and you will find the pretty group called *Cassiopeia.* It looks like a *chair.*

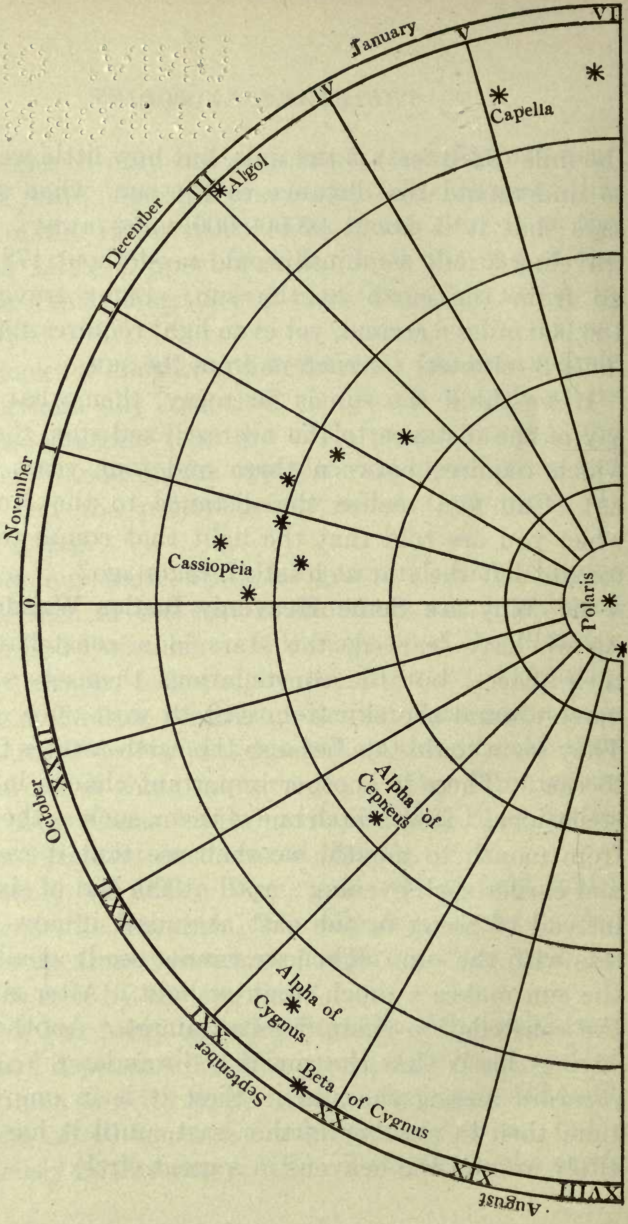
Probably our most beautiful group of constellations is the one seen in the east in the early evening during November and December. It is made up of the *Pleiades,* a brilliant cluster, followed by the red star, *Aldebaran,* in the eye of Taurus, the Bull. Behind these and a little farther south is *Orion,* with his belt of three bright stars and his sword of three fainter ones. After Orion comes the *Great Dog* (Canis Major) with the Dog Star, *Sirius.* This is the brightest fixed star of the sky.

The *Galaxy,* or Milky Way, is a belt of light which passes across the heavens. The telescope shows us that it is made up almost entirely of separate stars, each too small to be seen by the eye alone.

88. How Far Away are the Stars? — The brightness of the stars depends upon how much light they give off and also upon how far away from us they are. The star Sirius gives off 40 times as much light as our sun, but it is enormously farther away. For distances on the earth, the mile (5280 feet) is the unit, but how little we are able to understand the distance to the sun, when some one says that it is about 93,000,000 miles away! A train traveling a mile a minute would need about 178 years to go from the earth to the sun. Light travels about 186,000 miles a second, yet even light requires 499 seconds (over 8 minutes) to reach us from the sun.

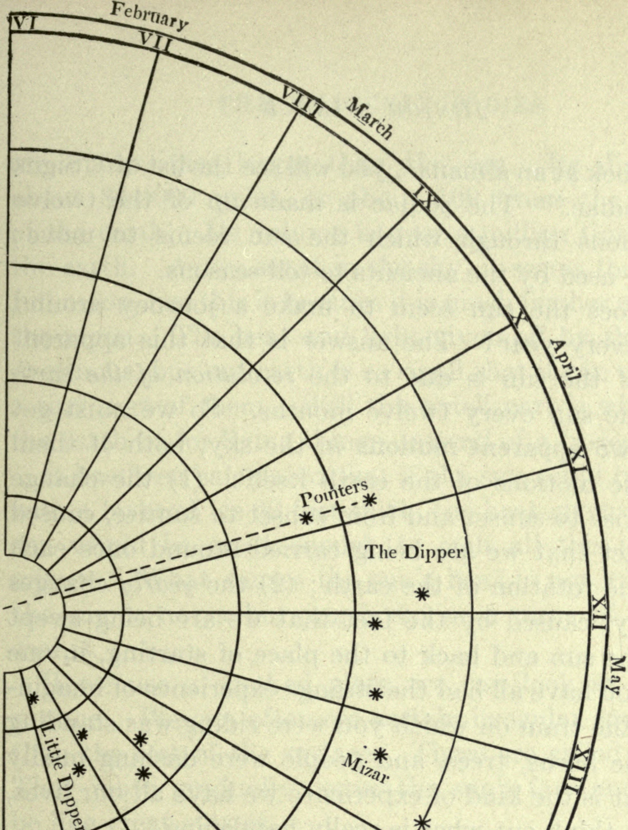
If we think the sun is far away, then what shall we say of the distance to the nearest fixed star, the light of which requires between three and four years to reach us? Can you realize the distance to the North Star when you are told that the light that comes to our eye tonight left the star at least 47 years ago?

89. Why are Some Heavenly Bodies Wanderers? — As we have learned, the stars in a constellation hold their places, but the constellations themselves seem to move around the sky from east to west once each day. They seem to do this because the earth rotates from west to east. There is another important change in the constellations. If we watch one of them, such as the Pleiades, from month to month, we shall see that it rises earlier and earlier each evening; until at the end of six months, instead of rising in the east at sunset it now rises and sets with the sun. Then we cannot see it at all, because the sun makes a much brighter light. After six months the constellation again rises at sunset. Another way of saying this is that the sun is a "wanderer" and moves *eastward* among the stars. First it is in one constellation, then in another farther east, until it has gone entirely around the heavens in a great circle.



a.

FIG. 57, *a* and *b*. — Fold the inner margin of the page so that the halves hold the map so that the North Star of the map is directed toward the North of the map; the stars will then appear somewhat as they should be at about from the pole. (Suggested by Young's Astronomy.)



b.

of the map come together. Grasp the book with both hands, face north and Star of the sky. Turn the map so that the present month shall be at the top 8 P.M. The map shows some of the constellations that are less than 50 degrees

If you look at an almanac, you will see the list of "Signs of the Zodiac." The zodiac is made up of the twelve constellations through which the sun seems to move; they were used by the ancients to tell seasons.

Why does the sun seem to make a journey around the sky every year? The answer is that this apparent moving of the sun is due to the *revolution of the earth* around the sun every twelve months. So we must get used to **two apparent motions** in the sky, both of them due to the motions of the earth itself: (1) the change from sunrise to sunset and from sunset to sunrise, caused by the fact that we are being carried around once each day by the rotation of the earth; (2) the *yearly* changes in the sky, caused by the fact that we are being swept around the sun and back to the place of starting, in one year. You have all had the strange experience of imagining that the train on which you were riding was standing still, while barns, trees, and people were dashing madly by. That is the kind of experience we have all our lives, unless we think out what is really happening.

Besides the sun and the moon, there are several other heavenly bodies which do not remain in any constellation as the fixed stars do; these are the **planets**, or wandering stars. They appear to move irregularly among the stars because they really revolve about the sun, just as our earth revolves around it. When they seem to be in a certain constellation, it is because they are between the earth and that constellation.

90. What is the Sun Like? — The sun is a star. While it seems to us to be very large, we know that there are many stars larger than the sun. Its diameter is about 864,000 miles, or about 109 times the diameter of the earth. Its volume is over a million times that of the earth. As we see it in the sky, it seems the size of a full moon, but this is because it is much farther away than the moon. The heat and light given off by the sun are enormous, but our earth is so small that it can catch only a tiny part of them. Still this small part is what makes the earth fit for living things, instead of a frozen ball.

It has been calculated that if the sun could be covered with a layer of ice 60 feet thick, the heat given off by the sun would be great enough to melt all this ice in one minute. What causes the sun's heat is not known, but the sun is not a burning body, as a piece of white-hot coal is.

If we use a smoked glass, we can look at the sun's surface. We can often see certain irregular spots darker than the rest of the surface. These are called **sunspots.** They move gradually across the sun's face and seem to be like great storms.

The sun rotates on its axis, as the earth does.

91. What is the Solar System? — The planets are bodies like the earth in that they revolve about the sun and shine by the reflected light of the sun. Many of them have moons that revolve about them. So the sun, the planets, and the moons are all parts of the solar system. The planets, in the order of their distance from the sun, are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune (Fig. 58). The largest of these is Jupiter, with a diameter nearly 11 times that of the earth. However, all the planets together contain only about $\frac{1}{700}$ as much matter as the sun.

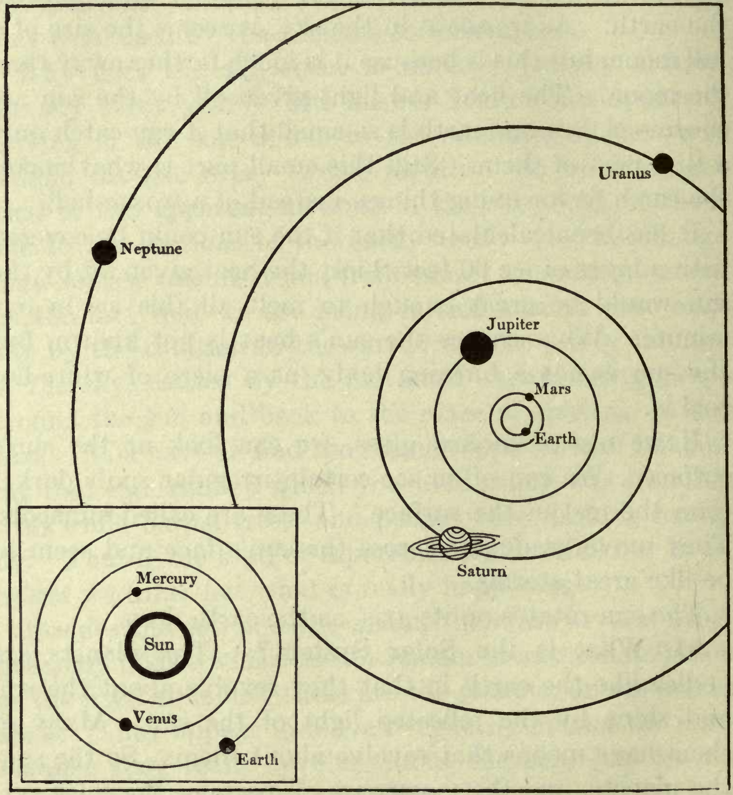


FIG. 58. — The planets revolve about the sun. The average distance of Neptune from the sun is about 2,700,000,000 miles. What is that of the earth?

Mercury, Uranus, and Neptune cannot be seen well without a telescope. The planets are always found in the same belt of constellations — the Zodiac — in which we see the sun and moon.

The **time** needed for each of the planets to revolve once about the sun is as follows:

Mercury	3 months	Jupiter	12 years
Venus	$7\frac{1}{2}$ months	Saturn	30 years
Earth	12 months	Uranus	84 years
Mars	22 months	Neptune	165 years

While the earth's rate of rotation at the equator is about 1000 miles an hour, its rate of revolution about the sun is about 1000 miles a *minute*. This is perhaps 40 times the speed of a bullet as it leaves the muzzle of an army rifle.

92. Our Neighbor, the Moon. — After we have thought of the enormous distances from the earth to the sun and the stars, the moon seems just across the way. The moon is our nearest neighbor in the heavens; its average distance is about 240,000 miles. The moon's diameter is 2163 miles and its volume is about $\frac{1}{49}$ that of the earth.

Our moon revolves in a path, or orbit, that is nearly a circle. From new moon to new moon is a "moon," or a *lunar month;* it is about 29 days, and was formerly used in reckoning time. The surface of the moon (Fig. 59) is made up of what seem to be smooth plains and also mountains which have hollows, or *craters*, that make them look like volcanoes.

We have all watched the change, night after night, from new moon to full moon. Some evening, just after sunset, a slender *crescent* is seen in the west. This is really a day or two after new moon, because at new moon the moon is too near the sun to be seen at all. The next evening the crescent moon is thicker and farther away from the sun. This continues until the half moon is seen; the moon then sets about 6 hours after the sun. The period from new moon to half moon is called the "first quarter." From new moon to full moon the moon is said to be "waxing" or growing. The full moon rises at sunset; why? From half moon to full moon is the "second quarter." After full moon the moon is "waning." From full moon to half moon is the "third quarter." In the "fourth quarter" the moon shrinks once more to a crescent (the "old moon") and finally

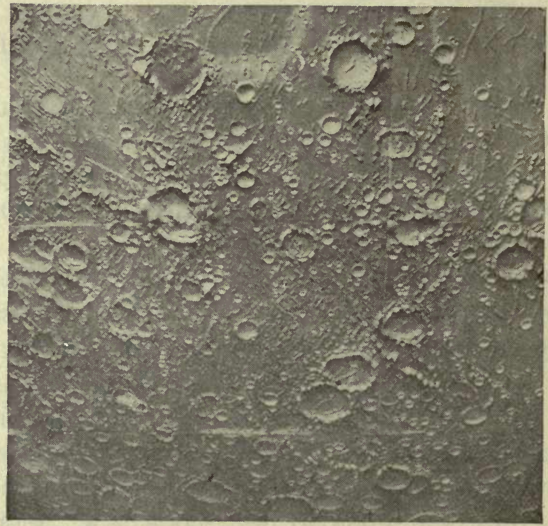


FIG. 59. — A part of the moon's surface.

rises just before the sun. But the moon rises about 50 minutes later, on the average, each day and soon appears again as a crescent just after sunset.

Half of the moon's surface is always lighted by the sun, but we see only that part of the lighted surface which is turned toward us. When we see the "old moon in the new moon's arms," we see the "old moon" by **earth shine**, that is, by sunlight that is first reflected by the earth to the moon and then back from the moon to us.

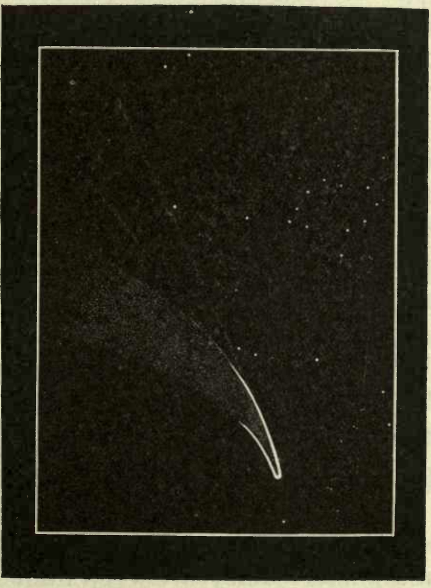


FIG. 60. — Naked-eye view of a great comet. (After Young.)

93. What are Comets and Meteors? — What a wonder and a terror a comet (Fig. 60) must have been to early man! Comets usually appear in the heavens unexpectedly, grow brighter night after night, move among the constellations until they rise and set with the sun, then move away from the sun, grow smaller, and finally disappear.

Most comets are small, but some have been very large and beautiful. Usually they can be seen only at night, but the very bright ones are also visible in the daytime. A comet has the appearance of a shining fog, or veil. It is rounded off at one end into a blunt "head," while a "tail" of light is spread out behind it. The tail always points away from the sun. Stars can be seen shining right through the material of a comet. The comets we see all revolve about the sun, but in paths that take them far out of our vision (see Fig. 58) for many years at a time.

Meteors are heavenly bodies that fall on or into the earth. When seen at night, a meteor is like a ball of fire followed by a stream of light. If we were near enough, we could hear a dull roar as it tears its way through the air. Usually it throws off sparks and fragments of matter during its passage. Sometimes the meteor disappears; sometimes we learn where it strikes. Usually, instead of falling to the earth as one body, it bursts into many pieces. Often tons of stones come from a single meteor. A few meteors consist of almost pure iron mixed with nickel.

Did you ever see a **shooting star?** Shooting stars are small fragments of matter that fall into the earth's atmosphere. They are very numerous and many may be seen on a clear night. They never reach the ground, except in the form of dust and ashes so fine that we cannot see them falling. Did you ever realize before that matter comes to us all the time from the space through which the earth moves?

94. Exercises. — 1. Have you read about "daylight saving"? Why was it carried out? How?

2. Why is a day divided into "forenoon" and "afternoon" instead of day and night?

3. The Indian said that an event was so many "moons" ago; what did he mean?

4. What festival is still fixed by lunar, or moon, time?

5. Name the planets in the order of their distance from the sun.

6. Coat a piece of glass with soot and see if you can find "sun-spots" on the sun.

7. Does the moon revolve about the sun?

8. What causes the four "quarters" of the moon?

9. What is the horizon? The zenith? The zodiac?

10. When is wheat harvested in Iowa? In Argentina?

11. What do you suppose causes a "ring around the moon"? Is the ring near the moon?

12. How do you imagine the earth would look if seen from the moon?

13. What daily path would a star have if you were at the earth's north pole? What path would the sun have?

14. On a sunny day measure the length of the shadow of a certain post, such as a fence post, in the morning, at noon, and in the late afternoon. When is it the shortest? Why?

Measure the shadow at noon every week or two for several months and keep an accurate record of the month and day on which the measurement was taken. What change do you notice? Explain it. On what date would the noonday shadow be the longest? Why?

15. In an almanac read the time of sunrise and sunset from autumn to spring. What day is shortest? In what month does the sun rise at almost the same hour and minute for several days in succession? Is this true at any other season?

CHAPTER XII

FORCE AND ENERGY

95. What Holds the Solar System Together? — Have you been asking yourself, as you have studied about the solar system, why the planets in their great orbits swing around the sun year after year, and what it is that holds the sun and all its planets together? Before we answer this question, let us think of simpler questions. In the first place, why does a body that is not held up, or supported in some way, fall to the earth? Why is it that a bullet shot upward from a rifle does not continue in its flight off into space, but always returns to the earth? Sir Isaac Newton gave the reason when he said that the earth pulls objects toward itself, or **attracts** other objects. Do you suppose so small an object as an apple hanging on a tree attracts the earth? Why not? In proportion to its weight it pulls the earth as much as the earth pulls it.

Does it seem impossible that an orange lying on a table attracts, or draws toward it, another orange, lying beside it? It is not easy to show this, because the earth pulls both oranges strongly toward itself; but by means of a celebrated experiment it was shown clearly that one body of matter attracts another near it. A large ball of lead (Fig. 61) and a small one of copper were hung side by side, and it was possible to see distinctly that the copper ball moved over toward the lead ball. So we know that this pull which the earth has for bodies near it, is also present between two bodies on the earth. We call this earth pull, **gravity.** Scientists believe that the same pull that the earth has for objects near it also exists between the sun, the earth, and other planets. When we speak of this pull between the bodies of the solar system, we call it **gravitation.** Therefore, it is gravitation which holds the solar system together.

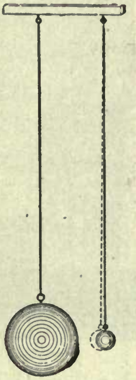


FIG. 61. — There is a pull, or attraction, between two portions of matter.

96. Why Does a Body Have Weight? — Do you know of any object that is without weight? We learned that gases, such as air, have weight, as well as do solids and liquids (cf. § 10). How do we weigh an object? If we use a spring balance (Fig. 62), we find that the balance consists of a spring which can be uncoiled or stretched by the object. When the object pulls the spring so far that the pointer is at the mark for 3 pounds, the object weighs 3 pounds. But why does the object stretch the spring at all? The answer is that the earth pulls the matter of the object toward itself with such a force that the spring is stretched to the 3-pound mark. So it is gravity, or the earth pull, that causes a body to have

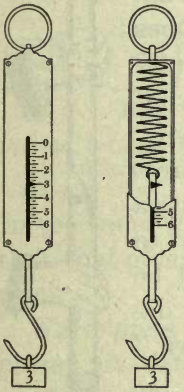


FIG. 62. — The spring is stretched by the earth's pull upon the object weighed.

(*Copyright by International Stereograph Co.*)

FIG. 63. — Leaning Tower of Pisa.

weight. Does it make any difference, so far as the earth is concerned, whether the object weighing 3 pounds is feathers, or water, or lead? Of course not, for the earth has the same pull upon all objects that contain equal quantities of matter, of whatever sort the matter may be.

97. In What Direction Does the Earth Pull? If you drop a stone from your hand, in what direction does it fall? It falls "straight down," or *vertically*, because gravity acts in that direction. Bricklayers, masons, and carpenters use a string with a weight attached (a *plumb line*) to guide their work, so that their walls shall be "plumb," or vertical. In doing this they depend upon gravity to pull "straight down" and to give them a reliable line.

FIG. 64.— In a vacuum light bodies and heavy bodies fall at the same rate.

Before the time of Galileo there was a belief that heavy materials, such as metals, fall more rapidly than light materials, such as papers or feathers. Galileo let objects of different materials fall from the leaning tower of Pisa (Fig. 63), and decided that the earth pull gives the same speed to all falling bodies, but that the air interferes with the lighter ones. When air pumps were made, so that a long glass tube could be freed from air (Fig. 64), it was found that a feather falls just as rapidly as a coin or a bullet.

98. What is the Density of Water? — Which is lighter, wood or lead? In saying that wood is lighter than lead, we do not mean that a large board is lighter than a small piece of lead, but we mean that if we have a block of wood of the same size, or volume, as the lead, the wood is lighter than lead. We express this fact by saying that the **density** of the wood is less than that of the lead (Fig. 65).

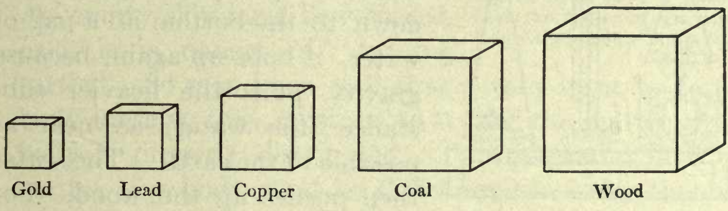


FIG. 65. — Cubes containing equal weights of these materials have very different volumes. Which is the more dense, lead or copper?

In the same way we say that the density of water is less than that of lead or iron, but greater than that of kerosene or air.

We express the density of a solid or liquid by comparing its density with that of water (Table III, Appendix). Thus, when we say that marble has a density of 2.7, we mean that it is 2.7 times as heavy as water.

99. Why Does a Body Float? — If you are asked why a cork or a pine board floats on water, you answer that it is lighter than water, or has a *smaller density* than water. Does any body float wholly on the surface, without pushing some of the water out of the way? Of course not; the heavier it is, so long as it floats at all, the deeper it will sink into the water. A piece of cork with a density of $\frac{1}{4}$ will sink until $\frac{1}{4}$ of its volume is below water; a piece of pine wood with a density of $\frac{1}{2}$ will sink halfway. A cake of ice having a density of about 0.92 will sink until 0.92 of its volume is below water. Thus less than $\frac{1}{10}$ of an iceberg is above water.

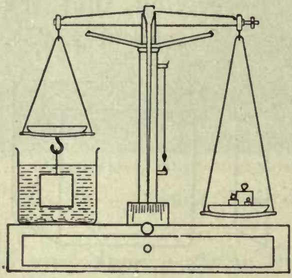


FIG. 66. — An object weighs less in water than in air, because it is buoyed up by the water.

Did you ever think that it is gravity that makes bodies sink or float? If you push a pine block down to the bottom of a pail of water, it bobs up again, because gravity pulls the heavier substance (the water) as near as possible to the earth. The water then pushes up the wood. For the same reason, when we say that a column of warm air ascends, we mean that gravity pulls down on the heavy, cold air, and this heavier air pushes the warm air up. This is the way that gravity causes the winds (cf. § 79).

Have you ever tried to lift a heavy stone up from the bottom of a stream or pond? If you have, you must have been surprised to find that the stone seemed to get heavier when it left the water. In the case of a floating board the water supports all of the weight. In the case of the stone the water supports part of its weight. We have to make a greater effort when we lift the stone entirely out of the water, for the water then ceases to push up, or **buoy up**, the stone. For this reason any object weighs less in water than in air (Fig. 66).

100. Can You Stand an Egg on End? — Why does an egg or a top prefer to lie on its side? Why is it so hard to make a slender stick stand upright? Everywhere we find examples of the fact that irregular bodies must be placed in certain positions, or they will turn over. You have seen tops that stood upright while spinning. A pencil may be made to stand on its point if weights, such as knives, are attached to it, as in Fig. 67. An empty ship must be *ballasted*, or it is in danger of "turning turtle." So men know well that if they want to keep a body upright, they must see to it that the matter of the body is properly distributed. To understand how the matter of a body must be distributed in order that the body may stand, let us use the following illustrations. If a wooden ball is placed on a smooth, horizontal surface, it will lie in any position, because all the matter in the ball is evenly distributed about its center, but if a ball is half wood and half lead, more of the matter is in the lead half of the ball than in the wood half, so that the ball turns until the lead is below. You have all played with the toy "tumbler" that will not lie on its side; this toy has

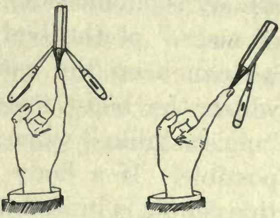


Fig. 67. — The pencil and knives take such a position that the center of gravity is below the point of support.

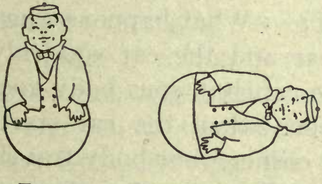


Fig. 68. — The lower part of the toy is of heavy material, while the upper part is of light material; so the toy cannot be made to lie on its side.

heavy material in its lower part and lighter material in the upper part (Fig. 68).

We speak of the point about which all the matter of a body is balanced as the " **center of gravity,**" or " center of mass," of the body. A body is able to stand when we can keep the center of gravity above the base on which the body rests. But a body stands best, or is " most stable," when this center is in the lowest position possible. If a body is free to move, it will turn until this center is in its lowest position.

Why, then, does an egg lie on its side? Because in this position the center of gravity of the egg is lowest. The egg is so rounded that we cannot support it and keep its center of gravity above the spot where the egg touches the table. If we make a dent in the end of the egg, of course we can make it stand upright. We ourselves can stand only when we keep the center of gravity of our bodies directly above our feet.

101. Can a Body Move Itself? — What happens when you are standing in a street car and the car suddenly stops? Your feet stop with the car, but your body goes on and you fall. What happens when the car starts suddenly? When a car turns a corner, your body travels straight ahead, while your feet follow the car. So you fall to one side. When you play " tag " and your playmate comes rushing toward you at full speed, why do you spring aside, or " dodge "? Is it not because you know that he cannot stop himself at once? What is true of our bodies is true of every body of matter. Does a baseball start itself? No, it must be thrown. Does it stop itself? No, it stops because it rubs against the uneven places on the ground, or because the air resists its passage, or because some one catches it. Bodies of matter are **helpless**, they cannot move themselves, or set themselves in motion, or stop themselves, or move in any direction except in a straight line, unless something acts upon them. We call this quality of matter **inertia.** So matter, besides taking up space and having weight, has inertia.

You can think of ever so many cases in which we make use of the inertia of matter; some have already been given. When you shake the dirt out of a rug, you really shake the rug away from the dirt; the dirt remains behind. Air has inertia, just as it occupies space and has weight. Just try to push the air away suddenly with a large fan or a hoop covered with a newspaper; or try to shut a door against a strong wind, and you will find that the air, too, is hard to stop and to start.

102. Why Does a Pendulum Swing? — Make a pendulum by hanging a weight, such as a piece of lead or iron, by means of a long thread from a gas jet or other support. Draw the weight aside and let go of it. What happens? Did you *lift* the weight when you drew it aside? Prove this by measuring the distance to the floor for both positions of the weight. Does the pendulum *fall* when you let go of it? What makes it swing? Why does it not stop at the lowest point of its path? Is a swing a pendulum? What stops the swing when we "let the old cat die"?

Make a pendulum with a thread about 39 inches long and count the number of swings it makes in a minute. Adjust the length of the thread so that the pendulum will make 60 swings a minute, or one a second. How long is the pendulum?

Try to make a pendulum that will swing 120 times a minute, or twice a second; how long is it? Make one with a thread about 13 feet long and find a support for it. Count the number of swings it makes in a minute.

103. What is a Force? — Think why it is that a baseball begins to move. Is it not because some other body — the pitcher, perhaps — gives motion to it, or "throws it"? Why does a bullet move? Is it not the exploding powder that causes the motion? Why does the cork of a popgun fly out? It is the air we have compressed in the "gun" that pushes out the cork. In the "bow and arrow," on the other hand, the bent bow straightens itself and so sends the arrow to its mark.

What shall we call a body of matter that gives motion to another body, or stops its motion, or changes the direction of its motion? We call it a **force**, or, better, we say that it **exerts force** upon the other body of matter. A force is a *push* or a *pull*. So the earth exerts force upon the moon and other bodies near it; we call this the force of gravitation. When a pitcher throws a ball, or a horse pulls a wagon, the muscular force of the pitcher or the horse is causing motion. Air exerts force both by pushing against bodies that pass through it, and also as wind, which is air in motion. The force of the air at rest makes it possible for a moving airplane to "fly" and a balloon to go up; while the force of air in motion makes kites rise, windmills turn, and ships sail the sea.

The **resistance** which a body meets when it pushes its way through air or water, or along the ground, and which one part of machinery meets as it rubs against another part, is a very important force; we call it **friction.** How do men make the friction between a wheel and its axle as small as possible?

104. When Has a Body Energy? — What do we mean when we say that one person has energy and another has not? In a general way, we mean that one person can do work and another cannot. This is what energy means in science, too: the *ability to do work.* When we lift a hammer, we do work upon that hammer. Because we lift it against gravity and thus do work upon it, it in turn can do work when gravity pulls it down: it helps us to break a nutshell, or drive a nail. Why is it so much harder to drive a nail into the ceiling than into the floor?

We can think of energy in two forms: **energy of position** and **energy of motion.** The hammer or pendulum, while it is held up in the air, has energy of position; when it falls, its energy is changed into energy of motion. The water of a waterfall has energy of position at the top of the fall, but it has energy of motion as it comes down. What kind of energy is in a wound-up clock spring?

105. Why Do Objects Fly from the Center? — Have you ever watched the mud fly off a carriage wheel, or the water fly off a revolving grindstone? If you have, you must have noticed that the mud or the water flies from the revolving wheel or stone in a *straight line.* Why is it that while the mud is attached to the wheel it revolves in a circle with the wheel, yet the instant it is free from the wheel it flies off in a straight line? We notice, too, that the lines along which the mud flies off do not come straight out from the center of the circle, but just touch the outside of the circle (Fig. 69, *a*) ; such lines are called **tangent** (tăn′jĕnt) lines. The reason for this " flying off from the center " is the same as the one that explains why you lurch sideways when a car moves around a curve : the **inertia** of matter keeps the mud moving in the same direction in which it was going at the moment it left the wheel.

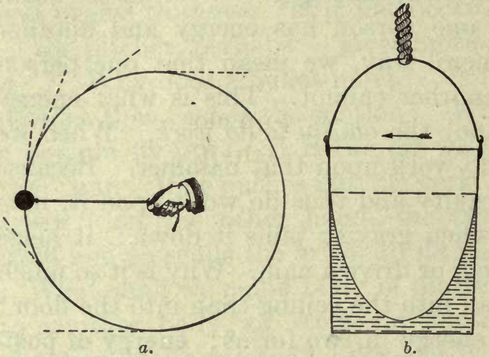


FIG. 69. — *a.* The ball moves in a circle because inertia tries to take it forward in a straight line, while the string holds it always at the same distance from the center. *b.* As the pail is whirled by the untwisting of the rope, the water is piled up against the sides of the pail. Why?

Attach a small rubber ball to a string and whirl it carefully about your hand. Its path is a circle; but if you let go of the string, the ball flies off in a tangent line. The circular path is caused by the resistance of the string, which makes the ball remain always at the same distance from your hand, and by the inertia of the ball, which, if it could, would make the ball fly off in a tangent line.

This pull which matter exerts in its effort to fly off a revolving body, is called the **centrifugal force** of the body.

It is, of course, a result of the inertia of the matter in the body. Do you suppose men can use centrifugal force for anything? Study a whirling pail (Fig. 69, *b*) and a dairy separator (Fig. 70).

106. Why Do Planets Revolve around the Sun?—The planets are much larger than the ball that we whirled with a string, but the reason why their path, or orbit, is round is much the same. Instead of a string we have the force of gravity. If this acted alone the planets would fall into the sun. If gravity were to stop, they would go off in straight lines into space And so the two forces: the tendency of matter to move off in tangent lines, together with gravitation, makes the planets revolve about the sun, just as the ball we whirl revolves about our hand.

(Copyright by McIntosh Stereopticon Co.)

FIG. 70. — In the dairy separator use is made of "centrifugal force." During the whirling, the skim milk, which is heavier than the cream, moves out farther than the cream; thus the two are separated. What was the old way of removing the cream?

107. Is There Any Force in a Water Surface? — Have you ever thought why a piece of clean glass becomes wet when put into water, while a piece of greasy glass does not? If we hold a sheet of glass down against a water surface, and then try to pull the glass away, we find that we must exert more force than is needed to lift the glass against gravity alone (Fig. 71). Another force resists our tearing the glass away. The force that holds the water particles together is called **cohesion**, while the force that holds two different substances, as water and glass, together is called **adhesion.** A postage stamp *adheres* to the envelope. The adhesion of water to glass is a greater force than the cohesion of water, or the water would not wet the glass.

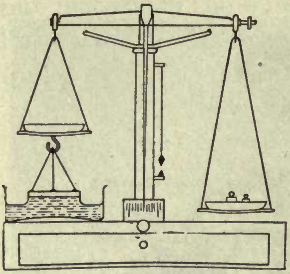


FIG. 71. — Force must be exerted to tear the glass away from the water.

Have you ever thought why liquids form **drops**? We know that a large surface of water is flat (horizontal), because gravity pulls down on all parts of the surface. But when the body of water is small (a drop), the effect of gravity is also small, and cohesion is able to pull the water into the form of a sphere. The water surface acts like a tightly stretched, elastic covering, say of rubber. That there is such an elastic surface is shown by the trick by which we can float a needle upon water (Fig. 72). We grease the needle slightly, so that water will not wet it, and then put it down carefully on the water's surface. A fork will help us to do this. Note how the needle stretches the elastic water surface, without breaking it. Is the needle heavier, or lighter, than water?

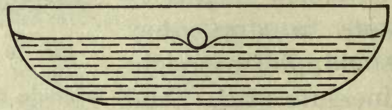


FIG. 72. — The greased needle stretches the water surface without breaking it.

108. Why Does a Blotter Absorb Ink? — Did you ever wonder why, if you touch a drop of ink with a blotter, the whole drop flows into the blotter? Or have you ever left one corner of a dry towel in a dish of water and found the water rose into the towel? The force exerted is called **capillary action.** Capillary means *hairlike.* The action is so called because it takes place best in tiny tubes.

Capillary action takes place between water and glass tubes because the water wets the inside of the tube and because the surface of the water is elastic. If we have some water in a dish, or in a large tube, the water is raised only at its edge (Fig. 73). The elastic surface does not have force enough to lift the water in a column. But if we use a tiny tube — a capillary tube — the weight of water is small and the force of the elastic surface pulls the column of water up in the tube. In blotters, cloth, string, soil, and other loose materials, the spaces are so small that they act as a multitude of fine tubes.

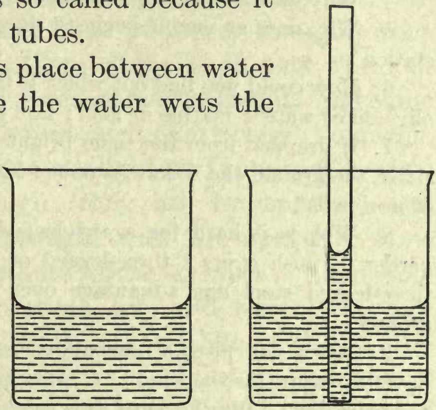


FIG. 73. — The elastic water surface has force enough to lift the water, against gravity, up into the tube and around the side of the dish.

In watering a potted plant we often set the pot in a dish of water; how does the water get up to the plant?

109. Exercises. — 1. What do we call the force which you must overcome in driving a nail into wood?

2. What causes water, mercury, kerosene, and other liquids to form drops? Why does a drop of water not remain spherical on a table while a drop of mercury does?

3. Why is it possible to ride on a bicycle and not fall to one side or the other?

4. Why does a steel ship float?

5. Why does an engine begin to slow up long before it is near the station?

6. How could you find out which is the heavier, gasoline or water; olive oil or water; marble or gold; iron or lead; salt brine or water?

7. If dropped from the same height at the same time, which will strike the ground the sooner, a pound bag of feathers or a pound bag of iron nails?

8. Why is it hard for a two-legged chair to stand? Which is harder to push over, a three-legged or a four-legged stool? Has a three-legged stool *any* advantage over a four-legged one on rough ground?

9. When you pitch a baseball, or bat a tennis ball, why do you have to "allow for the wind"? Does an apple fall straight down on a windy day? Why? Does this mean that gravity is not pulling straight down on such a day?

10. Why should a brick or stone wall be built "plumb"? Why does not the "leaning tower" fall over?

11. Would it be easier for you to float in fresh water or salt water? Why?

12. Would iron float on mercury? See Appendix, Table III. About how much of the iron would sink into the mercury?

CHAPTER XIII

SUBSTANCES

110. What is a Substance? — Substances are the different kinds of matter; have you ever thought what a wonderful variety of them there is in this world of ours? Some of them are gases, some are liquids and some are solids. Some are colorless, some have color; some dissolve, others do not; some are light and some are heavy; some we can see through (they are **transparent**) and others we cannot see through (they are **opaque**); some we can set on fire and others refuse to burn. Then, too, some substances, as limestone, air, and water, are very abundant in the earth, while others, like gold and diamonds, are rare. Thousands of different substances are known and many more will probably be discovered as time goes on. The *qualities* by which we tell substances from one another are called the **properties** of those substances. Thus, one of the properties of salt and sugar is their taste; the color, odor, and density of a substance, whether it will dissolve or burn, and many other qualities are also properties of the substance.

Tell all the properties you know of pine wood, soap, sugar, glass, iron, and milk.

111. Can Substances Be Changed? — It is easy for us to see that many substances change, for they gain new properties or lose old ones. Liquid water becomes a gas (water vapor) or a solid (ice). A " tin " can rusts away. Fruit juices ferment; milk sours; cut grass becomes hay. If we examine a cliff, we see heaps of chips and dust at its base; these were broken off from the cliff. Wonderful changes take place in our own bodies. Men eat many different kinds of food, but in some way these foods are changed into the material of which man's body is built up.

If we put iron into a fire, it becomes hot. It may become red or white-hot and give off light. But if it is removed from the fire, it gradually gives off the heat it gained and finally looks just as at first. Men may break off coal in a mine hoist it above the surface, and haul it to our coal bin, but it is still coal. These changes have not really altered the coal. We call such changes **physical changes**. But if the iron poker is left in a damp cellar, it rusts (cf. § 34). If we burn the coal, its carbon disappears and carbon dioxide is formed. The iron of the poker and the carbon of the coal have each combined with oxygen to form new substances: rust and carbon dioxide. Such changes as these are called **chemical changes**, because they are studied in chemistry.

112. Can Water Be Changed? — Of course we know that water can be changed to a gas or a solid and then changed back into liquid water. But can it be broken up into other substances? If you can get the apparatus, the following **experiment** (Fig. 74) will give you the answer:

Let two wires from a battery of several cells, or some other source of the electric current, pass into a vessel containing water and a very little sulphuric acid. The wires inside the vessel are of platinum and they have tips of platinum *foil* so as to make their surfaces larger. We call the ends of the wires the **poles** of the battery. If we were to put the platinum poles together, the current would have a complete passageway, or *circuit,* without going through the dilute acid. But if we keep the poles apart, the current must pass through the dilute acid. While the acid is carrying the current from one pole to another, a strange thing happens: **bubbles of gas** arise from each pole. We can collect the gas by putting over each pole a test tube filled with some of the dilute acid. We then see that one tube becomes filled with the bubbles about twice as rapidly as the other. If we put a burning splinter into the gas that is collected the more slowly, the splinter burns more brightly than in air. If the splinter is merely glowing, it will burst into flame. The gas in this tube is **oxygen.** If we bring a flame near the other gas, the gas takes fire with a slight explosion, or "pop," and then burns with a blue flame that is almost invisible. This gas is called **hydrogen,** meaning "water-former." The hydrogen and oxygen are obtained by the breaking up of water by the electric current; we call the experiment the **electrolysis** (ē-lĕk-trŏl′ĭ-sĭs) of water. Is it a physical change, or a chemical one?

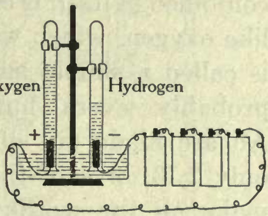


FIG. 74. — The electric current breaks up the water (it is really very dilute sulphuric acid) into hydrogen and oxygen.

113. What is an Element? — The breaking up of water by the electric current was a great triumph for science. Has the question come to you: "Can hydrogen and oxygen in their turn be broken up into some other substances, as water was?" The answer is that they have never been broken up, up to the present time. A substance like pure water, which is not mixed with something else and which has at least two kinds of matter combined in itself is called a **compound.** A kind of matter like oxygen, which we have never been able to break up, is called a **simple substance**, or an **element.** There are probably several hundred thousand known compounds. All are made out of 80 or 90 elements. Most contain only 2, 3, or 4 of these elements. In the same way we make all the words of our language out of 26 letters. Carbon is an element, too; also iron, nitrogen, sulphur, mercury, and phosphorus.

Mixtures are very different from compounds. Sugar is a compound and salt is a compound, but when the two are powdered and rubbed together we get a *mixture* of these two compounds. When sugar and sulphur are rubbed together, we get a mixture of a compound with an element. When powdered iron and sulphur are rubbed together, we get a mixture of two elements. **Soil** is a mixture of many substances. **Air** is a mixture of nitrogen, oxygen, water vapor, carbon dioxide, and small amounts of other gases (cf. § 26).

114. How Can We Prepare Hydrogen? — If we want to get some hydrogen for study, we might get it out of water, by the action of the electric current; but there are easier ways. You remember how marble foamed when you put hydrochloric acid upon it (cf. § 38). The gas given off was carbon dioxide. When "dilute" hydrochloric acid (that is, hydrochloric acid mixed with much water) is put upon zinc or iron, a similar foaming takes place, but in this case the gas is hydrogen. The hydrogen is present in the acid; the action of the metal sets the hydrogen free as an element.

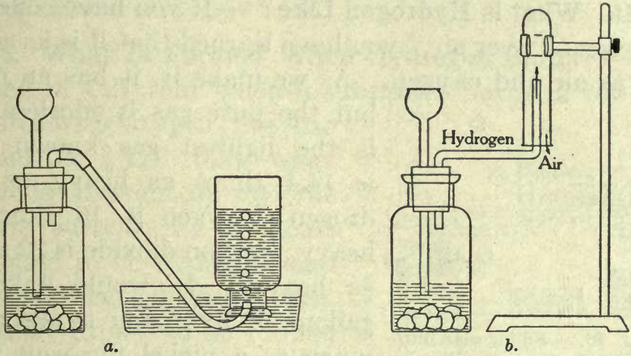


FIG. 75, *a* and *b*. — Hydrogen being prepared from zinc and a dilute acid. It may be collected "over water" or "over air."

Put some bits of zinc in a glass tube (test tube) or a small wide-mouthed bottle (see Fig. 22), and cover the zinc with dilute hydrochloric or sulphuric acid. See how the liquid foams, owing to the escape of tiny hydrogen bubbles. If the zinc does not act rapidly with the acid, pour off the acid and cover the zinc with a dilute solution of *blue vitriol* (copper sulphate); after a few moments pour the solution off. The zinc will then be covered with a thin, black coating of copper. If you now add the acid to the zinc, the two will act rapidly. When the mixture is foaming, apply a match to the mouth of the test tube. Be careful. Do you get any evidence that hydrogen burns?

We can prepare more hydrogen in a bottle which is fitted with a two-hole stopper, a "thistle" tube, and a delivery tube reaching into a water pan (Fig. 75, *a*). The thistle tube allows us to add fresh supplies of the acid; it also lets the hydrogen escape if the delivery tube is stopped up. Hydrogen is collected over water, as oxygen is, because only a little dissolves in the water.

We can also collect hydrogen "over air," as is shown in Fig. 75, *b*. Do you think from this fact that it is lighter, or heavier, than air?

115. What is Hydrogen Like? — If you have collected hydrogen "over air," you have learned that it is as colorless as air and oxygen. As we make it, it has an odor, but the pure gas is odorless. It is the lightest gas known: air is 14.4 times as heavy as hydrogen; oxygen is 16 times as heavy; carbon dioxide is 22 times as heavy. It would take 15 gallons of hydrogen to weigh as much as a nickel five-cent piece (5 grams).

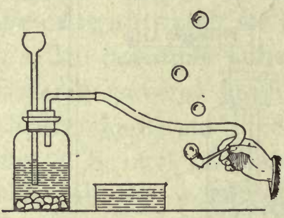


FIG. 76. — Filling soap bubbles with hydrogen. Why do they rise?

One way to show how light hydrogen is, is to fill soap bubbles with it (Fig. 76). For this purpose a clay pipe may be used instead of a delivery tube. The bubbles will rise rapidly. Do you suppose hydrogen would be useful in the making of airships and balloons?

If you collect a bottle of hydrogen, as is shown in § 114, you can find out whether hydrogen allows wood to burn in it, as oxygen did. First let the hydrogen escape for a minute or two from the bottle in which it is being prepared, so as to make sure that the air that was in the bottle at first has been swept out. Then collect a bottleful of hydrogen "over water." Now raise the bottle of gas, keeping the bottle mouth downward, and put a burning splinter up into the bottle. There will be a slight "pop" as the hydrogen is set on fire at the mouth of the bottle, but the flame on the splinter up in the bottle will be put out. This shows that hydrogen burns where it can get at the oxygen of the air, but wood does not burn in, or unite with, the hydrogen as it does with oxygen. A burning candle, a burning strip of paper, or a burning wick containing kerosene would all act as the wood does. We say that hydrogen "burns, but does not support combustion." Hydrogen is not poisonous. Do you think we could breathe it instead of oxygen?

116. What Is Formed When Hydrogen Burns? — We learned in § 27 that when a substance burns in the air, it unites with oxygen; we also learned in § 112 that when water is broken up by the electric current, its elements are found to be hydrogen and oxygen. What substance, then, might we expect to be formed when hydrogen burns in air?

If you wish to light a jet of hydrogen, you must take care that the hydrogen is not mixed with air. If it is mixed with air, there will be a violent explosion when the flame is brought near it, and the glass may be blown into your face. So be sure to make the following test for hydrogen:

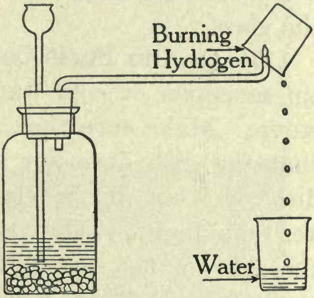


FIG. 77. — Burning hydrogen. Before lighting the gas be sure to make the "safety test." As the hydrogen burns, a fog forms on the inside of the beaker and finally water drops from the edge of the beaker. With what element does hydrogen unite when it burns?

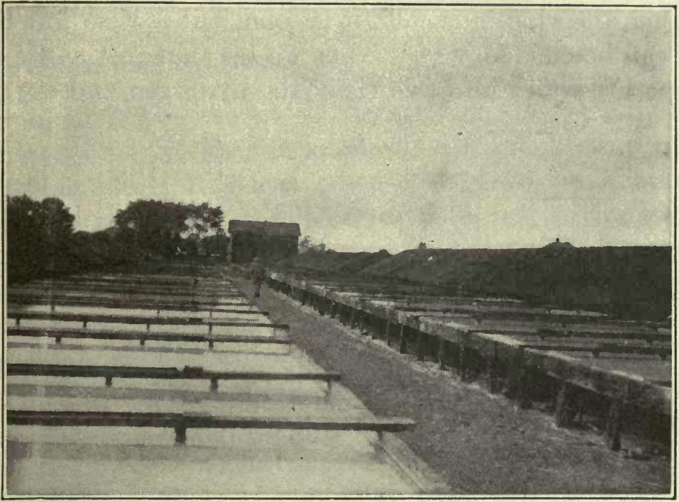
Safety Test for Hydrogen. — First be sure that the gas is coming off rapidly. Put a test tube down over the outlet tube, as in Fig. 75, *b*, for a full minute; now carry the tube, with its mouth downward, to a flame at least 3 feet away. Finally carry the test tube, still with its mouth downward, back to the jet of hydrogen. Repeat the test until the test tube of burning hydrogen sets the jet on fire (Fig. 77).

You will find that the flame is nearly colorless, but very hot. If we put over the jet of burning hydrogen a large glass or bottle, the inside will soon be covered with a watery mist; after a while drops of water run down and drip from the mouth of the jar So it is **water** that is formed when hydrogen burns in air. After the hydrogen has heated the tip of the glass, the flame becomes yellow. This is due to an element named *sodium*, which is part of the glass.

117. Do Our Fuels Contain Hydrogen? — Put a bright tin saucepan of cold water over a gas burner, or a gas stove. Make sure that the outside is perfectly dry and that the dish does not leak. If possible, put a second dish over an alcohol lamp or over the chimney of a kerosene lamp. What is deposited over the bottom and the sides of the dish? Can it be water? Where did it come from? This experiment shows us that the gas, alcohol, and kerosene contain hydrogen. When they are burned, their hydrogen unites with the oxygen of the air to form *water*. The carbon they contain burns to form *carbon dioxide*. This is not condensed by the cold dish. So in most of our fuels we are really burning hydrogen as well as carbon, and water is formed as well as carbon dioxide.

118. Is Salt an Element? — All of us know something of salt, the substance we use in seasoning our food and in preserving certain foods, such as salted meats and fish. It is found in large amounts in sea water and in salt water; it is also found in layers in the earth, as *rock salt.* We obtain salt from salt water by letting the sun evaporate the water, or by boiling it off over a fire.

Perform this **experiment**: Dissolve as much salt as possible in a small amount of clear water and let a thin layer of this solution stand in a shallow dish until the water evaporates. If you examine the lumps of salt left, especially with a magnifying glass, you will find that they are cubes and that they are arranged in masses that are "hopper shaped," that is, like a four-sided funnel. When a substance separates from a solution in regular shapes, it is said to *crystallize*, and the regular-shaped masses which it forms are called **crystals.** In salt these crystals are often very large. You have also seen crystals of sugar. Large sugar crystals we call "rock candy" (Fig. 79).



(From Hopkins' Physical Geography.)

FIG. 78. — The preparation of salt for our use is a great industry.

If we heat salt, we find we cannot change it, even at red heat. If the salt is heated white hot, it melts, as ice does at 0° C. When men passed an electric current through melted salt, an interesting change took place. At one pole there was found a shining *metal*, looking like silver. This is called **sodium**. At the other pole there appeared a greenish-yellow gas called **chlorine** (chlōr′ĭn). When the sodium is cold, it is solid, but it is so soft that it can be cut like wax. Thus we see that just as we can separate water into two elements, hydrogen and oxygen, so we can separate salt into sodium and chlorine. The chemist calls salt, **sodium chloride**, to show that it contains sodium and chlorine. What might water be called? Review § 32.

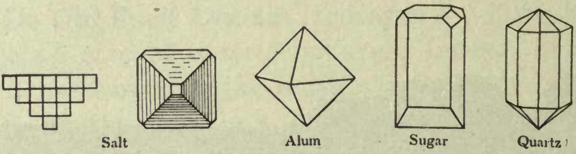


Fig. 79. — Crystals of salt, alum, sugar, and quartz. Note the beautiful forms in which matter arranges itself.

Just as we can cause hydrogen and oxygen to reunite to form water, so we can get sodium and chlorine to form salt. If a thin shaving of sodium is put into chlorine, the shiny sodium and the green chlorine disappear, leaving white salt in their place.

119. What is Sulphur Like? — Examine some of the substance known as **sulphur**, or "brimstone." It is a yellow solid having no odor. Sulphur does not dissolve in water or in the mouth; so it has no taste. If you drop a lump into water, it will sink, because its density is greater than water.

If you heat some sulphur carefully in a test tube or porcelain dish, you find that it melts to form a light-yellow liquid which is easily poured. As you heat it hotter, the sulphur becomes darker and harder to pour. Heat it still hotter and you will find it remains dark in color, but can now be poured. If you boil the sulphur, you will see that its vapor is light brown. If you pour the boiling sulphur into cold water, you will get an elastic solid. This is still sulphur, but it changes back to its original form very slowly.

Sulphur is an element, so neither heat, nor electricity, nor any other means we know of, will break it up into anything else. It burns when heated to its kindling temperature, forming **sulphur dioxide** (cf. § 24), a gas with a sharp odor. We often get this odor when a match is struck, because of the sulphur in the match head. Sulphur combines with many metals, even when they are simply rubbed with it.

Clean a one-cent piece with gasolene and rub it dry, then put on it a bit of sulphur and rub the two together. The black spot which appears is **copper sulphide.** If we know that there is sulphur in eggs, can you tell why silver egg spoons become black?

The sulphur in the United States is obtained in Louisiana, where there is a deposit half a mile in diameter. Some is also found in Texas and California. Europe gets most of its supply from Sicily.

120. What is Phosphorus Like? — We have already learned something of the element phosphorus, of the great activity of the yellow form, and of the power of burning phosphorus to remove all the oxygen from a bottle of air. Phosphorus is one of the elements necessary for the bodies of animals. When the bones of an animal are burned, a compound of calcium, phosphorus, and oxygen (**calcium phosphate**) forms a large part of the ashes. It is out of these bone ashes and out of natural calcium phosphate found as a rock that phosphorus is made.

Yellow phosphorus unites readily with oxygen, even when it is cold; in doing so it gives off light. You have seen the bright streak left when phosphorus matches are struck in the dark. The name *phosphorescence,* meaning "producing of bright light," is applied to this. *Yellow* phosphorus is used as a poison for rats and other vermin, as well as in matches. *Red* phosphorus is used in the making of safety matches.

121. What is a Match? — We rarely think of the convenience of having matches until we are without them. Matches were first made in 1827. They "work" because phosphorus is easily set on fire by rubbing (friction), if there is present a substance to give it oxygen. The "parlor" match, which can be struck anywhere, has a tip containing yellow phosphorus, paraffin, or sulphur, and an oxidizing substance like potassium chlorate or red lead. Glue is used to make the substances stick to the splinter. When the match is rubbed or struck, the phosphorus unites with the oxygen of the potassium chlorate or red lead. The heat produced by the burning of the phosphorus sets the paraffin or sulphur on fire and the heat from this fire heats the wood to the temperature at which it begins to burn.

Safety matches are not so convenient as parlor matches because they must be struck on the box. The surface of the box contains the phosphorus; it is **red** phosphorus instead of the yellow form. When the tip of the match is rubbed against the surface of the box, a little of the red phosphorus is changed to the yellow, and the burning of this substance starts the burning of the match tip.

The use of yellow phosphorus for matches is forbidden in many countries of Europe. Its use is prevented in the United States by a tax on matches containing it. The reason why matches containing yellow phosphorus are not wanted is, first, that they are easily set on fire by careless handling, by children, and even by rats and mice. Great fire losses occur where parlor matches are used. A second reason is that the vapor from them is dangerous to the workmen who make or handle them.

" Strike anywhere " matches are now being made with a compound of phosphorus and sulphur (*phosphorus sulphide*) which does not give off the vapor of phosphorus and which is not so easily set on fire as phosphorus itself.

What a great deal of science there is in the striking of a match!

122. Exercises. — 1. Read a recipe for the making of johnny-cake. Is johnny-cake a mixture or a compound? What reason have you for thinking that wood is not an element?

2. Judging from the names of the following compounds, tell what elements are in each: lead sulphide, iron oxide, carbon dioxide, sodium chloride.

3. If you had a bottle of carbon dioxide and one of hydrogen, how could you tell which was which?

4. When you put a cold lamp chimney upon a lighted kerosene lamp, the inside of the chimney becomes covered with mist. What substance is the mist? Where does it come from? Why does the bottom of a teakettle filled with cold water become wet when you put it over a gas flame?

5. Name several uses of salt.

6. How has civilization been helped by the invention of matches?

CHAPTER XIV

WATER

123. Where Is Water Found? — How much there is to know about the common substance "water"! You think of it as a liquid that flows from hydrants or is pumped from wells, or that flows in streams, from the little springs and brooks to the great rivers of the earth; you think, too, of ponds and lakes and the mighty oceans. You must also think of it as rain, as clouds, as ice and snow, as the invisible water vapor that rises from teakettles and from the sea, to become a part of our atmosphere, until it condenses and returns once more to the earth's surface. Water is not only on the surface and in the atmosphere, but in the rocks as well. No matter where we dig, we find it, even in the desert. Water is a large part of all plants and animals as well as of our food. The following table shows how much of it there is in our bodies and in some of our foods:

	Per Cent of Water		Per Cent of Water
Human body	70	Watermelon	92
Milk	87	White bread	35
Potatoes	78	Beef	62

The farmer looks for water anxiously in the growing season, because he says, "No one ever starved in a wet year"; the scientist says: "There is no life without water."

124. What is Water Like? — We already know something of what water is like. In a small amount it is without color, but a large amount of it looks blue. Our drinking water has a taste, because of substances dissolved in it, but water that has nothing in it is tasteless and flat, much like boiled water. We have learned that the boiling point of water is 100° C. and is used as a standard mark on the thermometer, as is also its freezing point, 0° C. A cubic foot of water weighs about 62.5 pounds and a cubic centimeter of it at 4° C. weighs one gram. If you put warm water in a flask with a very small neck and cool the flask, the water shrinks in volume until its temperature is 4° C. (39° F.); then it expands until its temperature is 0° C. Water is therefore *most dense*, or heavy, at 4° C. and not at 0° C. Because of this fact the water at the bottom of lakes is rarely cooled lower than 4° C.; for if it becomes colder, it expands, and rises instead of sinking. When water freezes, it expands, so that 100 cubic feet of water become 109 cubic feet of ice. So when we have ice at the top, we have water near 0° C. just under the ice, and water near 4° C. at the bottom. Because this is so, water animals and plants can live through the winter and in the deep waters of the frigid zone. Ice, like water, is blue in large masses.

You know how readily salt, sugar, soda, and many other substances disappear in water; we say they *dissolve*, and that water is the **solvent**. Other liquids, such as alcohol, are used to dissolve substances which water cannot, but water is our most common solvent.

Hold a lump of **sugar** so that its lower side just touches the surface of some water in a clear glass and watch the appearance of the liquid. The oily appearance is caused by the sinking of the sugar solution before it has mixed with the rest of the water. Do the same with a lump of copper sulphate (bluestone or blue vitriol). Are the solutions of sugar and blue vitriol heavier or lighter than the water used? What are the colors of the solutions?

125. How Does Water Boil? — Watch the water in a pan as it nears boiling. At first there are tiny bubbles that escape; these are chiefly **air** that was dissolved in the water. Then, as the temperature rises, there are larger bubbles of **steam** that start from the bottom, but do not rise to the top. These condense and cause the "singing" of the water, but the water is not yet boiling. Finally the bubbles rise to the surface and burst; as they do so, they have force enough to push out the air. The bubbles jump up and down when there is real boiling. Then and then only, will a thermometer register the boiling point of water.

We must remember that the temperature at which water boils depends on how heavily the atmosphere presses down upon the water. As we ascend a mountain and leave more and more of the atmosphere below us, water does not need to be heated so hot to make it boil. The steam bubbles do not need to have as much force to push away from the water as they did when the air was pressing harder upon them. The boiling point is lowered about **1° C.** for every 960 feet we ascend above sea level. So water boils at 92.3° C. at Mexico City, 7500 feet above the sea. At Denver, 5500 feet high, it boils at about 95° C. At about what temperature will it boil on Pikes Peak, 14,108 feet high?

126. How Is Ice Made? — Years ago ice was carried to tropical countries in ships, but modern methods of living require so much ice that a great deal of our ice is manufactured, even in temperate zones. How can we make ice in summer? We have already learned that the reason why perspiration cools us is that the heat needed to evaporate it comes from our bodies (cf. § 71). Water evaporated in a porous jug cools the water inside.

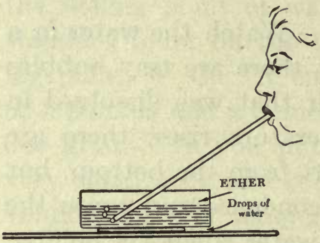


FIG. 80. — By causing the ether to evaporate rapidly you can freeze the water under the pan. Use a long tube and perform the experiment near a window with an outgoing draft.

Substances that evaporate rapidly can be made to take away so much heat that very low temperatures can be obtained. Pour out a little ether into a shallow pan, such as the cover of a baking-powder can (Fig. 80), set it on a few drops of water placed on some folded writing paper, and by means of a tube and bellows (your cheeks will serve as bellows) force air rapidly through the ether. The dish can be *frozen* to the paper! The principle of **rapid evaporation** is used to make artificial ice. Think what a blessing it is that hot countries can have ice for keeping food and water cool.

The liquid that is used to freeze water is **liquid ammonia.** This is not ammonia water, but the gas ammonia which has been strongly compressed until it turns to the liquid state.

Usually the liquid ammonia is made in strong pipes (Fig. 81). When the gas is compressed into the liquid form, it becomes hot; so men cool it by spraying running water over the pipes which hold the ammonia. Now, when the pressure is removed, the ammonia boils vigorously and in so doing takes up a great deal of heat; for just as much heat is needed to turn the liquid ammonia back into the ammonia gas, as was given off by the gas when it was compressed to a liquid. So the pipes become very cold, and when they are run through a salt brine, they cool it to perhaps −15° C. This cold salt brine is used for cooling purposes, just as hot water is used for heating. If we put it around molds, or tanks of water, heat is taken from the water until it is frozen (Fig. 81). Cold brine is also used in cold-storage warehouses and in refrigerator cars to produce a low temperature. In this way butter, eggs, meat, and fruits are kept cold to prevent their spoiling (Fig. 82).

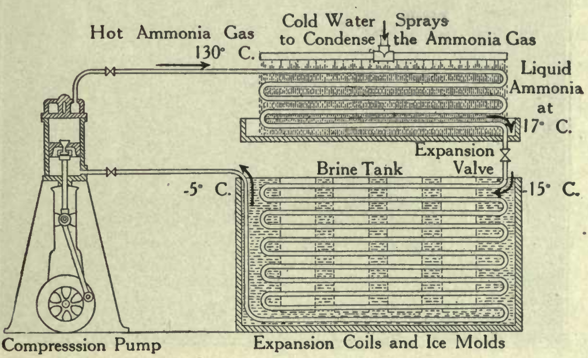


FIG. 81. — When liquid ammonia is allowed to boil rapidly, it takes up heat from the salt brine and thus cools it below the freezing point of water.

127. How Is Ice Cream Frozen? — You know how ice cream is made. The cream is placed in a pail surrounded by a mixture of salt and ice. As the freezer is turned, the cream comes in contact with the cold walls of the pail and is frozen. But why does a mixture of ice and salt give a colder temperature than ice alone?

When we draw water from a faucet and put ice into it, the ice melts. Where does the heat come from that is needed to melt the ice? It comes from the water; therefore the water is cooled, if there is enough ice, to 0° C., which is the temperature of melting ice or freezing water.

FIG. 82. — Rooms in which meats and other perishable goods are kept are cooled by pipes carrying cold brine.

What happens when we put salt upon ice? The ice begins to melt, forming water, and the salt dissolves in the water, producing a salt solution, or salt brine. The ice is really melting in salt brine. The heat needed to keep up the melting comes from the brine. But as salt brine does not freeze until it is cooled to about $-20°$ C., the melting of the ice will continue until this temperature is reached. Now, while a temperature of 0° C. is not low enough to freeze cream, one of $-20°$ C. is.

How is the making of artificial ice different from the freezing of cream? In the making of ice we produce a cold brine by the **rapid boiling** of liquid ammonia; in freezing ice cream we cool the brine by the **rapid melting** of ice in the brine.

128. How Do Bodies of Water Affect Climate? — Have you ever wondered why peaches are grown so successfully in the "peach belt" on the eastern shore of Lake Michigan, while they cannot be grown successfully at many places that are much farther south, but away from the water? Can you tell why grapes are grown in large quantities on the eastern and southeastern shores of Lake Erie, in New York, Pennsylvania, and Ohio? The answer is found in a peculiar quality, or property, of *water*.

If you try to heat a pound of water and a pound of iron over two burners giving the same amount of heat, the iron reaches 100° C. long before the water does. But when you stop heating them, the iron cools much more rapidly than the water. If you have a pound of iron and one of hot water, both at 100°, and put each separately into a pan of ice, the heat in the water will melt about 9 times as much ice as the heat in the iron will. We say that water has a greater **heat capacity** than the iron has. Now the land, like iron, has a small heat capacity. Because of this it is heated up more rapidly by the sun than water is, but it also cools more rapidly. So a place that is inland, or away from the water, has great extremes of heat and cold, while a place near a large body of water is kept warmer in winter and cooler in summer by the presence of the water.

We can now answer the question regarding the peach orchards on the eastern shore of Lake Michigan and the grape vineyards on the southeastern shore of Lake Erie. The prevailing cold winds of the winter in the region of the Great Lakes are from the northwest, and the winds are warmed as they pass over these large bodies of water. As a result the weather of winter is less severe on the eastern shores than on the western shores of these lakes.

Why is the eastern shore of Lake Michigan dotted with summer resorts? Why do people go to the shore of the ocean in hot weather?

This effect of water upon the land is much greater if currents of cold or of warm water flow along the shore. Thus the shores of Alaska, British Columbia, and the Pacific Northwest have a mild winter climate, owing to the Japan current which passes along the coast. The Gulf Stream, containing warm water, carries heat from the tropics up to the western coast of Europe and keeps open water in the most northern Norwegian ports.

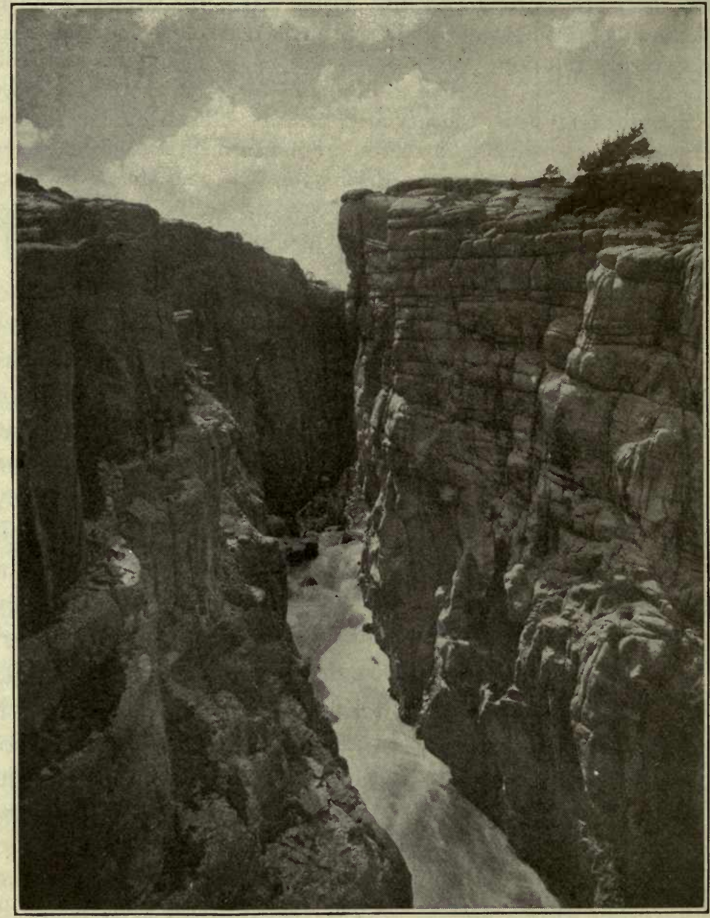
129. How Does Water Change the Earth's Surface?— Did you ever wonder what becomes of all the rain? About 35,000 cubic miles of it fall upon the land every year. This is nearly seven times as much water as is stored in our Great Lakes. The rain that falls upon the earth and washes away the soil, the crystals of frost that freeze within the cracks of the rocks and burst the rocks apart, the great sheets of snow and ice that have moved over large areas of the earth — these have chiseled the land into its present forms. Water is thus not only the storehouse of the sun's heat, but also the great **sculptor** of the earth's surface.

You have heard of the **Grand Cañon** of the Colorado River and of other deep cañons, or gorges, like it (Fig. 83). The Grand Cañon is 217 miles long, 8 to 15 miles wide, and a mile deep. Do you think that the river just ran down into a deep crack in the mountains and took it for its bed? No; the river itself dug its own bed by wearing away the rock little by little, century after century. The Ohio has carried the wearing-away process farther and flows through a peaceful valley bordered by rounded hills; the Mississippi, Nile, and Hoang-Ho have worn down their valleys to low, fertile *flood plains*, but little above sea level. What force causes water to fall and to run downhill to the sea? What lifted the water to the mountain tops?

Why is it that the seashore is so interesting to you? Because there are long stretches of sandy beaches, great waves, and ships on long voyages. The shoreline is a place of great interest to the scientist also. There the land and sea meet and carry on their agelong struggle for the possession of the dry ground. The rain wears away the land, the rivers carry their sediments to the sea, and the sea, not satisfied with the work of its allies, the rain and the rivers, pounds away at the shore itself, slowly cutting it away, so as to extend the empire of water. Which will win? The average height of the continents above sea level is about 2300 feet; but the average depth of the sea is about six times as great, or 13,000 feet. So, if the sea could get the complete mastery, its waters could cover all the land with a layer of water about two miles deep.

130. Exercises. — 1. Explain why water is believed to be a compound rather than an element.

2. Is a cubic foot of water heavier, or lighter, than a cubic foot of ice? How do you know?



(From Hopkins' Physical Geography.)

Fig. 83.—In the Cañon of the North Platte River, south of Casper, Wyoming.

3. Do lakes and ponds generally freeze to the bottom? Would they be more, or less, likely to, if ice were heavier than water?

4. How is salt commonly obtained from salt water?

5. Do you suppose any substances besides water act as solvents? What is the solvent used in most medicines?

6. When the water used for cooking potatoes has begun boiling, will the potatoes be cooked more quickly, if there are two burners instead of one under the boiling water?

7. Is any dessert made by freezing flavored water instead of cream?

8. What causes the bursting of water pipes in winter? Why are hydrants sometimes left turned on a little during a very cold night?

9. Why is it easier to swim in the ocean than in fresh water?

10. How does the freezing of the ground help to break it up for the next year's crops?

CHAPTER XV

WATER SUPPLY AND SEWERAGE

131. Why Do We Need So Much Water? — Have you ever thought how much we depend upon an abundant supply of water? In our homes we need it for bathing, for cooking and for drinking, for washing dishes and clothing, for spraying lawns and gardens and to carry waste material into the sewerage system. As ice it preserves our food and with salt makes our common freezing mixture.

Industries need water to furnish steam power for machinery. Some industries, like refineries for petroleum and sugar, as well as laundries, tanneries, slaughter houses, starch factories, gas works, paper mills, and dye works, need it for washing and rinsing on a large scale. Cities need water for fire protection and for cleaning streets and to carry away sewage.

132. How Do Cities Get Their Water? — Have you ever seen the waterworks of your community? It is necessary that water shall have some pressure in the pipes, so that it will flow from the faucets rapidly and will rise to the top floors of buildings. There must also be enough pressure so that we can throw a powerful stream of water in case of fire. Some cities get their water to flow by a " gravity " system. This means that the water level of some pure stream, reservoir, or lake near the city is higher than any buildings of the city, so the water can simply flow downhill to the city and up into its buildings. Denver has such a water supply. If a gravity system is not possible, water is often pumped by a strong steam force pump up into a high tank, or reservoir, or " standpipe "; from this it can flow down to the ground and up into buildings.

You have seen pictures of the great Roman **aqueducts**, by which water was brought to the city of Rome from distant lakes or springs. New York City now receives its water through a great aqueduct from the Catskills, 90 miles away. At one place the water is carried under the Hudson River. Los Angeles gets its water from mountains many miles away. The cities on the Great Lakes get their water supply from the lakes. As the sewage from the city may pollute the water, the " intakes " (places where the water is taken in) are usually several miles from the shore. Chicago has built the " Drainage Canal " at great cost, to carry water from Lake Michigan into the Illinois River; thus it sends the city's sewage into the Mississippi instead of letting it pollute Lake Michigan.

133. How Do We Get Water in the Country? — In the country we get water from cisterns, wells, or springs. We dig wells, not to strike underground streams or " veins " of water, but to make holes into which the " groundwater " can run. This is the water which *saturates* the ground everywhere below certain levels. You can see how this is, if you dig a hole into ground that is water-soaked after a rain. **Deep wells** are not dug, but are *drilled*, that is, bored through soil and rock until a level is reached at which good water in sufficient amounts enters the well. The deeper a well, the greater is the area of the ground from which its water will be collected and the more likely it will be to last through a dry season. **Artesian wells** are deep wells drilled through a layer of rock or clay which holds the water at great pressure. When the covering is pierced, the pressure of the water forces the stream to the top of the well and sometimes high into the air.

Springs have a different origin. When water soaks into the ground until it reaches a layer of rock or clay that it cannot penetrate very easily, it will collect above this layer. If the ground is sloping and the rock layer comes near the surface, as on a hillside, the water bubbles out as a spring (Fig. 84).

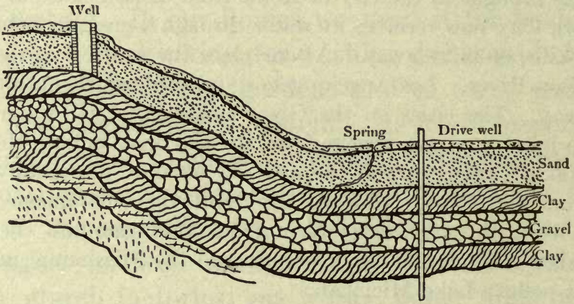


FIG. 84. — Water soaks through the porous sand until it reaches the compact clay which it cannot penetrate. At the bottom of the hill a spring is formed.

134. What is Plumbing? — How much does your family pay for water? In some cities you pay a "flat rate," that is, no matter how much you use, you pay a certain sum. In other places a *meter* is put into your house to measure the volume of water which flows from the street main into your plumbing system. "Plumbing" comes from the Latin word for "lead"; the plumbing includes the pipes, the faucets, and the traps through which fresh water is carried into the house and waste water is carried away from it. Iron pipes as well as lead ones are used for plumbing; the iron is "galvanized," or covered with zinc, to prevent rusting.

Lead is used because it does not rust easily and can easily be bent around corners. When lead pipes are fresh, the lead may be oxidized to compounds that dissolve in water. These may cause serious sickness; hence we should always let water run for a minute from new lead pipes. Old lead pipes become covered inside with a coating that stops further action of the water upon the lead.

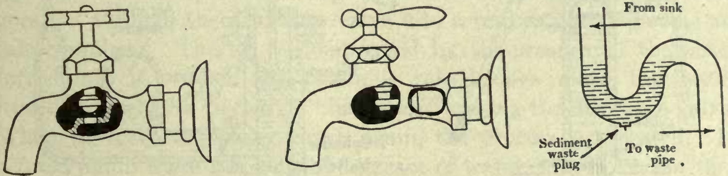


Fig. 85. — The faucet on the left is "compression bibb"; the handle must be turned round and round until the rubber tip closes the hole below it. The faucet in the middle is a "Fuller" faucet. In the cut the faucet is open; we close it by pulling the handle forward. This pulls the acorn-shaped rubber "gasket" forward, so that it closes the hole through which the water escapes. The figure on the right shows a "trap."

Faucets, also called "hydrants" or "bibbs," are usually made of brass. Two forms are shown in Fig. 85.

Did you ever notice the waste pipe of your kitchen sink? A **trap** (Fig. 85) is a bend in the waste pipe; it remains full of water and thus forms a "waterseal." This keeps the air of the sewer from entering the house. Water should be run through all sinks and floor drains every day, so that the traps may be kept full of water.

135. What is a Pump? — Water is often raised from a cistern or well by means of a pump. The common pump (Fig. 86, *a*) first removes the air from a pipe extending under the surface of the water, just as we do when we drink lemonade through a straw. The air pressure forces the water up to the piston of the pump, if the piston is not too high above the water level. When the piston is forced down by the next stroke of the pump a valve in the piston is pushed open, and water rushes above the piston. When the piston is forced up once more, the water pressure above it closes the valve and the water above the piston is lifted to the height of the spout. This is called a **lift pump** and is useful for the height to which air pressure can raise water, that is, for anything

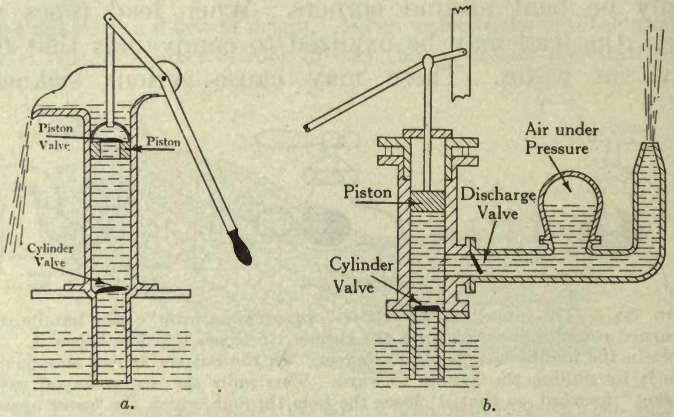


FIG. 86. — *a*. When the pump handle is pushed down, the piston is raised and the water above the piston is lifted to the level of the spout and overflows. When the pump handle is raised, the piston is pushed down and its valve is opened, while the "cylinder valve" is closed. *b*. A force pump throws a constant stream of water because of the compressed air in the air chamber.

less than 34 feet. Lift pumps are not perfect and so can rarely raise water more than 28 or 30 feet (cf. § 17).

136. What is a Force Pump? — Did you ever watch a fire engine in action when it was pumping water upon a fire? A fire engine is an example of a **force pump** (Fig. 86, *b*).

A force pump has no valve in the piston. When the piston is raised, the pressure of the atmosphere forces the water into the pipe and cylinder. When we force the piston down, the water below closes the valve in the cylinder. The water cannot go up or down, so it goes out through the discharge valve into a tank containing some air (air chamber). The air is compressed by the pressure of the water forced into it. When the piston is raised once more, the water forced through the discharge "backs up," closing the discharge valve. When we force the piston down again, the process is repeated. In a force pump there is a constant stream of water, for the reason that between the strokes of the piston, when the piston itself is not forcing the water out, the pressure in the air chamber does so. What advantage has a force pump over a lift pump?

137. What are the Dangers in Water? — What is meant by "pure" water? That depends upon the use we wish to make of it. Natural water is never pure. You can see that if the soil contains substances that are soluble in water, the rain that has flowed through it will contain some of these substances also. Water is often roily, or cloudy, because of tiny particles that it carries along without dissolving them. Much of this matter is carried to the sea. The undissolved particles are dropped as a sediment, and the dissolved substances are left when the sea water evaporates. There are nearly 2.5 pounds of salt in every 100 pounds of sea water, and much more in such bodies as the Dead Sea and the Great Salt Lake.

If we want to use water for **drinking**, we do not worry much over the dissolved gases and minerals, but we are careful to find out about its injurious *bacteria*, or *germs*, and the decaying matter upon which they live. If we take bacteria of certain diseases, such as typhoid fever and cholera, in our drinking water, we may "catch" those diseases. If there is any chance that drinking water may be impure, we should have it tested. We cannot depend upon the appearance of water, for a dirty looking water may be safe, while one as clear as a crystal may contain deadly germs. A shallow well, either on a farm or in a village, is always to be thought of as a possible danger, for surface filth may be washed into it by rain. Besides, kitchen drains, outbuildings, and barns may be near enough to pollute it. Ice made from filthy water is also dangerous, for the disease germs are not killed by freezing, but are only made inactive. They become active again as soon as they get into food and when we take them into our bodies.

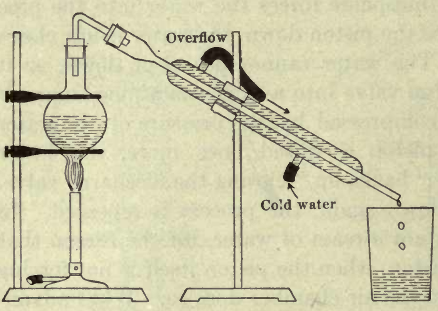


FIG. 87. — How water is distilled. The water is turned into steam and the steam passes through a "condenser" surrounded by a "jacket" of cold water. The cold water enters at the bottom of the jacket and overflows at the top. Why?

138. How Can We Get Pure Drinking Water? — When the chemist wants pure water, he **distils** it (Fig. 87). We can get pure drinking water in the same way. The impurities are left behind. In the household it is easier to **boil** water than to distil it. Boiling kills the germs, but leaves much of the dissolved materials in the water.

Do you like the flavor of distilled or boiled water? Its flat taste is due largely to the absence of the gases that are present in natural waters. We can improve the taste by shaking the water in a bottle with some air, or by pouring the water several times in a small stream from one vessel to another. Another way is to **filter** it through porous stones. In these ways the water may be made to dissolve some of the air it lost when it was distilled or boiled, and it will then have a better taste. Many people use a filter to purify water.

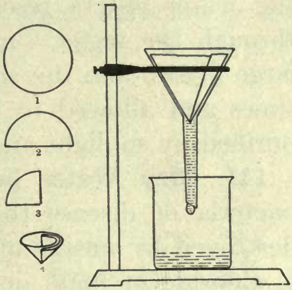


Fig. 88. — Figures 1, 2, 3, and 4, on the left, show how a circular piece of filter paper must be folded, so that it will form a cone that will fit nicely into the funnel.

139. What is a Filter? — A filter is a screen with very small openings so that only liquids and dissolved substances can pass through (Fig. 88). In household filters gravel, charcoal, and porous stone may be used as filtering materials. These strain out the impurities which are floating in the water, including the bacteria. Small porous-stone filters may be attached to faucets. The water runs through from the outside to the inside of the filter, and the dirt collects on the outside where it may be removed easily. If a filter is not cleaned often, it becomes clogged with dirt and bacteria and is worse than no filter at all.

140. Can a City Filter Its Water? — How do you suppose a city filters its water? City filter systems are made of beds of **sand**; these are often acres in extent. Sand is loose and contains much air. The oxygen of the air (cf. § 34) can thus penetrate far into it and destroy the bacteria of disease. After soaking through the sand, the water enters reservoirs from which it is pumped through the water "mains" into the houses. But the large filters, like the small ones, must be emptied sometimes and allowed to lie idle, so that the sand may be purified by sunlight and air.

141. May Water be Purified by Chemicals? — The bacteria of disease that are present in water may be destroyed by means of certain chemicals. One of these is chloride of lime, or "bleaching powder." This is a white solid that can be bought in metal cans. A certain amount of it when put into the city's water supply will make the water fit to drink, but it may give the water a slight taste. You can make a purifying solution for your own water supply, if you wish, in the following way:

Rub an even teaspoonful of chloride of lime with a little water until all the lumps are broken up and you get a smooth paste. Then mix the paste with four cupfuls of water. Put this solution into a bottle, stopper it tightly, and let it settle. To purify two gallons of water, add a teaspoonful of the clear chloride of lime solution, stir up the water, and let it stand for ten minutes.

142. What is Hard Water? — We often hear water spoken of as "hard," or as "soft," water. If you live in a village or in the country, you have probably noticed that water from a cistern is often used for washing purposes, while water from the faucet or well is used for drinking purposes. Cistern water is very likely to be impure, in that it contains many bacteria, and it may, therefore, be unfit to drink. Why is it better, then, for washing? When soap is used in the soft rain water of the cistern, a lather, or suds, is quickly and easily formed, but the soap lathers with great difficulty in the hard water. Rain water is always soft. Since well and spring waters were once rain water, they must have become hard in their passage through the ground. In seeping through rock and ground layers, the water dissolves some substances which make it hard. Some of these substances are made insoluble when the water is boiled and come out as " scale " (Fig. 89); others must be forced out by means of some chemical, such as ammonia. Ask your mother what substances besides ammonia are used to make water soft. Does soap soften hard water?

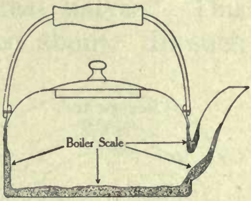


FIG. 89. — How the "hardness" of water is deposited on the inside of a teakettle.

143. Exercises. — 1. Is your city water hard or soft? Does the inside of your teakettle have a scaly deposit? Where does it come from? What is the source of your water supply? Put a clean pebble into your teakettle and leave it there for some weeks. Examine it from time to time to see if it increases in size.

2. What is the danger in drinking surface water?

3. What are the dangers in camping? How may they be overcome?

4. What are the ways of purifying water?

5. Why is it necessary to clean a filter frequently?

6. What is the value of a " trap "?

7. Make a definition for distillation.

8. Find out what industries in your city, or the city nearest you, need a large supply of water and why.

9. Find out from the water department of your city how many gallons of water the city uses in a year. What is the population of your city? How much is its *per capita* consumption of water?

CHAPTER XVI

ROCKS AND SOIL

144. What is the Earth's Crust? — What do you suppose the inside of the earth would look like, if we could cut it through its center into two great halves? This is something men have often wondered about. In such a cutting, or *cross section* (Fig. 90), there would be at least **four** different layers to think of. First, there is the **atmosphere**, or gas layer; then there is the **water** layer that covers about ¾ of the earth; the third is the *land* layer, or **crust**, upon which we live; the fourth is the inside, or **core**.

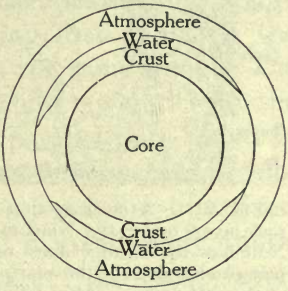


FIG. 90. — This gives us an idea how a cross section of the earth would look. Of course, the outer layers are not nearly so thick as the figure shows them.

In this chapter we consider the third layer: the crust. You may have heard people say: "Now we are at the bed rock of the argument." What did they mean by this? They meant that they were through with all the little, outside reasons and had reached the most important of all. In the earth's crust there are two layers: the **mantle rock** and the **bed rock.** The mantle rock is the loose, outer covering of soil, sand, clay, gravel, and pebbles. This may usually be worked without much difficulty. But the bed rock underneath is firm, hard, and difficult to cut through. A railroad cut or a road cut is sometimes deep enough to cut through the mantle rock into the bed rock. Mantle rock is much thinner at some places than others; in fact the bed rock sometimes comes to the surface and we have an **outcrop**. Have you ever seen a river which has cut down to bed rock?

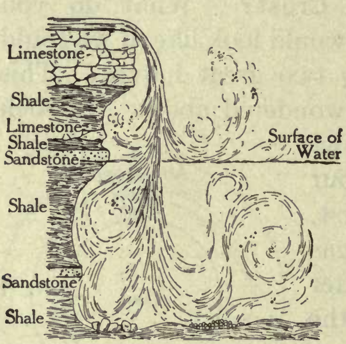


Fig. 91. — A cross section of the rock layers under the Niagara Falls. Note how the layers of hard rock are being undermined by the wearing away of the soft rocks. (After Gilbert.)

145. What are the Classes of Rocks? — Examine a piece of soft coal and note that a cross section of the coal is marked by a multitude of parallel lines, because the coal is made of thin layers. Limestone looks much the same. Such rocks are called **stratified**, or "made in layers." One layer of material seems to have been spread evenly over another, just as one leaf of a book is laid upon another.

The rocks into which Niagara Falls (Fig. 91) has cut are good examples of stratified rocks. The rock under the Niagara River is a hard limestone. This covers a soft shale layer and farther down we find some sandstone layers. Limestone, sandstone, and shale are stratified rocks.

Some rocks are not composed of layers. They are formed of crystallized masses which are interlaced and pressed tightly together. These are **unstratified** rocks. Granite, lava, and pumice are good examples of unstratified rocks.

Marble is believed to be a stratified rock which has been changed by heat and pressure, until it has the appearance of an unstratified rock.

146. How Are Stratified Rocks Formed? — How are these great layers of hard rock formed one above the other? When a stream empties into a pond, it drops its load of sand and dirt and this, settling to the bottom, forms a cover over the whole pond floor. A rain comes, enlarging the stream, and a considerable amount of dirt is deposited. The larger pieces fall first and then the fine dirt. Later another rain does the same thing. The large particles again fall first and are covered with the finer ones. This makes the fine, parallel lines found in the stratified rocks, one line for each flood time. Suppose this happened, not simply in a pond, but in a river, a lake, or the sea, and happened a great many times, until there was a very thick deposit; the lower layers would be pressed down by the weight of those above and would become very dense and compact. Then, if a cementing material were present, the clay deposits in the pond would be changed to shale, the sand deposits to sandstone.

147. What are Fossils? — When we break apart a mass of stratified rock, we often find a strange figure: something that looks exactly like a leaf with its stem and delicate veining (Fig. 92). Have you ever found one? It is as though the leaf had "turned to stone," or *petrified.* Sometimes we find a piece of stem, with the scars of leaves, or a piece of a tree's trunk, with the "rings of growth" of the wood. We may even find the seeds and fruit, all petrified. Often we find the imprints of animals; creatures with shells looking like those of snails and clams. In some rocks the imprints are those of fishes, turtles, and lizards, and of strange insects and birds. All these marks are called **fossils.** We may define a fossil as the evidence of some former plant or animal. How could fossils be formed in rock, far below the earth's surface?

(Copyright by McIntosh Stereopticon Co.)

FIG. 92. — A fossil of the long ago.

To explain how fossils might be made we must again picture to ourselves how stratified rocks are formed. Then, as now, leaves, or whole trees, fell into the water and were covered with mud and sand. Sometimes dead fishes, snails, birds, or insects sank into the stream and were buried. When the mud and sand hardened to rock, the impression of the creature remained to tell us, many centuries afterward, of the life that was once upon our earth.

148. How Are Unstratified Rocks Formed? — While we can go to a pond and by careful investigation find out how stratified rocks are formed, it is not so easy to find unstratified rocks in the making. Some volcanoes in action throw out rivers of molten rock; these cool to a glassy, brittle rock which we call **lava.** Sometimes the mass of lava is full of gas bubbles and cools to form our porous **pumice.** Sometimes the lava flows up into cracks in the earth and hardens in large crystals. **Granite** is a volcanic rock that has cooled slowly, under great pressure, as it would far under the earth's surface. When stratified rocks are heated by the molten rock near them, they are altered. Thus a layer of limestone might be changed to marble.

149. What is Weathering? — Did you ever think how untiring and how unceasing in her labors nature is? By the long, gradual process which we have just been studying, nature builds her rocks; now we shall learn how busy she is tearing down those rocks already made, at the same time that she is building up new rocks. The process by which rocks are broken down to form sand, clay, soil, and such small particles, is called **weathering**, or *erosion*, or "wearing away." Weathering is made possible by the combined work of wind, water, ice, plant life, and heat.

150. How Do Plants Cause Weathering? — We know that plants grow in soil, but did you ever think that plants can make soil out of rock? This is true even of such tiny plants as molds, fungi, and bacteria. Many of these are far too small to be seen without a microscope. They grow in the ground and break it up into fine particles. They even take materials from hard rocks and cause the rocks to crumble. Not only do the living plants act upon rock, but when they decay they produce acids (cf. § 175) and other compounds which attack the rock.

(*From Hopkins' Physical Geography.*)

FIG. 93. — How a tree may help in breaking up rocks.

While these small plants aid in making the soil fine and powdery, large plants aid by pushing their roots down into cracks in the rocks; thus they split rocks and force them apart (Fig. 93). Have you ever seen an old cement or brick sidewalk which has been broken by the growing roots of a tree under it?

How Do Plants Hinder Weathering? — Plant life has one way of defeating, or holding back, erosion. If you have a terrace in your yard, you have seen that grass seed is carefully sowed there until a firm sod results. If there isn't a firm sod, the water that runs off will cut the terrace and wash parts of it away. The sod prevents this by holding the ground and keeping a smooth, regular surface. How does the grass hold the dirt? Great forests act in the same way on a hillside. *Conservation* of the forests is thus very important. The great floods of China are said to be partly due to the cutting away of her forests. Why?

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

FIG. 94. — The tiny particles of desert sand, blown by the winds of centuries, wear away the hardest rock.

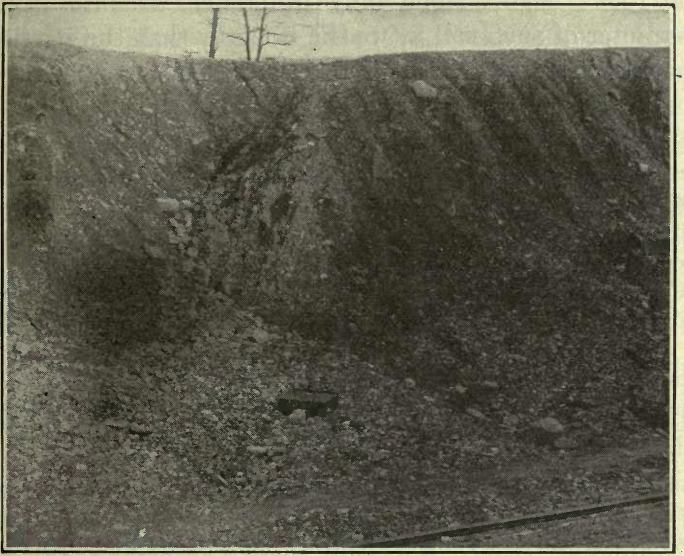
151. How Does the Air Aid Weathering? — Even the invisible air helps to destroy rocks, for it furnishes oxygen which unites with rock substances to soften and break them up. What happens to a piece of iron if it is left out of doors for some time? We say it rusts; that is, it unites with oxygen from the air and forms iron oxide, which is the red powder, rust. In the same way other hard, firm substances are changed to fine particles after uniting with oxygen. The carbon dioxide in the air unites with water and forms an acid (carbonic acid); this breaks up certain rocks.

Air in motion, as wind, assists in erosion, especially in dry climates and desert regions. Great windstorms carry fine, loose particles of sand and throw them violently against any object, rock, or plant which the wind passes over. Huge mounds of sand are moved by the wind, and each grain hitting a rock surface chips it a little. The great stone monuments which were built in Egypt thousands of years ago show well the power of the wind and sand to break off a great deal of stone if given time enough (Fig. 94).

152. How Do Water and Ice Cause Weathering? — The water of streams, lakes, and oceans aids in the weathering of rocks in ways which we have already studied. Frost and ice are powerful agents in breaking up rocks. If you leave water in your pipes on a cold winter's night, and do not have a fire in the house, the next morning you may find that one of the pipes has frozen and burst. Why does it burst?

Perform this **experiment**: Fill an old medicine bottle entirely full of water and stopper it tightly. Leave it outside on a freezing night. The next morning you will probably find that the stopper has either been forced out, or the bottle is broken. Water expands when it freezes (cf. § 124). In the same way water seeps into cracks and joints in the rocks; there it freezes, expands, and forces even great rocks apart. After a cold winter in which there has been a great deal of freezing weather, chips of rock and even large slabs are found at the foot of cliffs. These are forced off by the ice and frost.

Great **sheets** of ice assisted erosion in past ages, and **ice streams** (glaciers) are at work in the mountains now. An immense ice sheet once covered the Great Lakes region of the United States. Huge deposits of mud and rock (Fig. 95) were left after the melting of the ice. With the rocks frozen in its under side, the ice sheet was able to scour and scrape out lakes and to grind surface rocks to powder.



(From Hopkins' Physical Geography.)

FIG. 95. — Rocks brought by the great ice sheets and left when the ice melted.

153. How Is Our Soil Formed? — Did you ever wonder how " hard heads," or granite bowlders, came to our fields, when the bed rock below may not be granite at all? Is it possible that the soil of our gardens was not always where we find it, but was brought from other regions? There are two ways in which soil is formed on any particular spot. First, we have the soil which was formed from the rocks beneath it by the weathering of those rocks. It is composed of the same substance as the rocks below. The only difference we find in the character of such soil as we dig down is that the particles become larger all the time, until we strike bed rock.

The other class of soil is that which is brought, or **deposited** there, from a distance. Glacial soil belongs to this class; it is that brought by glaciers and spread over immense areas; these may have a totally different sort of bed rock. Another soil is formed on the slopes of hillsides or mountains. The action of gravity and of the rain causes great masses of it to move slowly down into the valleys. **Alluvial** soil is formed by the deposits of lakes and streams. A fourth kind of soil is fine and loose and deposited by the **wind**. It is found chiefly in desert regions. In general, the transported soils are made up of particles weathered from rocks of many kinds and are a richer combination for the growing of crops than the soils which were formed where we find them. Why?

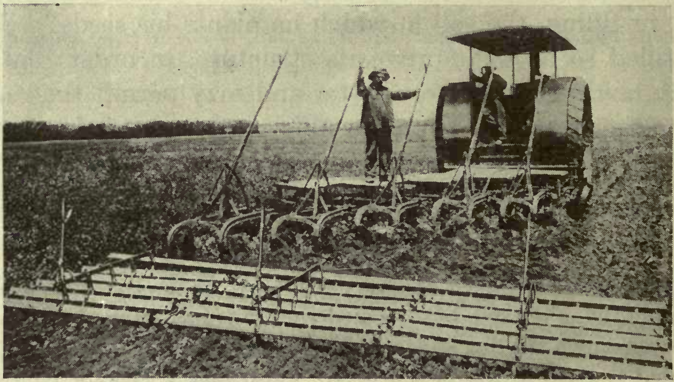
154. What is the Structure of Soil? — We can see, as we look at it carefully, that soil is made up of particles of different sizes. We call them, according to size, *gravel, sand, silt,* and *clay.* Which has the smallest particles? Usually there is also decayed vegetable matter, or *humus.* Each tiny particle is surrounded by a film, or covering, of water. Water is also held between the particles by capillary action (cf. § 108), so that the plant can draw moisture from deep down in the ground, even in dry weather. The water holds in solution those substances which are needed by the plant and which must be taken from the ground. Thus water is absolutely necessary to the life of the plant. Plants die if their leaves are not in the air, so that they can breathe; there must be air in the soil, too, so that the roots also can breathe. A soil that is very solid and airless chokes the roots so that the health of the plant suffers.

155. Why Must Soil Be Tilled? — Did you ever notice how much labor a farmer or gardener spends in stirring up, or **tilling**, the soil in which he plants his seeds? Soil is tilled so as to improve its structure, in order that it may hold air and water better and may permit the roots to gather the plant's food from larger amounts of ground. Tillage also turns under rubbish, manure, and other fertilizers, so that they become a part of the soil and enrich it.

In ancient times men had very few tools, or implements, to help them in tilling the soil, but the modern farmer has many of them. A **plow** is really a slanting knife, or shovel, that is forced into the ground, so that it turns a slice of soil over. **Cultivating** is shallow plowing; it stirs up the top layer of the ground, so that it is in a powdery condition. **Disk plows** have a revolving cutting instrument called a disk, instead of a knife plowshare. A **gang plow** consists of many plowshares or disks attached to one frame. It is drawn by many horses or by an engine, or **tractor** (Fig. 96).

156. What is Irrigation? — If you go to the Far West you will be shown great mountains, cañons, and cataracts as its wonders; but these are not the only great wonders of the west. As great a marvel as any is the transformation of land once a desert waste into fertile orchards and farms. How has this apparent miracle come about?

In dry, desert areas plants and crops cannot grow unless the soil receives more water than is given to it by the rain. Even in almost rainless regions there is usually a lake or stream that has a large amount of water during the rainy season, or in the spring, when the mountain snow melts. But in the summer there is no water. To even up the water supply large **reservoirs** are built and filled by damming up lakes or streams. These reservoirs hold the water of the rainy season for use during the summer. Irrigation **canals** carry water from the reservoirs to the farms.



(Courtesy of Deere & Co.)

FIG. 96. — How machinery makes it possible for men to farm on a large scale.

157. Do Crops Rob the Soil? — When we speak of the fertility of the soil, we mean its crop-producing power. This power depends upon the elements contained in the soil, the structure of the soil, and the water supply. However, a perfect soil for a certain plant cannot produce that plant if the climate is unfavorable. A soil which produces oranges in Florida could not produce them in Illinois. About ten elements are necessary for plant life. They are: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, sulphur, magnesium, and iron. Which of these come in part from the air?

Fertility is lost by the growing of plants because the plants need to take certain elements from the soil. If, then, we remove or harvest the plant, the ground gets nothing in return. This loss of fertility cannot be avoided. However, soil loses fertility in some ways which can be avoided. Thus, improper draining on sloping land allows rains to wash away valuable materials. Then, too, if certain crops are grown too long upon a piece of land, its soil becomes acid, or sour, and thus loses fertility.

158. How Can Soil be Kept Fertile? — While we cannot help removing fertility when we remove a crop, yet the loss can be restored. We must put everything back on the land that is not actually sold or used. That is why the farmer uses manure, the most common of fertilizers; it restores plant food to the soil. The farmer does not profit if he sells the fertility of his soil at too low a price. Thus, when grains are cheap, it may be most profitable to use them as cattle food, because the price received for farm fertility as meat is often greater than that received for it as grain. Besides, when cattle are raised, much of the farm's fertility can be restored as manure.

Dairying is profitable, because dairy products (What are they?) bring a good price, and because they do not remove much fertility. If we sell butter, for example, we are selling chiefly fat. Now, fat is composed of carbon, oxygen, and hydrogen (cf. § 189), which are elements coming from water and from the carbon dioxide of the air. If the skim milk is used on the farm, the soil need not lose its fertility.

159. Why Should Crops Be Rotated? — Rotation, or *changing of crops*, on a certain piece of land, is now used by all good farmers. Different crops use different soil elements. Corn removes much of all three of the elements nitrogen, phosphorus, and potassium, and should not be planted every year. Grains, such as wheat, which take up phosphorus, and grass, which takes up little phosphorus, are often grown for two years and then corn in the third year.

Rotation is good in other ways, for roots of different plants differ from one another and one plant will often break up the ground for another. The diseases and pests of plants differ, too, and one plant will not be affected by those of another.

Have you seen **artificial fertilizers?** They are usually powdered substances which contain the elements, or some of the elements, needed to give back to the soil what has been taken from it by crops. Fertilizers are spread over the ground, or "plowed under." Generally they supply one or more of the three elements: phosphorus, potassium, and nitrogen.

160. Exercises. — 1. Make definitions for these terms: fossil, bed rock, outcrop, stratified rock, weathering, soil, glacier, irrigation, soil fertility.

2. Why are beach pebbles rounded?

3. Report some case of weathering you saw on the way to school.

4. Find out from a gardener what kind of soil is best for the growing of potatoes.

5. Ask a florist how he prepares soil for the growing of flowers.

6. Why do farmers " cultivate " the soil between rows of corn?

7. Of what use are song birds to the farmer?

8. What are some of the tools and implements used on the farm?

9. What advantages has a child that grows up on the farm? What disadvantages?

10. Do you think that a farmer ought to burn up the stubble in his fields, or let it rot and become part of the soil? Find out the reasons.

11. Find out what substances are in skim milk. For what can skim milk be used?

12. Bring to school some samples of stratified and of unstratified rocks.

CHAPTER XVII

MINERALS AND METALS

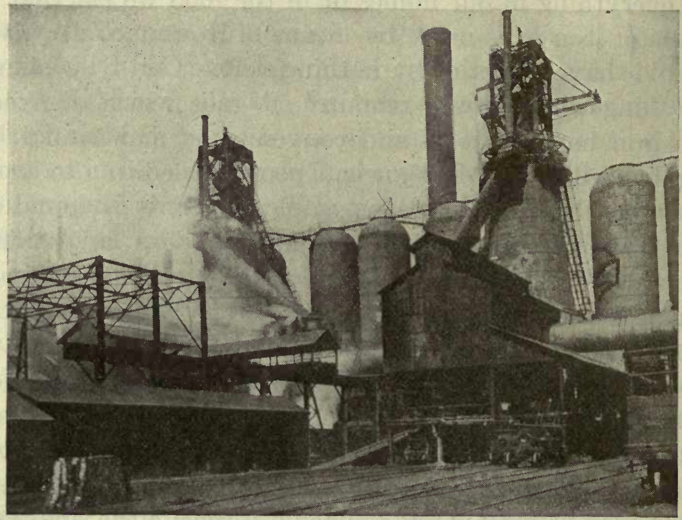
161. What are Minerals? — We have already looked at our earth as made up of several layers: the air, the water, the crust, and the interior, or core; we have also looked upon it as made up of *elements* (cf. § 113). We may now look upon it as made up of animal, vegetable, and **mineral** material. When we realize that rocks are made up of minerals, we can understand that minerals make up much more of the earth than the other two put together. Some of these minerals, such as granite, seem never to have had anything to do with life, while others, such as coal, are the remains of former living things. Those substances which are, or have been, part of a living thing, or *organism*, we call **organic** substances. Name some of them.

Quartz, clay, sand, flint, chalk, gold, copper, and even water are minerals, so you see that minerals differ greatly in their qualities. Most of the metals are found united with other materials, just as hydrogen and oxygen are united in water. Those minerals from which we may take out, or "extract," a metal are called **ores** of that metal. Most of our common, useful metals are found in ores. Lead, iron, tin, zinc, silver, gold, and copper are taken from the ground as ores, although gold and copper are sometimes found in nature in a pure form. To start with the lead ore and to turn out a lead pipe takes a great deal of time, machinery, and labor. Many huge factories all over our country are working to get the useful metals out of the ores in which nature placed them.

162. Is Iron Necessary to Man? — If we were to give up everything in our homes or in the food we eat that is made of iron or is made by means of iron machinery, we should have practically nothing left. Can you name anything which would remain? A race which does not use iron has few tools and conveniences and cannot be highly civilized. Most ancient peoples used iron to some extent: the old Egyptians employed it; it is found in the ruins of Babylon. Could our modern inventions, such as the automobile, telephone, victrola, and steam engine, exist without iron?

163. How Is Iron Found? — The commonest ore of iron, which furnishes half of all the iron used, is called **hematite.** Hematite is a compound of iron and oxygen, a rough, ordinary-looking rock varying in color from gray to reddish brown. The ore is often in great ledges and has to be blasted out. Then it is sent to the **smelters,** or furnaces, to be *smelted,* or turned into metal. The smelter is usually built near some industrial center that has good coal within easy reach; for coal is needed to remove the oxygen of the ore. Much of the iron ore from the deposits in Minnesota, Wisconsin, and Upper Michigan is sent down the Great Lakes in large steamers. Did you ever see one?

164. How Is Iron Prepared? — How do you suppose early man learned to smelt iron? The ancients did it in a very primitive manner. They built fires in the rocks in such a way that there was a strong wind blowing through the fire. When iron ore was placed in the fire, the fuel (wood or charcoal) united with the oxygen of the ore, leaving the iron. The iron metal melted and ran to the bottom of the fire, while the dirt and stone of the ore remained with the ashes.



(*Copyright by McIntosh Stereopticon Co.*)

FIG. 97. — In a blast furnace iron ore, coal, or coke, and limestone are heated together to produce pig iron and slag.

There have been many improvements upon this method, until we now have the modern **blast furnace** (Fig. 97). The blast furnace is about 100 feet high and is filled, by means of machinery, with coal or coke, iron ore, and limestone. Limestone is used because it unites with the dirt and stone of the ore to form **slag** and thus leaves a purer iron. A strong artificial wind (a "blast" of hot air) enters at the bottom of the furnace; the whitehot iron runs down into the hearth, where it is drawn off into sand troughs. Why is sand used?

The iron in this stage, or form, is called "pig iron," or **cast iron.** This pig iron still contains many impurities; they are removed by another process, until **wrought iron,** or soft iron, is obtained. **Steel** is a most useful form of iron, hard and durable, yet elastic. It can be "tempered," so that it becomes very hard and can be sharpened to a keen edge, as in cutting tools, such as axes, saws, knives, and razors.

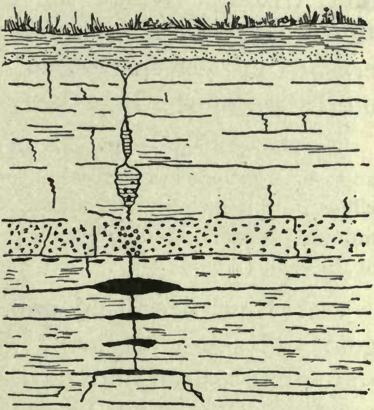


FIG. 98. — How a deposit of lead ore might look in the ground. The black spots represent the ore.

165. How Is Lead Obtained? — Lead is extracted from *galena,* a heavy, gray ore (Fig. 98) which is a compound of lead and sulphur. Galena is usually smelted by heating it with iron. The sulphur then unites with the iron and the free lead sinks to the bottom of the furnace.

Lead is used in pipes for plumbing, in storage batteries, for paints (you have heard painters speak of "white lead"), and in making mixtures, or **alloys,** with other metals. Some of these alloys are solder, pewter, shot metal, and the type metals used in printing.

166. How Is Copper Obtained? — The free metal copper is found in the regions of Lake Superior; from these it was obtained by some of the Indians before the coming of the white man and was used for the making of knives and other implements. The greatest copper mines in the United States are in Michigan, Montana, and Arizona. Where the copper is found as a metal, the smelting of its ore is a simple process. The ore is crushed in very fine pieces and the copper is separated out by washing. It is then melted and run into molds.

The **alloys** of copper are very important. **Brass** is made of copper and zinc. **Bronze** is a mixture of copper, tin, zinc, and lead. **German silver** is copper, zinc, and nickel. Copper and aluminum form **aluminum bronze**, resembling gold. Can you name some of the uses of these alloys?

167. How Are Gold and Silver Found? — Why are gold and silver precious? They are beautiful in their soft, pretty sheen, but their being precious is due largely to the fact that they are scarce. Gold is not found even as abundantly as silver and is, therefore, more precious than silver. Because of its attractive color, gold was probably the first metal found by man.

Much gold is found as fine grains in the gravel of streams. This was once in rocks, but the decay of the rocks has freed the gold. Men wash gold grains out of loose soil and gravel by the use of streams of water. As the water containing gold is passed over mercury, even the smallest pieces of the gold are dissolved in the mercury. Later the mercury is distilled off, leaving the gold.

In early days gold grains were washed out of loose soil and gravel by the use of water in a **pan** (Fig. 99). As the water was stirred up, the lighter particles of soil, sand, and gravel could be poured off with the water, while the gold, which was heavier, remained in the bottom of the pan.

What is the meaning of the expression: "How is this going to 'pan out'?" What is "pay dirt"?

(Copyright by McIntosh Stereopticon Co.)

Fig. 99. — Panning river gravel for the heavy grains of gold.

Silver is often found, in nature, united with sulphur. The fact that a silver spoon turns black when used with an egg (which contains sulphur) shows how readily silver unites with sulphur.

168. What is 22-Carat Gold? — Gold and silver are both too soft to use in their pure state, and they must be *alloyed* (or mixed) with a hard metal to make them fit for use. The purity of gold is stated in *carats*. Pure gold is "24 carats fine." Jeweler's gold is 22 carats fine. This means that 22 parts of it are pure gold and 2 parts are alloy. Ten-carat gold is 10 parts gold and 14 parts alloy. Gold is usually alloyed with silver and copper. Silver is alloyed with copper.

169. How Do Men Find Precious Stones? — The precious stones, such as diamonds, rubies, sapphires, and emeralds, are found loose in earth or in rocks. When found, the stones are surrounded by rocky material which has to be removed. Then the stone is "cut," or ground. After the cutting, rays of light can pass through the stone at many different angles and make it more beautiful. Much of the beauty of a gem lies in the skill with which it is cut (Fig. 100).

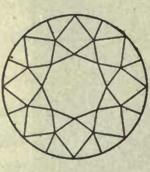


FIG. 100. — How a diamond is cut so as to give it many "facets," or surfaces, for the flashing of light.

The precious stones are among the *hardest* substances known to man. Indeed, the diamond, which is the most precious of all, is the hardest substance in nature. The greatest number of diamonds, and the largest of them, are mined in South Africa. Sometimes we see a diamond which has a flaw in it: a small, dark spot. This shows the origin of the stone. The brilliant, flashing diamond is only a pure form of common carbon, such as is in coal or charcoal. But it is carbon which has probably been heated and kept for years under intense pressure.

Like gold and silver, our precious stones are precious quite as much because of their scarcity as because of their beauty.

170. What is Coal? — When you sit in front of your grate fire, watching the flames play about the coal, do you ever wonder how we happen to have coal? Yes, you know that coal is mined, or taken from the ground, and brought to you; but how did it get into the ground? It is not like the other rocks of the earth's crust. Then what is it, and how did it get between the rock layers? Thousands of years ago great, luxuriant forests grew on the places where we now find coal fields. They grew up and lived and died and fell to the marshy ground on which they stood. Others grew up in their place; they, too, fell in turn into the marshy land and were covered by water. Sometimes, probably, the land was lowered and the former forests were under water and covered with sediment and mud. This sediment afterwards became rock. Some of the gases escaped, but the rest of the carbon of the plants was held under the great pressure of the layers of rock and water above it, until it gradually hardened to form coal (Fig. 101).

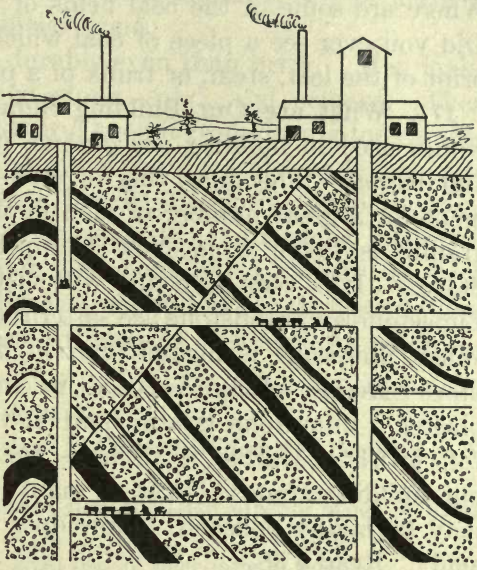


FIG. 101. — What a cross section of a coal mine might look like. Note the great crack across the rock layers and the way in which the upper part has slipped down, producing a *fault*.

In swampy regions we can see soft **peat** being formed today. This was probably the first form of soft, or **bituminous**, coal. Hard coal is also called **anthracite**; it gives off much less gas than soft coal (cf. § 28) and so is harder to set on fire. Where are some of the coal fields of the United States? Did you ever see a piece of coal which had on it the imprint of the leaf, stem, or trunk of a plant or tree?

171. What are Our Building Stones? — Some of the stones used in building are *granite*, *limestone*, *sandstone*, and *marble*. The quarrying of stone furnishes employment for a great number of men in this country. Much granite is taken from New Hampshire, the "Granite State." It is very hard and will sustain a great weight. Limestone and sandstone are softer rocks, but very useful. When limestone is heated, carbon dioxide escapes and lime remains. Lime is used in making mortar and plaster. Limestone is also used in the smelting of iron (cf. § 164). Marble is perhaps the most beautiful of our building stones. It is of many different colors and may be highly polished. How does marble act with an acid? Read § 38.

172. Does Man Ever Make Stones? — You have heard of artificial jewels, but have you ever seen artificial building stones? Of course you have. Man has not always been able to get, or been satisfied with, natural stones, so he has *made* certain ones for himself. Such are **bricks** and **concrete**.

Bricks were made long ago in Egypt, Assyria, and Babylonia, and they are made in great quantities even now in our own country. Finely powdered clay is mixed with water and the mixture is either packed into molds or is cut into bricks by machinery. The bricks are then dried in the air for several days and later baked in immense ovens for several more days.

Mortar, used to fasten bricks together, sets or hardens to form another artificial stone.

Concrete is more durable even than brick. Men make it by mixing crushed stone, sand, and cement. Then they put it into molds and keep it from drying too rapidly by covering it. You have seen freshly-made concrete sidewalks covered with boards, or cloths, until the concrete has "set," or hardened. It hardens better if sprinkled with water occasionally. Concrete is used not only for sidewalks and floors, but for the foundations and walls of buildings, for bridges, and even for ships!

173. Exercises. — 1. Why are layers of limestone and sandstone often found between layers of coal?

2. Is petroleum a mineral? Where is it found? For what is it used?

3. Why is iron ore shipped from the Lake Superior region to Pennsylvania to be smelted?

4. Name five or more great uses of some form of iron.

5. Why do we believe that coal is made up of the material of ancient forests?

6. What metals are called "precious" metals? What are the "base" metals?

7. Find out the value of the silver in a silver dollar.

8. What is solder used for? Pewter?

9. Why is iron often covered (plated) with tin? With a magnet test a pin and then a needle. Is either made of a form of iron?

PART IV

SCIENCE IN THE HOUSEHOLD

CHAPTER XVIII

ACIDS AND ALKALIES

174. Do We Use Science in the Home? — Have you ever thought how strange it is that men have learned to gather and to prepare so many different substances and to use each of them for some special purpose? Just think what a collection of substances there is in a druggist's shop. The modern housewife has not nearly so many as the druggist, yet she has a long list. Here are some of them: baking soda, washing soda, chloride of lime, lye, bluing, borax, starch, cream of tartar, salt, ammonia water, vinegar, sugar, flour, lard, baking powder, soap, ink, to say nothing of milk, butter, and our other foods. It is out of these materials that our meals are made ready for the table, our laundry work is done, our letters are written, our stains are erased. Can you name any other household substances?

175. Where Are Acids Found? — As you know very well, we use vinegar to make certain articles of food sour, or "acid." This is true of beets, pickles, and salads. The chemist says that vinegar is sour because it contains an acid: acetic (pronounced ă-sēt′ĭc) acid. Most acids have a sour taste.

Vinegar is the result of a **fermentation**, or change caused by a ferment (Fig. 102). Ferments are found in small organisms that exist in nature and in some way or other get into our fruit juices and other food materials. In the fall you may have seen how a cider press extracts the juice of apples and so makes "sweet cider." If we try to keep sweet cider very long, it bubbles and becomes "hard." The bubbling is due to the escape of *carbon dioxide;* the "hardness" is due to *alcohol.* The reason for this is that the **sugar** of the apple juice is changed into alcohol and carbon dioxide. Yeast cells which are in the air fall into the juice and cause this change (cf. § 201).

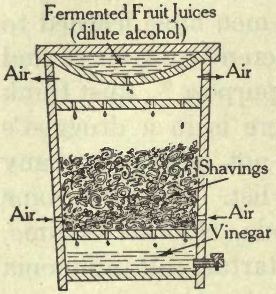


FIG. 102. — We make vinegar by letting the air oxidize fermented fruit juices, so that their alcohol is changed to acetic acid.

When the hard cider is allowed to stand longer, a mold called "mother" begins to grow in it; this changes the alcohol to acetic acid and we then have *cider vinegar.* **Grape juice** is changed in the same way, first into **wine,** which contains alcohol and carbon dioxide, then into *wine vinegar,* which contains acetic acid.

Milk sours because one particular kind of ferment gets into milk and changes the sugar of milk into **lactic acid.** This acid causes the milk to become curdy and to taste sour. The same acid is present in dill pickles and sauerkraut.

Many fruits, such as tomatoes, cherries, and green apples, and some plant stems, such as rhubarb and sour grass, are strongly acid. Lemons, oranges, and grapefruit contain **citric** acid; grape juice contains **tartaric** acid.

All of the acids we have named are compounds of carbon, hydrogen, and oxygen. There is also another very important acid which contains sulphur, hydrogen, and oxygen; this is **sulphuric acid**, or vitriol. **Hydrochloric acid** is another very important acid. Its old name is "muriatic" acid. It contains hydrogen united with chlorine. Chlorine, you remember, is present in salt.

176. What Makes a Compound an Acid? — In telling what acids are like, we can say, first, that they are sour. If acids are strong enough, they will "eat" the skin and clothing upon which they fall. Metals are also "eaten," or "etched," by acids. We have already learned that in making hydrogen (cf. § 114) zinc is used up, or eaten, by the acid, and disappears. Are copper and lead used for cooking vessels? They cannot be, because the acids in foods act upon the metals and cause poisonous compounds of copper and lead to be formed.

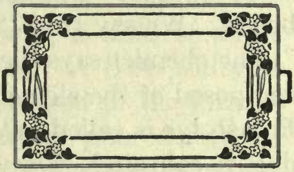


FIG. 103. — The metal is eaten out, or etched wherever it is exposed to the action of the acid.

Have you ever seen copper which has been etched so that it shows a beautiful design, as in Fig. 103? The design is made by covering all the copper, except where the lines are to be, with asphalt paint. Then the copper is put into **nitric acid**; the acid eats it wherever it is not covered. When the copper is removed from the acid, the asphalt is scraped off and there is a design on the copper.

Acids also act with marble, limestone, or soda. When an acid is mixed with marble, carbon dioxide is given off (cf. § 38). This causes a great deal of bubbling, or effervescence. Bones, which contain much limestone, lose their stiffening (largely limestone) by being placed in an acid. Why can a dog eat bones? Can it be that the acid in the dog's stomach is strong enough to destroy the hard part of the bone?

177. What are Bases Like? — Have you ever tried to wash a greasy pan with water alone? If you have, you know how hard it is to remove the grease, because it doesn't mix with the water. But if you put into the greasy pan some lye, or other washing powder, and add warm water to it, you find that the grease is easily washed off. It seems to dissolve and disappear. The lye and washing powder belong to the class of substances we call **bases.** We say they " cut " grease.

The chemist says lye is **sodium hydroxide**, to show it is composed of the elements sodium, hydrogen, and oxygen. Potash lye is called *potassium hydroxide.* What elements does it contain? Do you know what ammonia water is? It is a very strong-smelling liquid that acts in many ways like lye. You put some into water that you use for washing windows or glassware, because it removes grease and makes the glass bright and clean. Like lye it is a base.

There is another very common base; it is **lime.** Have you ever seen masons making mortar? They put lumps of a white solid (lime) into the vats of water, and the lime unites so vigorously with the water that the water becomes almost boiling hot. The product is **slaked lime.** Masons mix sand with the slaked lime and produce *mortar.* Lime will destroy animal substances, so men are able to use it for taking hair off from hides. Its solution, **limewater**, can be added to milk to sweeten it, if it has become slightly sour. Limewater mixed with olive oil is used to heal burns.

The strong bases all have a bitter taste even when dissolved in a great deal of water. If there is not much water mixed with the bases, their solutions will destroy skin and flesh and the mucous membrane that lines the mouth. Hence we must use a great deal of care in handling lye.

178. How Can We Test for Bases and Acids? — How do bases differ from acids? If you had a solution which looked like water, and yet you knew that it might contain an acid or a base, how would you find out which it was? The easiest way is to use **litmus.** Litmus is a coloring matter obtained from *lichens,* a kind of plant. An acid will turn blue litmus to red. A base will turn red litmus to blue. Litmus may be used in the form of a solution and a few drops of it may be poured into the liquid you are testing; or it may be in the form of colored paper and a slip of the paper may be dipped into the liquid. If you test orange juice, what happens to your litmus? Test some of the things you find at home to see which show an acid test and which show a basic test. Also bury a piece for an hour or two in some moist soil in a flower pot and see whether the soil is acid or not. Farmers use this test, because acid soil is not good for the raising of most crops. *Purple cabbage* solution may be used in exactly the same way as litmus solution.

179. How Does an Acid Act with a Base? — We can now learn something still more interesting about acids and bases. Dip your thumb and forefinger into a solution of caustic lye and then rub them together. They feel slippery, or slimy, do they not, as though they were covered with strong soap solution? Now add to the lye solution some vinegar, or lemon juice, a little at a time. You will soon find that the solution no longer has the slimy feel it had at first. The acid of the vinegar or lemon juice has destroyed this power of the lye. The chemist says the acid has **neutralized** the lye.

Put a piece of red litmus paper into some fresh caustic lye solution; what color does the litmus have now? Then add some hydrochloric acid solution, little by little, to the lye solution, stirring as you do so. What color does the litmus take on? The acid has neutralized, or destroyed, the power of the lye to turn litmus blue.

If there is no base left in the lye solution to which the hydrochloric acid was added, what do you suppose *is* left? Put the solution into a saucer or into an evaporating dish, and drive off the water by heating the dish gently. What is left in the dish? Taste it; it is **common salt.** So *salt* was formed when caustic lye was neutralized by hydrochloric acid. When vinegar or lemon juice neutralizes the caustic lye solution, there is another substance formed which is not common salt, but is like it in some ways. The chemist calls all such substances **salts,** since they are formed by the neutralization of a base by an acid, as common salt is.

Salts are very common. Marble, limestone, table salt, blue vitriol, saltpeter, and alum are all called *salts* by the chemist.

180. Exercises. — 1. Galvanized iron is iron covered with zinc. Is it a safe material for dishes in which acid fruits are cooked?

2. The acid present in canned tomatoes causes milk to become

curdy. In making "cream tomato" soup some baking soda is added to the tomato to prevent the curding; explain how it acts.

3. The spots of limestone on a glass water pitcher are easily removed by a little vinegar or lemon juice. Can you tell why?

4. Collect some wood ashes, cover them with water, and after the ashes have settled, pour off the water. Then test the water with pink and blue litmus paper. Does the solution have an acid or a basic action? Could you use wood ashes to "sweeten" a "sour" soil?

5. Test solutions of alum, washing soda, and common salt separately with pieces of red and blue litmus. How does each behave?

6. To a lump of old mortar in a dish add a few drops of a dilute acid. Describe what happens. Can you prove that the gas formed is carbon dioxide? What is left undissolved? What gas does fresh mortar take from the air as it hardens, or sets?

CHAPTER XIX

WASHING AND CLEANING

181. What are the Materials of Clothing? — In very ancient times savage men kept warm by clothing themselves with the skins of animals; even today furs are sometimes used for warmth as well as for decoration. Still, as you know, the common materials for our cloth-

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Fig. 104. — A cotton field of the South.

ing are *woven* fabrics; they come from both animal and vegetable sources. **Silk** and **wool** are from animals; while the vegetable fibers which can be woven to advantage are **cotton** and **flax.** What an interesting story it would be, if we could learn how men first came to use these materials for their clothing.

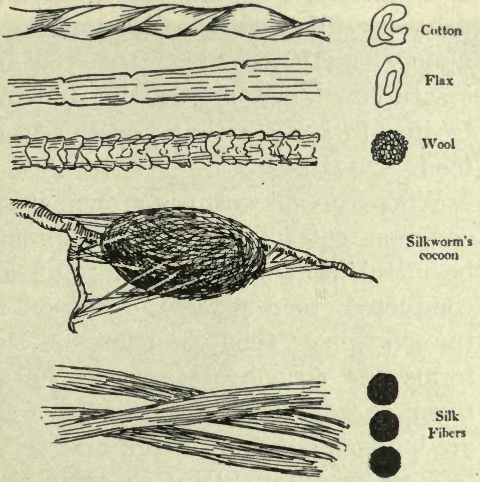


Fig. 105. — The fibers out of which fabrics are woven, and the silkworm's cocoon. Note the overlapping scales of wool fibers.

Cotton plants have a fluffy, soft covering made of long fibers for their seeds (Fig. 105). Men gather this covering from the plant, separate it from its seeds, and use the fibers in making cotton cloth. The fibers are hollow tubes, flat and twisted.

The stalks of the **flax** plant are used to make linen cloth. These fibers are hollow, like those of cotton, but straight instead of being twisted. They have thick walls with central openings. Linen cloth is stronger than cotton, but cotton is the lighter and more elastic.

Cotton and linen are easily destroyed by strong acids, but are not easily harmed by bases. In fact, if cotton is soaked in a strong base for a short time, and is then washed thoroughly, it is made stronger and has a glossy, silky appearance. Cotton thus treated is called "mercerized" cotton.

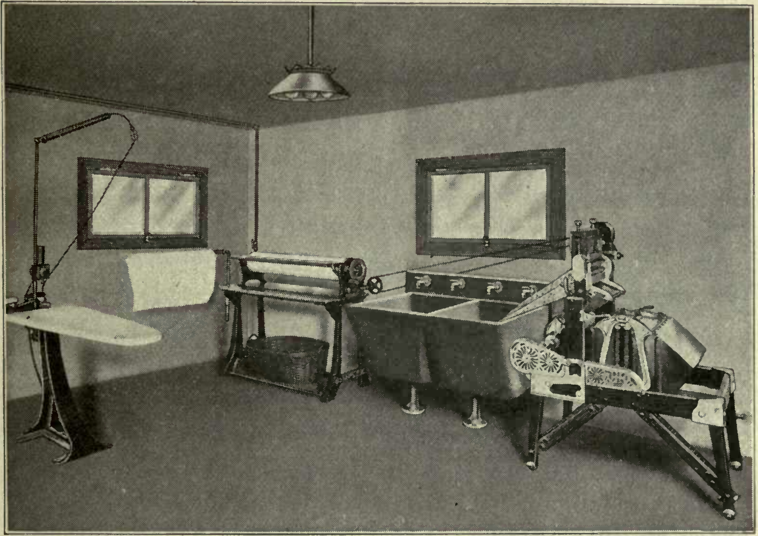
182. How Are Silk and Wool Obtained? — Silk and wool are obtained from animals. **Silk-growing** is one of the greatest industries of Japan and China. The eggs of the silkworm are allowed to hatch in long trays. These trays are filled with leaves and the tiny "worms" feed upon these leaves until they become large, fat, white creatures. There are usually so many of these "worms" feeding in a room that you can hear them crunch their food.

When the silkworm is grown, it spins a *cocoon*, as our common caterpillars do, and prepares to come out a beautiful, winged creature. But after the spinning is completed, men place the cocoon in hot water to kill the silkworm; then they unwind the tiny thread which forms the cocoon. Many of these threads are woven together to give us a little piece of silk cloth. Silk fibers are long, smooth, beautiful, and very strong.

Wool is obtained by shearing sheep; this is done in the spring time. The heavy, wool coat grows in the autumn to protect the animal from winter's cold and will drop off when warm weather comes, if it is not cut. The fibers of wool are short and thick, with projections that overlap one another (Fig. 105).

Unlike vegetable fibers, animal fibers are destroyed by bases, and are not readily acted upon by acids. No method of washing wool should be used which will force the cells closer together, or the wool will shrink and finally become stiff and board-like.

183. How Is Clothing Washed? — When fibers are woven into cloth, tiny spaces (pores) are left between the threads of the cloth. These pores form an absorbing surface for the skin (cf. § 108). Perspiration and the waste it removes from the body, as well as dead skin itself, are all caught in the surface of the cloth. Clothing that has been worn too long has a damp, sticky feel because its pores are filled. This clothing should not be worn again until it has been washed. The reason why clean garments "feel so good," as we say, is because they have a fresh absorbing surface.



(*Courtesy of the Judd Laundry Machine Co.*)

FIG. 106. — The equipment of a modern laundry. Name the different machines.

In ancient times the women took the soiled clothing of the family to a stream and rubbed it out upon the rocks. Later the washing was done at home with the aid of hot water and soap. Now we have stationary tubs, washing machines, wringers, and even machines run by electricity (Fig. 106). So our washing is done better and done more easily all the time, as we recognize the importance of clean clothing. What would you think of the practice, common in some countries, of sewing on heavy clothing in the fall and leaving it on all winter?

184. How Does Soap "Work"? — Why do we use soap? We say that it removes dirt. If you think of it, you will see that the dirt we want taken away from clothing is usually some form of grease or some form of soot. When, therefore, the soap solution is rubbed on greasy cloth, it breaks up the grease into tiny *droplets* and surrounds them. Thus they are separated from the cloth and can be washed away by the water. Water alone cannot do this.

If you try the action of soap upon some *kerosene*, you can understand its cleaning power for grease. Into a test tube or small-mouth bottle put some kerosene and water and shake the two together. The kerosene will break up into droplets, but when you stop shaking, the droplets will soon unite and the layer of kerosene will float upon the layer of water. But if you shake the kerosene with a dilute soap solution, the kerosene does not separate again into a layer by itself; it remains as tiny droplets mixed with the soap solution. In the same way, the butter fat of milk is kept suspended in tiny droplets by something in the milk. A mixture like this is called an **emulsion**.

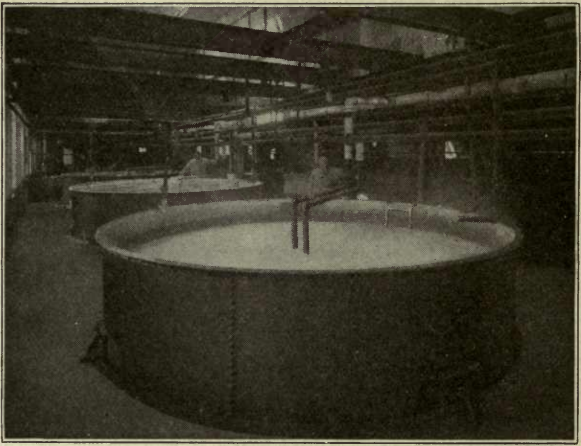
When a soap solution is rubbed upon soot, the tiny particles of soot are surrounded by the soap solution and so taken off the clothing.

How do you suppose people ever learned to use soap?

185. How Is Soap Made? — In primitive times soap-making was carried on by every family (Fig. 107). In the spring all the winter's wood ashes were pounded down in a barrel and water was allowed to soak through the ashes and caught when it came out at the bottom. This water was boiled down to form homemade **lye** (potash). Later, lye was bought instead of being made. Then the lye, either homemade or commercial, was placed in a huge kettle with melted fat (from the winter's supply of meat) and the two were cooked together in the open. Sometimes the cooking was continued for two or three days. Then the " soft soap " was cooled and put away in barrels for the next year's use.

Fig. 107. — The making of soap at home by the cooking of grease and lye.

Nowadays soap is made on a large scale in **factories** (Fig. 108). Nearly every meat-packing house has a soap factory as a part of its business. Why? When the meats are cut and packed, there are always fat portions that cannot be sold. These are used to make soap. Some soaps are made of vegetable fats, such as olive oil and cottonseed oil, instead of animal fats. Soap is made by boiling the fat or oil with sodium hydroxide (lye). The lye " cuts " the fat and it disappears into solution. Common table salt is then added to the solution, and the soap is " salted out." It floats on the top, is skimmed off, pressed, and cut into cakes. Sometimes a longer process is used, so that **glycerine** can be made at the same time. What sort of substance is glycerine? What are some of its uses?



(Courtesy of Swift & Co.)

FIG. 108. — How soap is made on a large scale. Such kettles are three stories high and hold enough material to make about 700,000 bars of soap.

186. What is Dry Cleaning? — Certain materials, such as silks, woolens, and kid gloves, lose their soft finish if they are washed often, as cotton and linen goods are. For this reason a **dry cleaning** shop is now found in even our small cities. Dry cleaning is done by means of gasoline instead of water. The gasoline used for the cleaning evaporates quickly from the material, leaving it clean and soft and as pretty as when new. People think of gasoline as a liquid; they should think of it as an **inflammable gas.** It must not, therefore, be used near a fire nor where its vapor can be carried to the fire, or it may burn with a frightful explosion.

187. Exercises. — 1. Why cannot clothing be washed properly in water alone, without soap?

2. Laundries sometimes use acids for the washing of clothing; do you think such fabrics will last long? What ones are especially injured?

3. Ask a good laundress how woolen clothing should be washed so that it will remain soft and porous.

4. Find out why "bluing" is used in the washing of white goods.

5. Does soap form suds as quickly in well water as in rain water? Why?

6. Soak some "strong" laundry soap in a little water and test the solution with litmus papers. Is the solution acid or basic? Do the same with some washing powder. Why is strong laundry soap not good for your hands?

7. Why is starch used in the laundry?

8. Is it true that the civilization of a country can be told from the amount of soap it uses? Why?

9. Can you give a good reason why towels should not be ironed?

CHAPTER XX

FOOD

188. Why Do We Need Food? — If we want to take a trip in an automobile, we are very careful to fill the gasoline tank before we start. When we are traveling across the country on a train, the train stops at certain places and takes on coal or water. If cars and trains run, they must be fed with gasoline or coal or other fuels. It is the same with our bodies. If we want to walk and move about, our bodies must have something to burn, in order that they may have **energy**. Now the body does not burn gasoline as a car does, or coal as an engine does; it burns food. The food which we eat is oxidized in the same way as the gasoline and coal are (cf. § 32) and yields, as they do, heat and energy.

However, there is one important difference between the human engine and the steam engine: the human machine is not built in its final form; it has to *grow*. It wears out, too, and has to make its own *repairs*.

Therefore **two kinds of food** are needed for the human engine: foods that will be burned, or oxidized, so that we may have **energy**, and foods of the other sorts to be used for the **growth and repair** of the body.

Think of all the different kinds of food we eat, yet all these may be divided into **five classes** of foods. They are:

1. Carbohydrates.
2. Fats.
3. Nitrogenous foods.
4. Minerals.
5. Water.

The first two are of use in furnishing energy, while the third is needed for building up new tissues and repairing old ones. See Fig. 109.

189. What Foods Give Us Energy? — *Carbohydrate* is a long word, but it means foods like sugar, starch, and cellulose. Carbohydrates and fats are all compounds of carbon, hydrogen, and oxygen. When they are taken into the body, they combine with more oxygen (obtained through the lungs) until the carbon and hydrogen are both completely oxidized. This process of oxidation is accompanied by heat. The heat keeps the body warm and makes movement possible. Why are girls and boys hungry after playing tennis, or hockey, or football? Why are they warm?

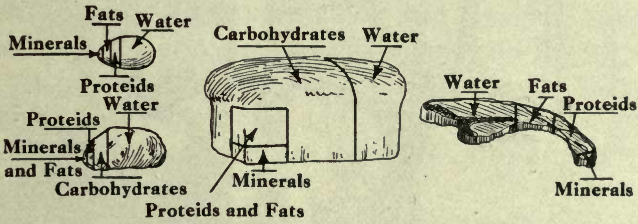


FIG. 109. — The amounts of the different classes of foods present in an egg, a potato, a loaf of bread, and a sirloin steak.

The carbohydrates are found almost entirely in vegetable foods. Except in milk, only traces of them are found in any animal food.

The **fats**, the other great class of energy producers, are found in both vegetable and animal foods. They are the oils and solid fats, such as beef suet, tallow, lard, olive oil, cottonseed oil, and butter (Fig. 110). The fats have a greater proportion of carbon than the carbohydrates, and therefore produce more heat when oxidized. A pound of fat produces $2\frac{1}{4}$ times as much heat as a pound of sugar or starch.

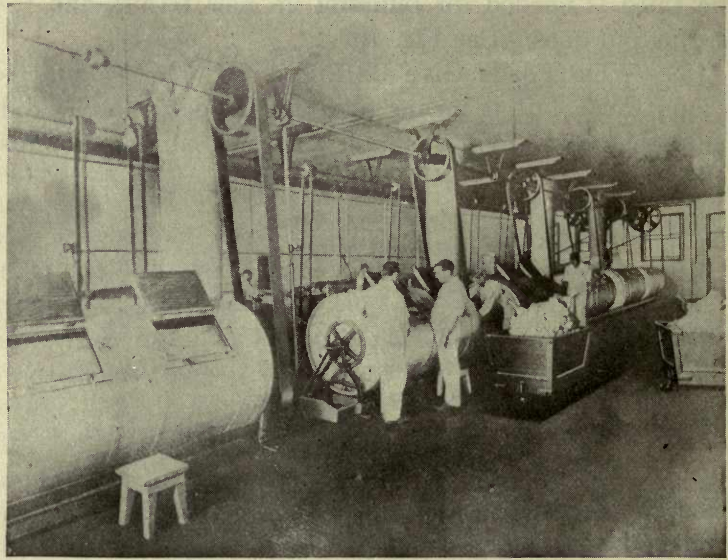


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FIG. 110. — Removing the butter from the churn in a large creamery.

190. What Foods Make Us Grow? — Every living organism or cell contains nitrogen, therefore foods which contain nitrogen are needed to build new cells or repair the old ones. Such foods are known as nitrogenous foods. They contain hydrogen, oxygen, carbon, and nitrogen. True, if an excess is eaten, the hydrogen and carbon may be oxidized to furnish energy just as the sugars and fats do. In that case, the nitrogen is wasted and forms compounds which are difficult for the body to get rid of. For that reason, and because the nitrogen foods are usually more expensive, it is wise to eat only as much of them as the body actually needs for growth and repair, and to depend solely upon the other foods (carbohydrates and fats) for heat and energy. Nitrogen cannot be stored in the body as sugars and fats can. If carbon, oxygen, and hydrogen are stored, they are changed to a form of fat and do not hold the nitrogen. How often should we eat meat (a nitrogenous food) during the day?

Lean meat, of course, is the most common food of this class. Milk, cheese (a product of milk), eggs, meat, nuts, peas, beans, and lentils are the foods which contain the most nitrogen, and are called the tissue-builders, or the nitrogenous foods. They are also sometimes called proteid foods.

An Experiment. — Do you want to separate the starch from the nitrogenous part of wheat flour? Then make a tough dough out of ¼ of a cupful of flour and a little water. Tie the dough in a piece of good cheesecloth and knead the dough under water. Note that the water becomes cloudy because of the **starch** that comes through the cloth. After no more starch can be pressed out of the flour, examine the substance inside the cloth. What is its color? Is it sticky? Elastic? It is the **gluten**, the nitrogenous part of the flour. Let the starchy water settle, then pour off all the water you can and the starch will remain as a sediment. Scrape the starch out on a piece of newspaper, and let it dry.

191. What are the Minerals in Foods? — The minerals found in some foods and water are often called the **body regulators.** Our table salt is a mineral without which we cannot exist. One of the most cruel methods the ancients had of inflicting punishment upon prisoners was to kill them by leaving salt out of their food. They died a slow, painful death.


FIG. 111. — The cheesecloth bag contains wheat-flour dough. When this is kneaded *under water*, the starch of the flour passes through the cloth, leaving the *gluten* inside.

Some foods, such as spinach, lettuce, onions, and different greens, consist almost entirely of water and minerals. Fruits and vegetables are rich in mineral matter. The elements which are required by the body are sulphur (found in great amounts in eggs), calcium (best source is in milk), potassium, phosphorus, chlorine, iron, and others. Our bones are made largely of **calcium** compounds. If we do not have enough of these compounds, we are likely to be weak-boned or undersized. At what ages do we need the most calcium? Experts say that young children should have a quart of milk a day and that older boys and girls should have at least a pint in order to be sure to get enough calcium compounds.

When **iron** is lacking in the diet, the disease *anemia* lays hold upon the person. Many pale children who seem dull and lifeless are suffering because there is not enough iron in the blood. The body cannot digest nails or a bar of iron, so we must get our iron by eating those foods which are rich in it. Spinach is especially rich in iron; so are eggs. Raisins, dates, figs, and prunes give it in quantities we can measure, and many vegetables contain a small per cent of iron.

Many people believe that a diet of meat, potatoes, and bread is sufficient to keep them in health. This is a mistake. If we wish to have splendid health and the perfect kind of body which has no weak points and so can resist disease, we must be careful to add milk to the list and to eat plenty of fresh fruits and vegetables. Only thus can we get the precious minerals we need.

When any food is burned completely, the ashes which remain are the minerals contained in that food.

Experiment. — Set the cover of a baking-powder can upon some hot coals, or over a gas flame, and in it heat a small piece of bread until all the charcoal has burned away and only grayish ashes remain. Is the amount great or small? Put the ashes in a glass dish and add a drop of some acid. What happens? What gas is probably given off (cf. § 38)?

192. Why Do We Need Water in the Diet? — Every food contains some **water**, and some foods, such as milk, are mostly water. Water is the most important thing in the diet. Man can live without food for days and days, but water is absolutely necessary if life is preserved for long. Water is used in building up the tissues, in carrying them supplies, and in carrying away wastes. Drinking water at meal time is not harmful, if we do not "wash down" half-chewed portions of food with it. A drink of water a little while before eating is of great benefit in preparing the digestive organs for receiving food. Some physicians advise the drinking of eight glasses of water every day; others say more or less. It is well for us to cultivate the habit of drinking a great deal of water; we shall have better health if we do.

193. How Do We Depend upon Plants? — Could we live without plants? No, we could not. Can we take a pinch of sulphur, a bit of carbon from coal, and a quart of nitrogen from the air? The question is ridiculous; yet we have to have those very elements if we would live. That is what plants do for us. Minerals, water, and the nitrogen and the carbon dioxide of the air are all taken into the plant as foods and are made part of the plant's body. The plant unites them into complex compounds, such as sugars, oils, and nitrogenous substances. Then animals eat the plants and get the food materials from them in a useful form. The animal food which we eat, such as meat, eggs, and milk, was formed by an animal from plant food eaten by that animal or by smaller animals upon which it feeds. What do sheep feed upon? Chickens?

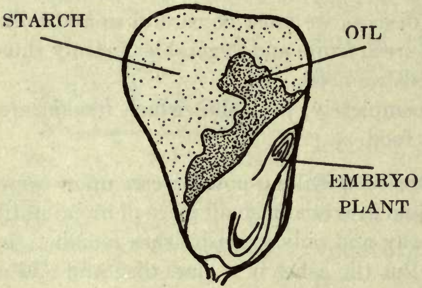

FIG. 112. — A kernel of corn, showing how the corn grain is stored with food (largely starch) for the young corn plant.

To make a *carbohydrate*, **carbon dioxide** is taken from the air and by a process which goes on in the plant is joined with **water** to form sugar or starch. These are oxidized in the animal body to give water and carbon dioxide again. Thus plant life and animal life help each other and a delicate balance is kept between the two.

The plant **stores food** to nourish its young. Examine a kernel of corn (Fig. 112). You will find there is a small dark spot at the tip. This is the *germ*, or living part, which will start growing if put into water. The greater part of the kernel is a white substance, *starch* (Fig. 113). This starch is stored around the germ so that the little plant when it starts growing will have some food close at hand in a form easy to use.

FIG. 113.—Grains of starch, much magnified.

It is these plant storehouses that we usually eat. Sometimes we eat the *leaves* (spinach), sometimes the *stalk* (celery), but more often it is the *seed* (peas, beans, rice, wheat) or the *fruit* (grapes and oranges). *Roots* and underground stems are often the storing places (potatoes, radishes, onions). Name some other plant seeds that we use as a food.

194. Exercises. — 1. Name the five classes of nutrients.

2. What are the chief nutrients in milk, meat, potatoes, bread, sugar, olive oil?

3. What is the value of a vegetable salad in a dinner?

4. What nutrients are not abundant enough in a meal of bread, boiled potatoes, and rice pudding?

5. What do you think of this as a "balanced" or proper kind of meal: meat, baked potatoes, celery and baked apples?

6. Why can a dog digest bone, while we cannot?

7. The body temperature of some Arctic explorers was found to be about 97° F. instead of 98.6°; why? What kinds of food did they need most?

8. Show that the energy of your body comes originally from the sun.

CHAPTER XXI

THE COOKING AND BAKING OF FOODS

195. Why Do We Cook Food? — When in his history do you suppose man invented cooking? No wild animal cooks its food; very early savage man doubtless ate flesh and other foods raw, as some savage races still do.

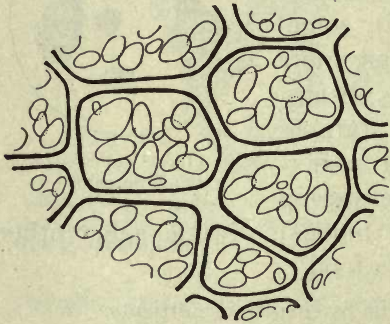
FIG. 114. — A cross section of potato cells, showing the cellulose walls and the starch grains inside.

No doubt the reason why man began to cook food was because he found that cooking improved the **flavor**; but he has found, as his knowledge has grown, that the most important reason for the cooking of food is to make it **digest** better. Cooking softens and breaks up the walls which surround the real food. These walls are of *cellulose* in vegetables and of a tough material called *connective tissue* in meat. If you examine a slice of potato under the microscope (Fig. 114), you will find that it is composed of many irregular cells; the cell walls are of cellulose, the grains within are grains of starch. Starch is digestible, but cellulose is not digested by man's digestive organs and must be softened and broken away from the food it wraps, so that the food may be digested. We find cellulose in fruits and vegetables. The celery plant has a good deal of cellulose; the tough strings we find on old string beans are cellulose. The "popping" of corn illustrates the complete breaking up of the cellulose which incloses the starch.

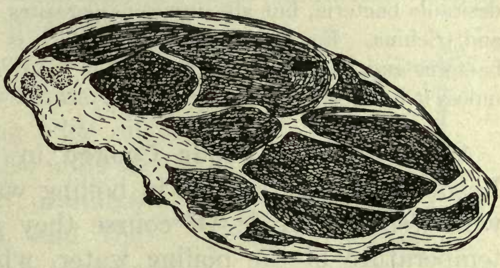

FIG. 115. — A steak is a cross section of muscle tissue. Note the connective tissue between the bundles of muscle fiber.

If you tear a piece of meat into small pieces (Fig. 115), you will find that it is in bundles of **muscle fiber** and that each bundle is made up of several smaller ones. Each big and each little bundle is surrounded by a coating of connective tissue. Connective tissue, like cellulose, needs to be softened by proper cooking.

Some **complete changes** of one food into another occur in the cooking of foods, and the new substances are more easily digested. For example, the brown covering on toast is starch which has been changed to dextrin, a compound still more easily digested than starch. When fatty meats, as bacon, are cooked, some of the oil is lost by simply being cooked out, or "tried" out. Meats, eggs, cheese, and nitrogenous foods of that sort break up into gases when heated to too high a temperature, and part of the food is lost. What remains is toughened and rendered less digestible. Should such foods be cooked at a really high temperature?

There is still **another reason** for cooking food. When one form of animal or vegetable life lives upon another, that dependent form is called a **parasite**. You know that meat often contains not only undesirable bacteria, but also injurious parasites, such as the tapeworm and trichina. For that reason pork, which is more likely to contain bacteria and parasites than any other meat, should never be eaten unless it has been thoroughly cooked.

196. Why Are Foods Cooked in Boiling Water? — Foods which are cooked in boiling water are cooked at what temperature? Of course they are cooked at the temperature of the boiling water, which is 212° F., or 100° C. The cooking of vegetables in boiling water is the simplest way of preparing them. Boiling does not permit of any drying out and most vegetables need water to give them a good appearance as well as a fresh taste. The objection to cooking in water is that minerals and other soluble materials, such as sugar and the delicate oils which give a food flavor, are lost in the water and drained off. We must always take care not to boil food too long, for over-boiled vegetables are soggy and tasteless.

The **steaming** of food is an excellent method of cooking, with all the advantages of boiling and many more. Steaming retains the minerals, sugar, and flavors in the food. Try boiling half of a small sweet potato and steaming the other half, and compare the flavor. When we cook food in a steamer, what is it that does the cooking?

197. What is Broiling? — Broiling was the first method of cooking meats. The most primitive people built fires and hung their food over the fire to brown (Fig. 116). Broiling is a delicious way of cooking meat, but a pan should be used to catch the juices and prevent waste.

198. How Do We Fry Foods? — There are two methods of frying: deep-fat frying and sautéing. Sautéing is the method used in our ordinary "fried" potatoes. Deep-fat frying is used in cooking doughnuts or croquettes. The whole food is immersed in the fat. Frying adds oil to the food and also adds to the flavor; but it produces a very rich food, and the stomach and other organs cannot digest very much of it. Fried potatoes are not healthful when they are "swimming in grease." Doughnuts and croquettes should be well drained and the fat properly hot to prevent them from being soggy and greasy. Frying is the least desirable method of cooking, because it is likely to make foods hard to digest. Can you name four ways of cooking eggs besides frying them?


Fig. 116. — Broiling a fowl on a spit over the open fire.

199. What is the Baking of Foods? — Baking is not limited to pies, cakes, and bread; vegetables and meats may be baked also. Baking is the heating of food in an inclosed space, such as an *oven*. The temperature may be higher than boiling water, or it may be lower. How is the oven's temperature regulated?

Have you ever thought why we should eat **baked** potatoes instead of fried ones? Why are baked potatoes given to invalids? There is a very good reason for this. The heat of the oven produces steam inside of the potato. The skin holds this steam in and makes a pressure. Under the pressure the starch cells burst and break up better than they do if cooked in any other way.

200. Why Is Baking Powder Used? — How do you think a cake would look or taste, if it did not have anything in it to make it rise? It would be a soggy, lumpy mass of dough and very indigestible as well. How do you suppose men first began to use **leavening**, or "raising," materials? There are now two principal ways of making dough rise. One is by the use of **baking powder**; the other is by the use of **yeast**.

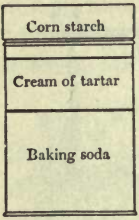

FIG. 117. — Baking powder is usually $\frac{1}{2}$ baking soda, $\frac{1}{4}$ cream of tartar, and $\frac{1}{4}$ corn starch.

Cream of tartar, sodium bicarbonate, and starch are used to make the most expensive baking powders (Fig. 117); in the cheap grades, phosphates and alum are found. Starch or flour is put into the mixture to keep it dry.

When the mixture becomes moist, as when it is mixed in a batter, and particularly when it is heated, carbon dioxide is formed. The carbon dioxide is a gas, as you know (cf. § 37). When it is formed in the biscuit or cake dough, it pushes holes for itself in the dough. When the dough is placed in the oven, each of these little, imprisoned bubbles of gas is expanded by the heat and pushes a larger hole for itself in the dough; then the dough bakes in this raised-up position.

What makes a cake "fall"? The reason is that if the dough is not thoroughly cooked and stiffened around the bubble, the carbon dioxide gas will not remain expanded when the cake leaves the oven and the dough will sink. Baking powder acts immediately upon being moistened and anything which is raised by baking powder should be put into the oven as soon as it is mixed. What would happen if it were not?

201. What is Yeast? — For centuries people have noticed that if fruit juices are left in an open dish, they *ferment.* Housewives also had a way of leaving bread dough in the air and letting it rise, but they did not understand the process. Now we know that the wild yeast of the air caused it. Yeast plants are too small for us to distinguish them with our unaided eyes (Fig. 118).

FIG. 118. — Cells of the yeast plant, most of them budding.

The yeast has three states of life: (1) the **resting** stage; (2) the **growing** stage; (3) the **spore** stage. In the resting stage yeast is blown against foods and starts its growth. It grows by "budding." Each plant shoots out several buds, which grow and have buds of their own (Fig. 118). When the conditions for its life are very unfavorable, each plant divides and bursts its cell walls, throwing off spores, or "seed-like" forms of the plant. These spores will resist great changes of temperature for a long time, are hard to kill, and are consequently found everywhere.

Yeast requires certain **sugar** solutions to grow in. If the solution does not have too much sugar in it, it will be acted upon by yeast if left in the air. The yeast grows and changes the sugar into **alcohol** and **carbon dioxide** (cf. §§ 175 and 204). This is the reason why grape juice, if left in the air, ferments and becomes wine.

Do this **experiment** (Fig. 119): Place a teaspoon of molasses and a cup of water in a flask or bottle. Add ¼ of a cake of yeast. Provide a stopper with one hole in it. Through this hole run a glass tube and let the other end of the tube dip under the surface of limewater which is in a test tube or slender bottle. As you found out in § 37, carbon dioxide makes limewater look milky. Leave the fermenting solution in a warm (not hot) place for several days. Look often for any change in the limewater. Note the smell of the sugar solution. What has been formed in it? For what is the limewater a test?

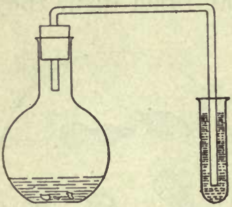

FIG. 119. — A sugar solution (molasses) being fermented by the action of yeast. The test tube contains limewater.

202. How Does Yeast Act in Making Bread?

— The yeast we buy and use is grown in a yeast factory. The yeast plants are produced in great numbers in a food they thrive on, then are gathered together into yeast cakes and pressed. **Dry yeast**, which contains the plants in the spore stage, may be kept for weeks or even months, but it takes longer to begin its growth when it is put into the sponge. "Compressed" yeast cakes are bought in a soft form, which contains the plants in the growing stage, but this form cannot be kept very long, especially in warm weather. The soft yeast has the advantage of acting much sooner than the dried. Rising bread should be kept at about 70°–90° F., as the plants do not grow if they are too cool and are easily killed (when growing) if too hot. The yeast in the bread produces alcohol and carbon dioxide, and the carbon dioxide and the alcohol vapor act just as the carbon dioxide does when formed from baking powder. The bubbles push the dough up and expand in the baking. During baking the yeast plants are killed and the alcohol is driven off.

What a wonderful process " raising bread by yeast " is!

203. Exercises. — 1. What are three good reasons for the cooking of food?

2. Ask your mother or a cook whether meat to be roasted should be put into a very hot oven or one of moderate temperature and why.

3. Why is some bread heavy, or soggy? Why is it not good to eat? How is " angel food " cake raised?

4. Tell why " toasted " bread is so healthful. Is a soft-boiled egg more digestible than a hard-boiled one? Why?

5. What is the difference between baking soda and baking powder?

6. Soda and sour milk are often used together to make dough rise. Why? What kind of substance does sour milk contain? How does this act with soda?

7. What nutrients are lost when food is cooked for a long time in water?

8. Find out what foods can be made out of skim milk.

CHAPTER XXII

THE PRESERVING OF FOODS

204. Why Do We Can and Preserve Foods? — You know what happens if most foods are left exposed to the air: they spoil, or "rot." The air about us is full of the spores of bacteria, yeast, and molds (cf. §§ 34, 175, 201), microscopic plants which include some of man's best friends as well as some of his worst enemies. As they float about in the air, the plant spores fall upon our foods, which are their foods also (Fig. 120). When these tiny plants feed upon our food they break it up into new compounds, some of which go off as gases. In time the food is completely destroyed. The result of the action of these unseen destroyers, when we look at it in the right way, is really very beneficial to the earth, for they remove waste foods and dead plant and animal matter. But if we wish to guard food that we want to eat, we must either seal it away from the air, or we must treat it in such a way that destructive plants cannot grow in it.

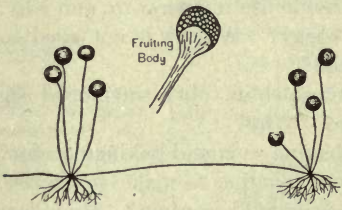

FIG. 120. — The mold that grows upon bread, and a fruiting body that produces the spores.

205. How Does Drying Preserve Food? — Drying is one way of treating food so that it will be impossible for bacteria to attack it. Bacteria and other germs need moisture for growth, just as a human being does. Although a dried apple may be covered with spores, they will not start growing until there is enough moisture present. The method of keeping fruits and vegetables by drying them was practiced by our ancestors long ago. It is easy and requires very little equipment. Old attics used to be hung with dried corn and apples; many of the medicines were dried herbs. In the dry sections of the West "jerked beef" was made by cutting the meat into strips and hanging it out of doors to dry in windy weather.

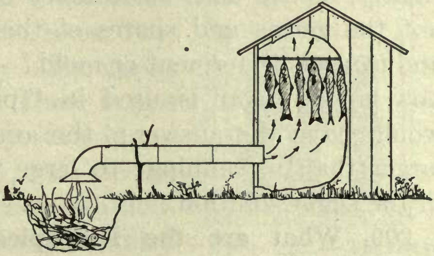

FIG. 121. — A smoke house for smoking fish. The smoke passes through a long pipe before it enters the house, in order that it may be cooled.

206. How Is Meat Smoked? — Every prosperous farmer, up to a generation ago, had a **smoke house.** Before the days of refrigerator cars and easy access to meat markets, the farmer killed his own meat, and as the meat could not all be eaten at once, some of it had to be preserved, or protected from the germs of the air. It was hung in the smoke from a wood fire until the smoke had not only given a delicious flavor to the meat, but also had rendered it safe. Smoke is a preservative because it contains a substance called *creosote.*

207. What are Salting and Pickling? — Two common home preservatives are **salt** and **vinegar**; they season food as well as preserve it. Salt and vinegar make solutions in which the germs of decay cannot live. **Saltpeter** (which the chemist calls *potassium nitrate*) is also used. It makes the red color of meat more intense. You know how red " corned beef " is; saltpeter is used in preserving it.

208. How Does Sugar Preserve Food? — Have you ever seen your mother put up preserves, or jelly, or candied fruits? She does not seal the jars or cans tightly, as she does in ordinary canning. Why then do not the germs and spores of the air fall into the fruit and cause it to ferment or mold? If you were to find out how much sugar is used in " preserving " fruits, you would have the answer: the amount of sugar is much larger than in canning; so large that germs cannot live in the sugar solution.

209. What are the Principles of Canning? — The methods of preserving food by smoking and by the use of salt, vinegar, and sugar have been practiced for many centuries. A wonderful step in progress was made in the nineteenth century, when the method of preserving food by sealing it tightly in glass or tin cans came into general use. The **principles of canning are**:

(1) to sterilize the food, that is, to kill any bacteria or spores which may be on it;

(2) to seal it air-tight and prevent the entrance of any more bacteria or spores.

Fruits and vegetables are attacked freely by germs from the air; in canning, the food is cooked until the temperature becomes too high for the germs to exist (212° F. or higher).

210. What are the Methods of Canning? — Several processes are used in canning. The oldest is the "open kettle" method. The food is put into a kettle and boiled. Then it is dipped out, put into a thoroughly cleaned and sterilized can, and sealed. How is the can sterilized, or freed from germs?

In changing the food from kettle to can, there is, of course, some little danger that bacteria or other germs will get on the fruit. There is also danger that germs may lurk in reused can covers, if they, too, are not very well sterilized by thorough boiling. The cans should always be filled to overflowing and no air bubbles should be left in them. Why?

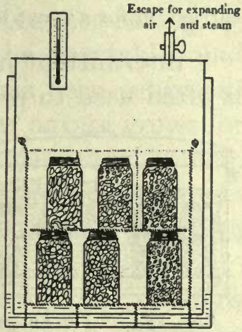

FIG. 122. — The steam canner, with a thermometer.

The **newer method** of canning is the "cold-pack" method. The government has an agricultural bulletin devoted to the description of this process; it gives information as to how long each particular food should be cooked and how each should be handled (Fig. 122).

If **fruit** is to be canned, it is made ready, placed in clean cans, covered with a sirup, and then the whole can is heated to the temperature of boiling water or higher. Sometimes the can is heated in the oven, sometimes by steam; but in the home the method of *immersing* the can is most often used (Fig. 123).

Vegetables are first " blanched," that is, are put into boiling water for a short time. Then they are chilled by cold water and are packed. Salt and sometimes water are added and then the cans are heated. The lids are put on the cans before they are heated, but they are not sealed tightly until the can is taken out of its water or steam bath. Vegetables have to be heated, or " processed," as we call it, much longer than the fruits. The reason for this is that there are *spores* on the vegetables, which are not killed by heat unless the heating is carried on for a great length of time.

" Intermittent heating," that is, heating several times, is often used to preserve vegetables; it is carried out by heating the can of vegetables for a little while on each of three days. The first heating is not long enough to kill all the spores, but when the vegetable begins to cool and reaches a nice, warm temperature, the spores that remain develop into the *growing* stage. The next day the can is heated, and as the bacteria in the growing stage are easily destroyed, the developed spores are killed.

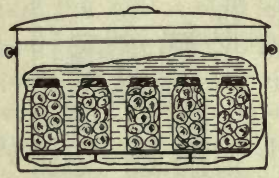

FIG. 123. — The hot water canner, made out of a wash boiler having a double bottom.

The cold-pack method makes more attractive canned products possible, because the fruit and vegetables are put in whole and are not handled again; hence they keep their shape. Tomatoes canned in this way make salads possible in the winter. The flavor and color are much finer. When you enter a house in which canning is being done by the open kettle method, the odor of the fruit is noticeable even though the cooking is being done in another room. Why? Much of the flavor of the fruit is lost in this odor. Much of the color is lost, too, by the open heating. When fruit is cooked in the can, its flavor and color are retained.

211. Does Canning Pay? — Do you think that people ought to cultivate the habit of canning? If we could once see the amount of good food that goes to waste in the ordinary family garden, we would realize, with a shock, that there is no better way to practice saving, or thrift, than to can for winter's use the vegetables and fruits of summer. Think of it! It has been estimated that half of all the fruit and vegetables nature grows for us are wasted every year. Sometimes they remain neglected in the garden; sometimes they are sent to market and through bad methods of packing or selling are allowed to spoil, unsold.

What examples of avoidable waste of food do you know of in your community? How could such waste be remedied?

212. Canning as a Factory Industry. — Have you ever thought how canning has changed our method of living? People find it so convenient to have the vegetables of summer all winter long, and so enjoy having on their tables the perishable products of distant regions, that the canning of fruits, vegetables, fish, and meat has become one of the large industries of the United States. In some cases the food is partly cooked before it is canned. This is true of sweet corn. Most foods, however, are packed cold. After the cans are filled, they are capped by machinery and then heated — usually under steam pressure.

The machinery which has been invented for the filling of cans, for moving them, and for heating and preparing the food to put into the cans, makes the canning process very easy and very rapid. *Peas*, for example, are canned in great quantities. The way in which they are graded for size is very interesting. The peas are passed over sieves or into a revolving cylinder having four sections, each with different-sized holes. The holes in the first cylinder are very small, those of the second are a little larger, and so on. The smallest peas are thus separated out first. They are the most expensive.

213. Do Preservatives Harm Foods? — Why go to all this trouble to preserve food by heating it and keeping it in air-tight cans? Why not put into the food a small amount of some chemical, such as *borax* or *formaldehyde*, which will destroy the germs and prevent natural decay? The answer of science is that such chemicals or preservatives are either poisons, or they keep our food from digesting properly. Food so preserved does us little good, but is largely wasted. In addition to this, food of poor quality, or slightly rotted, may be treated with preservatives and then sold to us as good food.

Children are in great danger when preservatives are used in milk, because milk forms so large a part of a child's diet.

Do you think a wise housekeeper will consent to feed her family with food containing injurious chemicals, or to put "acids" in her canned goods just to save herself the trouble of canning or preserving food properly?

214. Exercises. — 1. Give the reason why some foods must be canned if you wish to preserve them.

2. Give three good reasons for using the cold-pack method of canning.

3. Why must you not seal the can lid tightly, in the cold-pack method, before you begin heating?

4. If a tin can of tomatoes bulges inward, are the tomatoes likely to be spoiled? If it bulges outwards? Tell why.

5. Why is a "tin" can, that is, a can of iron covered with tin, used instead of one of iron alone? Would one covered with copper do as well?

6. What do you think of the use of chemicals to preserve the color of food, that is, to keep peas green and to redden canned cherries? What do you think of the use of artificial dyes in candies?

7. How does the atmosphere's pressure help to keep a glass fruit jar tightly sealed?

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

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* 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

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)
ambergris	(ăm′ber-grēs)
ameba	(ȧ-mē′bă)
andirons	(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)
asbestos	(ăs-bĕs′tŏs)
avoirdupois	(ăv′ẽr-dŭ-poiz′)
bacilli	(bȧ-sĭl′ī)
bacteria	(băk-tē′rĭ-ȧ)
barometer	(bȧ-rŏm′ē-tẽr)
biceps	(bī′sĕps)
bituminous	(bĭ-tūm′ĭ-nŭs)
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-tẽr)
calyx	(kā′lĭx)
canine	(kā-nīn′)
cañon	(kăn′yŏn)
capillary	(kăp′ĭl-ā′rĭ)
carat	(kăr′ăt)
carbohydrate	(kär′bō-hȳ′drāt)
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′tẽr)
centrifugal	(sĕn-trĭf′ū-găl)
cerebellum	(sĕr′ē-bĕl′ŭm)
cerebrum	(sĕr′ē-brŭm)
chloride	(klō′rĭd)
chlorine	(klō′rĭn)
chlorophyll	(klō′rō-fĭl)
chyle	(kīl)
chyme	(kīm)
cilia	(sĭl′ĭ-ä)
circuit	(sûr′kĭt)
cirrus	(sĭr′ŭs)
citric	(sĭt′rĭk)
coagulate	(kō-ăg′ū-lāt)
cochineal	(kŏch′ĭ-nēl)
cocoon	(kō-ko͞on′)
cohesion	(kō-hē′shŭn)
composite	(kŏm-pŏz′ĭt)
conifer	(kō′nĭ-fẽr)

constellation	(kŏn′stĕl-ā′shŭn)
contagious	(kŏn-tā′jŭs)
convection	(kŏn-vĕk′shŭn)
corolla	(kō-rŏl′ȧ)
corpuscle	(kôr′pŭs’l)
cotyledon	(kŏt′ĭ-lē′dŭn)
creosote	(krē′ō-sōt)
crescent	(krĕs′ĕnt)
croquette	(krō-kĕt′)
crustacea	(krŭs-tā′shē-ȧ)
crystalline	(krĭs′tăl-ĭn)
cumulus	(kū′mū-lŭs)
cyclone	(sī′klōn)
deciduous	(dē-sĭd′ū-ŭs)
decimeter	(dĕs′ĭ-mē′tẽr)
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)
embryo	(ĕm′brĭ-ō)
emulsion	(ē-mŭl′shŭn)
enamel	(ĕn-ăm′ĕl)
environment	(ĕn-vī′rŭn-mĕnt)
epidemic	(ĕp′ĭ-dĕm′ĭk)
epidermis	(ĕp′ĭ-dẽr′mĭs)
esophagus	(ē-sŏf′ȧ-gŭs)
experiment	(ĕks-pĕr′ĭ-mĕnt)
filings	(fīl′ĭngs)
formaldehyde	(fôr-măl′dē-hīd)
fossil	(fŏs′ĭl)

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)
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hydrogen	(hī′drō-gĕn)
hydroxide	(hī-drŏx′-ĭd)
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isolation	(ī′sō-lā′shŭn)
isotherm	(ī′sō-thẽrm)
kilometer	(kĭl′ō-mē′tẽr)
lactic	(lăk′tĭk)
la grippe	(lä grĭp′)
larvae	(lär′vē)
leaven	(lĕv′ĕn)

legume	(lĕg′ūm)
Leyden	(lī′dĕn)
lichen	(lī′kĕn)
lunar	(lū′nȧr)
magnesium	(măg-nēs′ĭ-ŭm)
manganese	(măn′găn-ēs)
mercerize	(mẽr′cẽr-īz)
meteor	(mē′tē-ŏr)
microbe	(mī′krōb)
millimeter	(mĭl′ĭ-mē′tẽr)
monsoon	(mŏn-so͞on′)
mucous	(mū′kŭs)
muriatic	(mūr′ĭ-ăt′ĭk)
neutralize	(nū′trăl-īz)
nimbus	(nĭm′bŭs)
nitrogen	(nī′trō-jĕn)
nitrogenous	(nī-trŏj′ĕ-nŭs)
nucleus	(nū′klē-ŭs)
octopus	(ŏk′tō-pŭs)
omnivorous	(ŏm-nĭv′ō-rŭs)
opaque	(ō-pāk′)
organism	(ŏr′găn-ĭsm)
Orion	(ō-rī′ŏn)
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oxidize	(ŏx′ĭd-īz)
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reservoir	(rĕs′ẽr-vwôr)
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retort	(rē-tôrt′)
rotate	(rō′tāt)
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