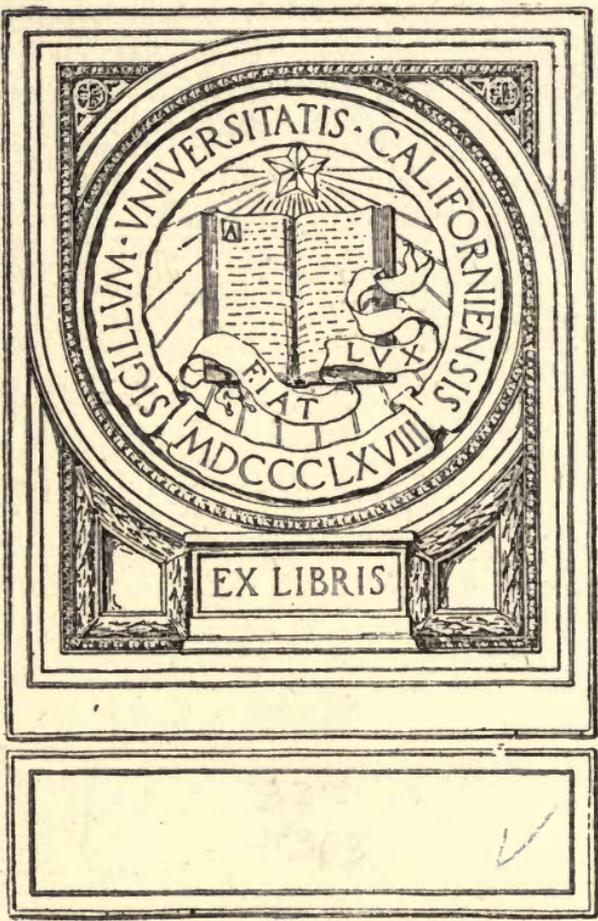




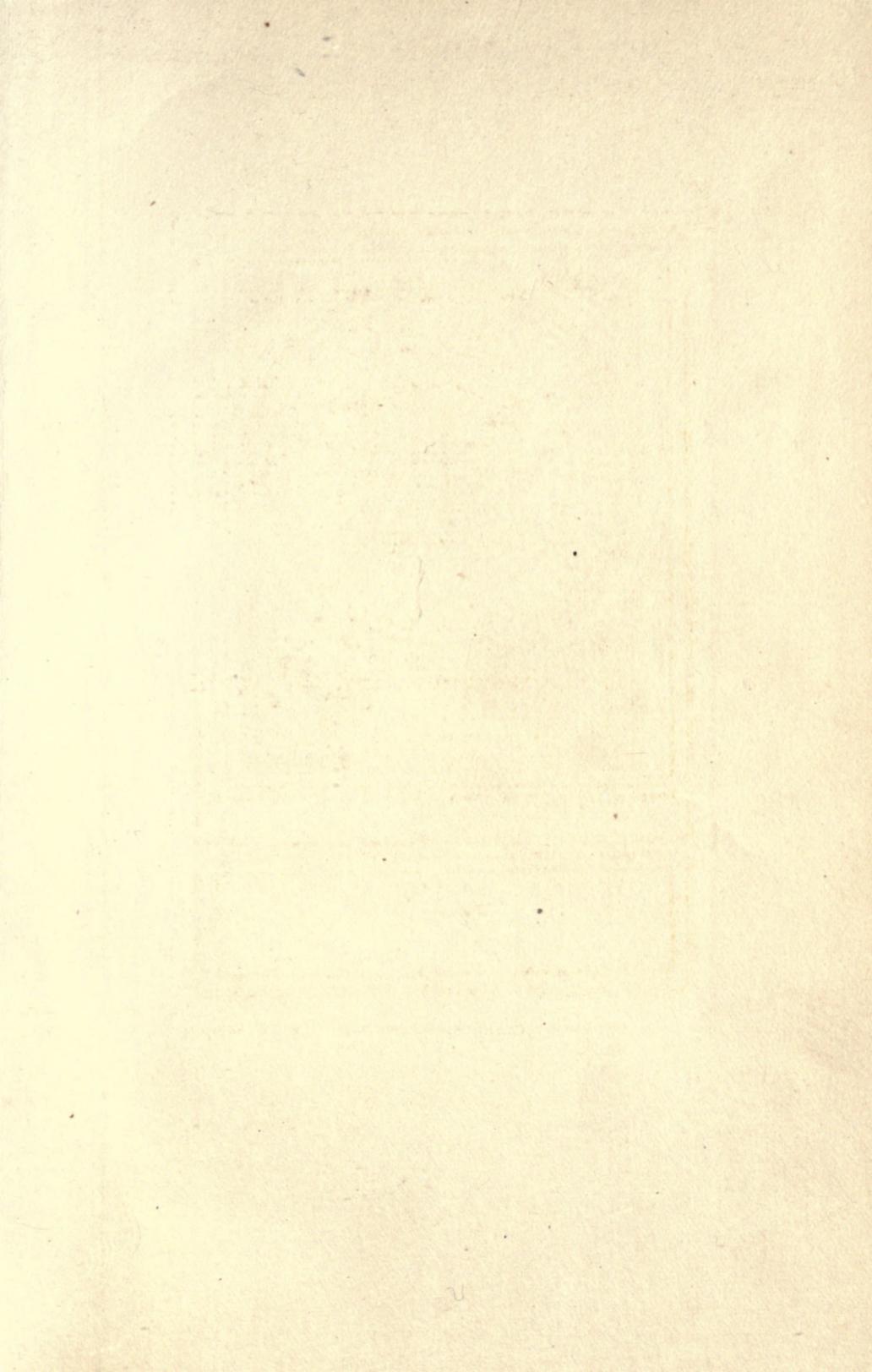
A FIRST YEAR COURSE
IN
GENERAL SCIENCE

PEASE





EX LIBRIS



A FIRST YEAR COURSE
IN
GENERAL SCIENCE

BY
CLARA A. PEASE
OF THE HIGH SCHOOL, HARTFORD, CONNECTICUT



UNIVERSITY OF
CALIFORNIA

CHARLES E. MERRILL COMPANY
NEW YORK CHICAGO

Q159
P4

COPYRIGHT, 1915
BY CHARLES E. MERRILL CO.

[4]

NO. 1000
MERRILL CO.

PREFACE

It is not necessary, in this period of the making of high school curricula, to show that, for the first year of a high school, a general course in science is better than a year's study of one branch of science. Without discussion of the advisability of a general course, therefore, the author would state her reasons for the wide choice of subjects considered in this book.

For pupils who complete a high school course, the study of general science should be an introduction to any ordinary high school work in biology, physics, chemistry, geology, and astronomy. No pupil can study all of these subjects, but he can learn that they are not separate sciences but branches of science. Whatever branch he studies later, he will find that the course in general science has given him the elements of the other divisions which dovetail into that branch.

To suit the needs of pupils who are not able to finish a high school course, this first year science course must present a comprehensive view, though with no attempt to be complete.

"The proper study of mankind" for the pupil at the age of twelve to fourteen years seems to be the world of which he is a part. The fact that the earth, important as it is to man, is not the only nor the greatest body in the universe; that it is not an independent body sufficient unto itself; and that its influence extends to other bodies—these are some of the subjects taken up in the first chapters.

Before studying the ever-changing surface of the earth and its life, there must be a study of matter in the mass and of the forces which act upon it from without; also of

the composition of matter and the behavior of the different kinds, alone and in combination.

The agencies which have given the earth its beauty, its wonders, and its fitness for the development of life are considered in chapters on physiography.

The living part of the earth and its relation to other forms of matter are emphasized in the later chapters.

It would not be right to call these chapters astronomy, physics, chemistry, etc., because no complete treatment of these subjects is attempted. The author believes it wise, however, to use the necessary scientific terms in describing phenomena, properties, and the like, instead of using circumlocution in order to keep within the every-day vocabulary of a young pupil.

It has seemed important to provide a simple laboratory course which is connected closely with the text, but which may be omitted without any break in continuity of subject. For many years the slogan has been "Study the thing itself, not study about it." Efforts to follow this rule have led, in many cases, to a disconnected array of facts learned from observation of unrelated subjects. Such a course has no connecting links. The laboratory work and the textbook should be closely related in order that the pupil may get the full value of the science course.

The Laboratory Exercises which accompany this book are designed:

First: to fix in the mind of the pupil important principles and facts which may have been known for hundreds of years, rather than to have them re-discovered by the pupil.

Second: to teach by experiment one or more applications of a principle and leave the pupil to make other applications whenever the principle again comes to his attention.

Third: to accustom the pupil to follow directions, and to make and record accurately observations of phenomena.

Fourth: to teach the pupil to draw reasonable conclusions from his own or reported observations.

The accomplishment of these things is a valuable asset to the pupil, whatever work he undertakes in the future.

Another object of this book is to show the future citizens of this country the wide range of scientific work done by the government, not only for the education of its people, but for their material welfare. The work of the Weather Bureau, the Naval Observatory, the Geological Survey, and the Divisions of Forestry and of Plant Industry, are all brought to the attention of the pupil, and material furnished by these departments is used.

The planning of this course was the work of five teachers of experience in a large high school. Prior to the publication of the textbook, the plan was followed for four years by teachers, experienced and inexperienced, with great success, if we may judge by the work of the pupils and by the number who have continued the study of science after the first year course.

The author makes grateful acknowledgment to many friends who have assisted in the preparation of this book: first of all, to her principal, Mr. Clement C. Hyde, and her associate teachers in the science department of the Hartford Public High School, for their unfailing consideration and encouragement while she was doing the double work of teaching and developing this course in General Science; to her former teacher, Professor William North Rice, of Wesleyan University, Middletown, Conn., for wise counsel on many subjects; and to Professors Edward L. Rice and Lewis G. Westgate of Ohio Wesleyan University, Miss Elisabeth W. Stone, and Mr. David G. Smyth of Hartford, who have read and criticized portions of the manuscript. For illustrations, grateful acknowledgment is made to Professor David P. Todd of Amherst, Mass., to Dr. Henry Fairfield Osborn of the American Museum of Natural History, to Professor

Lewis G. Westgate of Delaware, Ohio, to Mr. Harold M. Hine and Mr. Raymond B. Case of Hartford, to the Century Company of New York, to the Warner and Swasey Company of Cleveland, Ohio, to the Coe-Mortimer Company of New York, to Forecaster Neifert of the Hartford office of the Weather Bureau, to the Chamber of Commerce of Colorado Springs, to the Denver and Rio Grande Railroad, to the United States Geological Survey, and to the Forest Service.

CONTENTS

CHAPTER	PAGE
I. THE EARTH'S PLACE IN THE UNIVERSE	13
II. THE EARTH'S NEAREST NEIGHBORS: THE MOON AND THE PLANETS	33
III. MATTER AND ITS PROPERTIES	46
IV. FORCE AND MOTION: PHYSICAL STATES OF MATTER	56
V. HEAT: ITS DISTRIBUTION AND MEASUREMENT	71
VI. LIQUIDS AND THEIR PROPERTIES	81
VII. PROPERTIES OF GASES; THE ATMOSPHERE; ATMOSPHERIC PRESSURE	93
VIII. WEATHER; WINDS AND STORMS; CLIMATE	107
IX. LIGHT	120
X. ELECTRICITY AND MAGNETISM	128
XI. HOW MATTER CHANGES	138
XII. THE COMMON ELEMENTS OF THE EARTH.	147
XIII. SOME COMPOUNDS OF COMMON ELEMENTS	158
XIV. MINERALS AND ORES: THEIR VALUE AND SOURCE	167
XV. THE CRUST OF THE EARTH, MAN'S STOREHOUSE	177
XVI. CONTINENTS; OCEANS	190
XVII. MOUNTAINS; MINING; FORESTRY	202
XVIII. TOPOGRAPHIC MAPS	216
XIX. EARTHQUAKES; VOLCANOES	225
XX. RIVERS AND THEIR WORK	233
XXI. GLACIERS AND LAKES	244

CHAPTER	PAGE
XXII. LIVING MATTER	254
XXIII. THE LIFE OF A PLANT	265
XXIV. REPRODUCTION AND DEVELOPMENT OF PLANTS	276
XXV. THE LIFE OF AN ANIMAL	289
XXVI. REPRODUCTION AND DEVELOPMENT OF ANIMALS	298
INDEX	307

SUGGESTIONS TO TEACHERS

A FEW suggestions as to the use of this book may be helpful to the teachers who are using it. A glance will show that it is a textbook to be studied — not a reading book. The text of each chapter is organized in sections, which are numbered, and the subject of each section is given in heavy type. This will help the pupil to know what he is studying about before he begins a new subject.

A scientific term printed in heavy type usually serves to call attention to a definition or an explanation of the term in the same sentence or closely following it. This seems, for the first year science pupils, a better way to learn the use of words than by consulting a glossary or a dictionary. It will be helpful for the pupil to write out with each lesson the definition of the words occurring in heavy type. That gives him practise in stating definitions in good form, and helps him to avoid such expressions as “a force is when,” “a mountain is where,” etc.

A large dictionary — not one of the “handy” size — should be a constant book of reference for words not strictly scientific but not in the pupil’s every-day vocabulary. Pupils should be cautioned not to take the first definition given but to look for a distinction between general and scientific use and to learn the latter definition.

The exercises at the end of each chapter are not, in the ordinary sense, a review of the chapter. They are more in the nature of a test to see if the pupil can apply principles just learned. The exercises may be used as a test after completing the chapter, or may be selected, a few at a time, to accompany the subjects to which they apply. Not only

the principles of that chapter are involved but those of earlier chapters also.

The diagrams and illustrations are provided with the expectation that they will make clearer the teaching of the text and that original work will be done by the pupils in answering the questions which accompany them. This may be assigned as written work to be brought to the class and there used in various ways by the teacher.

If it is not possible to take a whole year for the course, it is advised that the work be done thoroughly as far as time allows and then dropped.

The references to laboratory work indicate the points at which the author thinks it best to have the exercises performed. If for any reason it is not possible to have all the students do all the work, there are three ways of using laboratory exercises to advantage. (1) Have one or two pupils do the work, while the others make notes of observations reported to them; then have the class work out the results from the data. (2) Let the teacher do the work, instead of the pupils, and then proceed as in the first case. (3) The teacher may discuss with the class the directions in the Laboratory Manual, give some supposed observations, and have the pupils finish as before. This last and least desirable method requires no special apparatus for this course but presupposes that the teacher has a laboratory knowledge of the subject. Some of the exercises are to be performed out of class with material which every pupil can obtain for himself.

A laboratory exercise in science may be, as in history or literature, the study of a subject from other sources than the textbook. A rich field for this work is provided in various government bulletins of the Departments of Agriculture and of the Interior. Lists of these bulletins may be obtained from the departments at Washington on request, and copies of such as are wanted will be furnished to a school

free, on application to the senator or representative from the district.

Another kind of work which may be included under laboratory exercises, is the observation of industries carried on in the town or city. Even if pupil and teacher do not understand perfectly all operations viewed in the paper mill, thread or cloth factory, dye works, foundry, machine shop, or other manufactory, they will see much that can be used in class to illustrate and apply the principles upon which those industries depend. Application from the principal of a school will usually gain permission for a small group of pupils, *accompanied by the teacher*, to visit some of the shops in the vicinity of the school. If there are several divisions of the class, each division might study a different industry. Each would learn something of value, though not all the same thing.

Field work and photographs can be employed to supplement the chapters on the surface features of the earth; the collection and recognition of minerals and rocks will add to the interest of some chapters which have little laboratory work. Observation of living things will bring a new interest to outdoor life. In fact, anything which encourages comparison and observation of details is an aid to mental development as well as an assistance in scientific training.

A FIRST YEAR COURSE IN GENERAL SCIENCE

CHAPTER I

THE EARTH'S PLACE IN THE UNIVERSE

1. The Earth and Other Bodies.— Many thousand years ago there were living in widely separated parts of the earth various groups of people. Each group, knowing nothing of the others, supposed that it contained all the inhabitants of the earth. These early peoples thought that the earth was flat and that if they should go beyond the portion they knew about, they would reach the edge and fall off.

They had various beliefs as to what kept the earth in place. Some thought it rested upon the shoulders of a giant, and some upon a turtle's back; others believed it was suspended from above.

As men ventured farther from home, they found that there were other peoples, that the earth was larger than they had supposed, and that if they went far enough in any direction, they came to the sea. They ventured out upon the sea, but always returned over nearly the same route by which they had gone. They still thought that the earth was flat.

Their ideas of the motion of the sun and stars were as simple as their other beliefs. They thought that these bodies moved daily over the earth, coming from the desert plain or from behind the mountains or out of the ocean, according to their point of observation.

Not until about five hundred years ago did any one suspect that the earth was like a globe or that it moved. More has been learned about the earth since the days when Columbus repeated to his timid captains the order, "Sail on," than had been learned in all the time before. Since that wonderful voyage, men have traveled over land and water around the earth and back to the place from which they started. They have found that there is no "edge," and that at no point does the earth rest upon or touch any other body.

We know that there *are* other bodies, for when we look away from the earth, we see many luminous or light-giving points, and we see two bodies whose shape we can determine. Men have been watching and studying these bodies for thousands of years. The ancients learned much that was interesting about them. Modern observers have learned infinitely more, and there is still a great deal to be learned. Some bodies are known to be entirely unlike the earth; a few are in some respects similar to the earth; but there has never been found any body in external condition exactly like the earth.

The place where these luminous bodies seem to be is called the sky, or the heavens, and the bodies are called the heavenly bodies. The sky looks like the inside of a great dome, where in the daytime we usually see but one bright body, the sun, which to us is by far the most important of all the heavenly bodies. At night we see stars, planets, the moon, and occasionally a comet, meteors, and shooting stars.

2. The Number of the Stars. — The stars are the most numerous of the heavenly bodies, but it is not strictly true to say that the number visible to us is countless.

In the whole sphere of the heavens, there are only about 7,000 stars bright enough to be seen without a telescope on a clear, moonless night. Half of that number are in the part of the sky that is visible to dwellers in the northern

hemisphere; but because of dust and vapor in the atmosphere, the number of these stars that can readily be seen is reduced to about 2,500. The use of an opera glass or a small telescope reveals many which cannot be seen by the naked eye. In the whole sky, with the largest telescope, 100,000,000 may be seen. The stars look like bright points and twinkle most perceptibly when they are near the **horizon**, which is the circle where earth and sky seem to meet.

3. Constellations. — Certain groups of bright stars near together are known as constellations. The people of ancient times gave names to these groups, sometimes in memory of

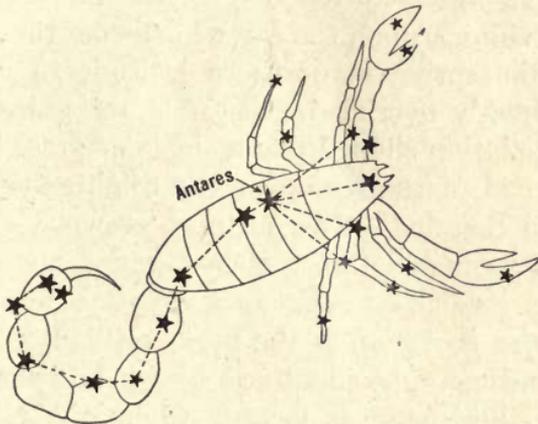


FIG. 1.—SCORPIO

The constellation Scorpio may be seen in the southern part of the sky during the summer. At 9 p. m. at the middle of July, the brightest star, Antares, is directly over the southern point of the horizon.

a hero or of an event. The brighter stars in a constellation outline an object or designate the position of some important part of the body of a man or animal. Aldebaran is a star in the eye of Taurus, the bull, and the cluster called the Pleiades is in his shoulder.

Orion is farther south than Taurus and rises a little later. He is a hunter who has his club raised to strike the bull.

The "belt of Orion" consists of three stars in a straight line, nearly perpendicular to the eastern horizon as the constellation rises. Below and nearly at right angles to the belt are three fainter stars called his sword. In northern countries Orion and Taurus are seen in the east early in the evening in November and December.

Orion is followed by two dogs. In Canis Major, the larger dog, is the star Sirius, which is also called the Dog Star. It is the brightest star in the whole sky and is visible nearly all winter. In summer it is in the same part of the sky as the sun, and is shining on us during the day, but is invisible because of the brighter light of the sun. The period known as "dog days" gets its name from the fact that the Dog Star is then shining upon the earth in the daytime.

Late in the spring in northern latitudes, Leo, the lion, is almost directly overhead. It can be recognized by a part of the constellation shaped like a sickle or grass hook. The star in the end of the handle is the brightest in the group and is called Regulus. The northern crown, Corona, is another summer constellation. It lies east of Leo and may be identified by its shape — that of a wreath or crown.

Scorpio, the scorpion, is the most brilliant summer constellation and may be identified by its kite-shaped figure. Antares, a reddish star, is located where the tail joins the body of the kite. Scorpio is seen in the south in August and is never high above the horizon in the latitude of the northern states.

4. To Find the North Star. — Look in the northern part of the sky for a group of seven stars which outline the form of a long-handled dipper. This group is called the Big Dipper. The two stars on the side of the bowl farther from the handle are called **the pointers**, because a line drawn through them points to the North Star. This imaginary line, extended northward for about five times the distance between the pointers, passes very near the North Star. This

is the only star near the line which is as bright as the pointers.

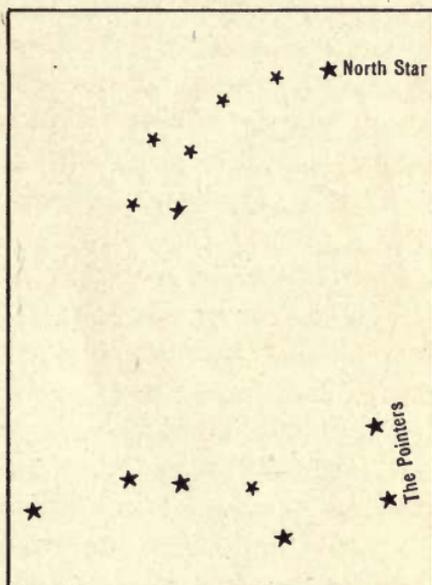
5. Stars Visible all the Year. — The constellations in the northern sky are visible any clear night in the year from all places in the northern hemisphere.

Three well-known groups are the Great Bear, the Little Bear, and Cassiopeia (sometimes called Cassiopeia in her

FIG. 2.—THE BIG DIPPER AND THE NORTH STAR

Distances in the sky are measured in degrees ($1^\circ = 1/360$ of a circle). The pointers are 5° apart; using this distance as a measure,

1. Estimate the distance between the stars at the top of the Dipper;
2. From either pointer in a straight line to the end of the handle;
3. From the North Star to the farther pointer.



Chair). A part of the Great Bear is known as the Big Dipper, and the tail of the bear is the handle of the dipper. The tail of the Little Bear makes the handle of the Little Dipper, and the North Star is at the end of the tail. Except for the stars that form the outlines of the dippers, there are no conspicuous stars in the constellations of the bears.

To locate Cassiopeia, imagine a circle around the North Star passing through the bowl of the Big Dipper. Look about half-way around the circle from the bowl and you find an open, sprawling, W-shaped figure. This is the brightest part of the chair. (LABORATORY MANUAL, Exercise I.)

6. **Reasons for Studying Constellations.** — If we are moving smoothly along in a train, it is sometimes necessary to look at a stationary object in order to realize our own motion. In the same way, observation of stars which are

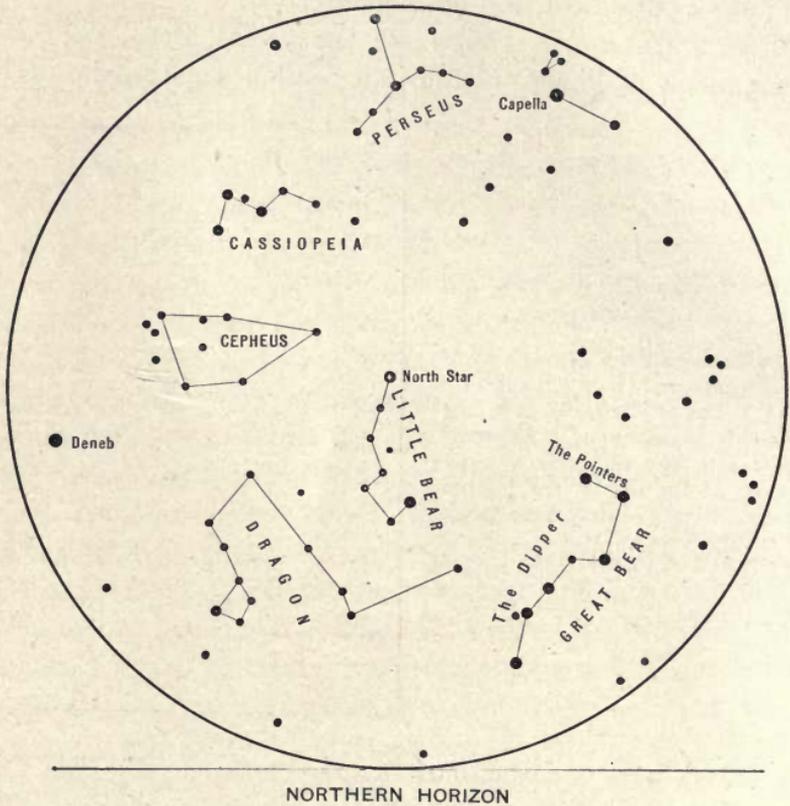


FIG. 3.—THE NORTHERN SKY

Copy or trace the diagram of the northern sky. Draw a line through the Pointers and the North Star across the circle. Draw a line at right angles to this line, also passing through the North Star.

1. What group is in the same quarter as the Big Dipper? 2. In what quarter is Cassiopeia's Chair?

stationary helps us to realize the motion of the earth. Many stars are so much alike that it is difficult to find the same star we observed a week or a month ago unless it forms a part of some group of definite shape. When we have learned

to recognize the groups, it is easy to find the "star in the end of the dipper handle," "the brightest star in Taurus," or "the belt of Orion," even if the group is in a different part of the sky from that in which we saw it last.

Another reason why we should know something about the constellations is the fact that references to the stars are found in the poetry and the history of all ages since men began to express their thoughts and record their observations in writing. We can better understand these references if we know the stars which, long before the pyramids of Egypt were built, were shining upon the earth just as they are today. Many of the names by which the stars were known to the Persians, the Egyptians, and the Greeks have been handed down to us.

7. The Brightness of the Stars. — Early astronomers thought the brightness of stars was due to their size, so they called the brightest ones first-magnitude stars, those a little less bright second-magnitude stars, and so on down to the sixth magnitude. In the city, where there is so much artificial light, we rarely see stars fainter than those of the third magnitude. Sirius, Vega, Regulus, and Aldebaran are first-magnitude stars; the North Star and the stars of the Big Dipper and of Cassiopeia are some of the second-magnitude stars.

It is now known that the brightness of a star depends not only on its size, but on its distance from the earth and on its temperature. Many of the stars are larger than the sun but are much more distant; they seem to us like mere points of light. Enough has been learned about the stars to make it clear that they are very unlike the earth in size, temperature, and condition.

8. The Distance of the Stars. — The stars are so far away that their distances cannot be expressed in any number that we can comprehend. When we say that the nearest star is millions of millions of miles away, it is impossible to

realize what these words mean. Supposing that an express train were traveling every day a thousand miles (about the distance from Chicago to Boston), it would take two years and nine months to travel *one* million miles.

Light passes from one place to another so rapidly that we think of its passage as instantaneous, that is, as taking no time at all. It has been proved, however, that light takes eight minutes to come from the sun to the earth, nearly ninety-three millions of miles. The nearest star is so far away that its light takes more than four years to come from the star to the earth. The light that we receive from the North Star to-night started nearly seventy years ago. Many stars are much more distant.

9. Why we should Know the North Star.—For determining direction, especially in navigation, the North Star is of very great importance. It is so situated that at most places north of the equator it can be seen in the northern part of the sky throughout any clear night in the year. It does not seem to change its position from hour to hour, as other stars do. The North Star is also called Polaris, or the Pole Star, because the imaginary axis of the earth, if extended from the north pole, would pierce the sky very near to this star. The stars in the northern sky seem to revolve about the Pole Star, just as all the lands near the north pole of a terrestrial globe seem to revolve around that point as the globe is rotated.

When we are looking directly at the North Star, we are facing north, and the point on the horizon in a vertical line below the star is the **north point**. As one travels northward, the North Star seems to rise higher and higher above the horizon. Commodore Peary must have seen it at the **zenith**, — that is, directly overhead — when he reached the north pole in 1909. He was then ninety degrees from the equator, and the distance from the horizon to the zenith, where he saw the North Star, is ninety degrees. The number of degrees of

the North Star above the horizon is always the same as the number of degrees of the observer from the equator.

10. The Motion of the Stars, Apparent from Hour to Hour. If we should watch the Dipper all night, we should find that it, and all other stars in the vicinity, appear to move in a circle around the Pole Star in a direction opposite to that of the hands of a clock. Other stars, which we saw in the east in the early evening, would rise higher, pass overhead, and set in the west, all moving in the same direction as the Dipper. At the end of a day (twenty-four hours), we should see each group almost where it was at the beginning. This *apparent* westward motion of the stars is due to the fact that the earth is turning about its axis, always toward the east. This motion of the earth makes the sun in the day, and the moon and stars at night, *seem* to move toward the west.

11. The Change in the Position of the Stars, Apparent from Month to Month. — If, instead of observing the position of the stars from hour to hour, we watch them at the same hour of the evening from month to month, we shall see that a group of stars, as the Dipper or the Sickel or Orion, has moved from its earlier position and that another constellation has taken its place.

People of ancient times reckoned the seasons by the positions of stars. In the same month of every year, a certain constellation is seen in the east as soon as it is dark: Leo in the spring, Scorpio in the early summer, and Taurus and Orion in the fall and winter. This change of position, which gives a different appearance to the sky at different seasons, is due to the motion of the earth around the sun. It moves eastward in its annual journey around the sun and thus changes its position with relation to the stars. At the end of a year, a given group will be found again where it was seen at the beginning of the year.

The *rotation* of the earth about its axis causes changes of position which can be observed from hour to hour; the

revolution around the sun causes changes of position which are apparent from month to month. The motions of the stars are always apparently westward, because the earth's motion around the sun is eastward.

12. The Solar System. — The sun is a moderate-sized star, very much nearer to us than any other star. There

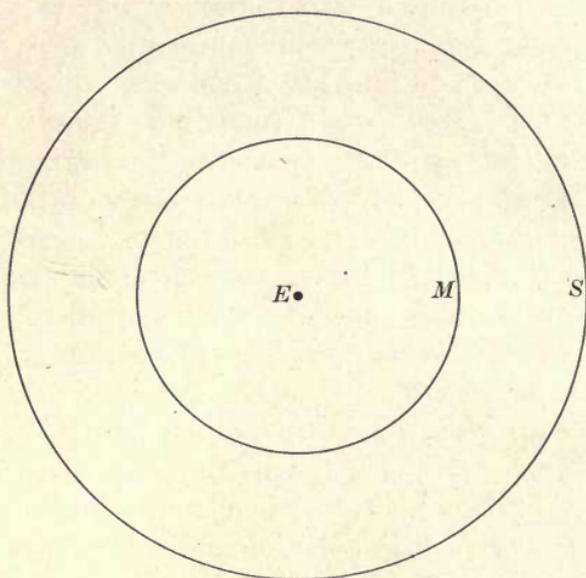


FIG. 4. — THE SIZE OF THE SUN COMPARED WITH THE DISTANCE FROM THE EARTH TO THE MOON

Imagine the earth at the center of the sun's sphere and the moon revolving around the earth on the circle within. Measure from E to M.

1. What fraction of the radius of the sun is the distance from E to M?
2. If E to M is 240,000 miles, what is the diameter of the sun?
3. At the rate of 1,000 miles a day, how long would it take the earth to travel across the sun's disk?

are other bodies, called planets, revolving about the sun; and other smaller bodies, called satellites, revolving about some of the planets. The sun and the planets with their satellites make up the **solar system**.

While the planets are revolving around the sun, they and their satellites are rotating upon their axes, each body having a definite **period** or time of rotation.

There is no star within millions of millions of miles of the solar system, and except an occasional comet or meteor, nothing ever enters the vast space between the solar system and the stars.

13. The Sun. — By far the largest and most important body in the solar system is the sun. Its diameter is more than one hundred times that of the earth. The distance from the center of the sun to its surface is nearly twice the distance from the earth to the moon.

The interior of the sun is thought to be like a heavy, white-hot liquid, but the outer portions, which we see, are known to be intensely heated gases. The sun is composed of the same elements as the earth, but the condition of these elements is so different that they can be recognized only by means of an instrument for the study of light, called the spectroscope. It is not known just what makes the sun hot, but it is known that it is not a *burning* body as some people have supposed. The condition of the sun is like that of the stars. It is so near us that, by looking through smoked or colored glass, we are able to see its shape and apparent size. It looks about the size of the full moon, but is really very many times as large.

14. Day and Night. — We learned when we were very young that the earth rotates on its axis, once in twenty-four hours. It is this rotation which makes it *seem* as if the sun rises in the east, passes across the sky, and then sinks below the western horizon. Half of the earth is turned toward the sun and hence is lighted at one time; in that half it is day, while in the unlighted half it is night. At the moment the sun is rising at a given place, there are 180 degrees of unlighted earth to the west of that place and 180 degrees of daylight to the east. The light is constantly advancing toward the west and retreating from the east. Places where the sun is setting are half-way around the earth from places where it is rising.

15. The Cause of Seasons. — The unequal length of day and night and the change of seasons depend on the position of the earth's axis. To illustrate conditions, draw upon a table as large a circle as possible, to represent the orbit or path of the earth around the sun. The table is the plane in which the circle lies, that is, the plane of the orbit. At opposite sides of the circle, mark Spring and Autumn. Darken the room and place a candle or low lamp in the center of the circle to represent the sun. Let a tennis ball represent the earth. Mark opposite points on the ball N and S. Pass a knitting needle through these two points, as the axis. Holding the axis *perpendicular* to the table at Spring, we see that the ball is lighted from the point N to the point S, most brightly half-way between. Keeping the axis perpendicular, move slowly around the circle, turning the ball at the same time. It is all the time lighted just as at first — one half light, the other half dark, with the points N and S marking the extent of light in each direction.

If, now, the axis is *tipped* so that it makes less than a right angle with the table, and the ball is placed at Spring, we see that it is, as before, lighted from N to S and most brightly at the line half-way between. But as we move around the circle, keeping the axis always pointing in the same direction, conditions change. At one position the north pole is turned away from the sun; then there is no light at the north pole, but there is light all around the south pole. At the opposite point on the circle, the reverse is true.

The facts in regard to the earth are these: its axis is inclined $23\frac{1}{2}^{\circ}$ to the plane of the earth's orbit, and always points in the same direction — almost directly to the North Star. Hence, the north pole is sometimes turned away from the sun, sometimes toward it. On two days, one in March and one in September, the sun's rays fall vertically upon the equator and obliquely 90° north and south of the equator,

that is, as far as the poles. Daylight then extends to both poles, and day and night are equal everywhere.

All that has been said about the direction of the light is also true about the heat received from the sun. From spring to autumn, the north pole is turned toward the sun. The sun's rays, giving light and heat, are then received vertically at places in the torrid zone north of the equator, and obliquely at places within a distance of 90° , that is, reaching to places beyond the north pole. It is summer in northern latitudes, and the days are longer and warmer there than in the other half of the earth. Just the reverse is true in the period between autumn and spring. It is winter in northern latitudes, and the days there are shorter and colder than in southern latitudes.

16. The Circles and Zones of Light. — If, by drawing a line upon the earth, we could connect all the places where the sun shines vertically at noon on March 21, we should have a circle around the earth equally distant from both poles. Because it is equidistant, it is called the **equator**.

A similar circle drawn on June 21 gives the tropic of Cancer, $23\frac{1}{2}^\circ$ north of the equator. The sun never shines vertically any farther north than the tropic of Cancer. On June 21, it shines obliquely upon the earth beyond the north pole just as far as the tropic of Cancer is north of the equator — that is, $23\frac{1}{2}^\circ$. Consequently the arctic circle marks the line $23\frac{1}{2}^\circ$ from the pole and $66\frac{1}{2}^\circ$ from the equator.

Within the arctic circle the sun is visible every day during the six months of summer, and during the winter it nowhere comes above the horizon for more than a short time each day. At the north pole it is visible for the whole day during the summer and is not seen at all during the winter. The nearer a place is to the pole, the longer are its summer days and the shorter its winter days. At Hammerfest, Norway, the most northern town of Europe, the sun never sets from

May 13 to July 29, and it never rises from November 18 to January 23.

17. The Place of Sunrise.— In March, when the sun is over the equator and midway between the north and south poles, it rises everywhere exactly in the east, midway between the north and south points on the horizon.

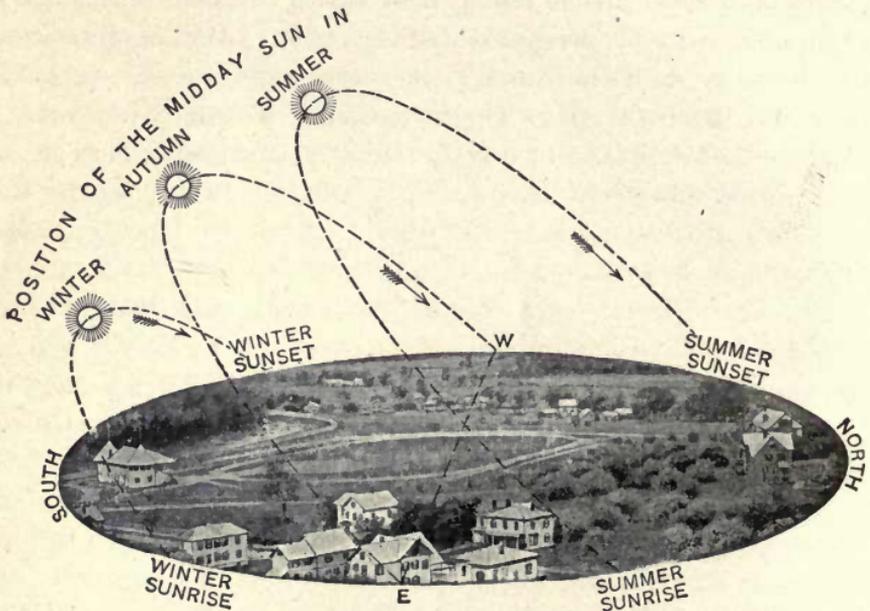


FIG. 5.—THE PLACE OF SUNRISE

1. If you were playing tennis on a spring morning at a position on the line EW, what would be the best direction to face? Why? 2. What position would be least favorable for a player during an autumn forenoon? Why? 3. In the afternoon in summer?

[This picture is from *A New Astronomy* by David Todd. Copyright, 1897 and 1906, by American Book Company. Reproduced by permission.]

During the spring months it shines each day over places farther north of the equator, because its place of rising is each day farther north of the east point, until June 21, when it rises $23\frac{1}{2}^{\circ}$ north of east. In the early summer only, in the northern hemisphere, does the morning sun shine even obliquely into windows on the north side of

the house. Again in September the sunrise is at the east point, but each day afterward it is farther south of east, until December 21, when it is $23\frac{1}{2}^{\circ}$ south of east. South windows then get sunshine very early in the forenoon and long after midday.

18. The Sun's Position at Noon. — Next in importance to the position of the North Star is the position of an imaginary line called the **celestial meridian**. This is a circle passing through the north point on the horizon, the zenith, and the south point, and then around the other side of the earth to the north point. It divides the sky into an east and a

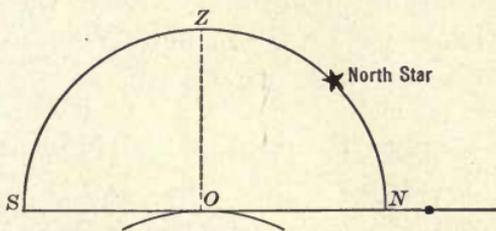


FIG. 6.—THE CELESTIAL MERIDIAN

1. What part of a circle does the line NZS form? 2. How many degrees from N to Z? 3. If the observer (O) is in lat. 30° , what is the position of the North Star on the meridian? (Answer in degrees from the nearest letter.) 4. The equator of the sky is about 90° from the North Star; locate the place where it crosses the meridian, in the same way that you answered 3. 5. At what times in the year is the sun on the equator?

west half; and since the circle always passes through the zenith, there is a celestial meridian for every observer. When the sun or the moon crosses the meridian, it has made half its daily journey from rising to setting. The abbreviations *a. m.* and *p. m.* refer to the time when the sun crosses the meridian. The letters *a. m.* stand for the Latin *ante meridiem*, before midday; *p. m.* for *post meridiem*, after midday.

At noon the sun is on the meridian over the south point in the horizon. In northern latitudes it is higher above the horizon at noon in June than at any other time in the

year, but even then the sun is not exactly overhead at any place north of the tropic of Cancer. If it were so, there would be no "shady side of the house" at noon. The sun is nearer the southern horizon at noon in December than at any other time, and in March and September it is half-way between its positions in June and December. (LABORATORY MANUAL, Exercise II.)

19. Latitude and Longitude. — We have been accustomed to learn the latitude and longitude of a place from a map in a geography without thought as to how these facts are known. The latitude and longitude of a place were originally determined by observations upon the position of the sun and stars as seen from that place, or as calculated from an observatory whose exact distance and direction from that place were known.

Sea captains find the latitude and longitude of their vessels by observations made daily, and if for some days neither sun nor stars are visible, a ship may go far out of her course. The United States government employs astronomers at the Naval Observatory at Washington to compute the positions of the sun, moon, and many of the stars for some years in advance. Thus navigators sailing on long voyages may be provided with the means of making rapid and accurate calculations from their observations.

If we could imagine ourselves ignorant of where we are, of the day of the year, and of the hour of the day, we might be able to realize something of what we owe to man's knowledge of the heavenly bodies. Calendars and timepieces are made and corrected with reference to the positions of the earth and the sun at certain times.

At least once every day the correct time, as determined by the position of the sun or some star, is telegraphed from the Naval Observatory to every city in the country. By electric connections, many clocks are thus set right once a day. The calendar, as we call the division of the year into

months and days, has been changed twice since the time of Julius Cæsar. These changes were necessary because of the neglect of a few seconds in calculating the length of a year. If the calendar had not been corrected, certain religious festivals would by this time be observed about a month later by the calendar than the seasons in which they originally occurred.

20. Longitude and Time. — The meridians of longitude on maps and globes correspond to the celestial meridians; that is, the meridian of longitude of a given place lies directly under the celestial meridian of that place. For example, the meridian of 90° west longitude — which passes through Memphis, Tenn., Jackson, Miss., and New Orleans, La. — lies on the earth directly under the celestial meridian of those three places. The meridian passing through Greenwich, England, has been adopted by all countries of Europe and the Americas as the **prime meridian**, or the meridian of 0° longitude. Places within 180° west of the prime meridian are in west longitude; places within 180° east are in east longitude. The national observatory of the United States, the Naval Observatory at Washington, is situated 77° west of the prime meridian, — therefore at 77° west longitude. Delhi, in northern India, is situated about 77° east of Greenwich.

When the sun crosses the meridian at Washington, it is noon there. It is *after* noon at places east of Washington and *before* noon at places to the west. In twenty-four hours the sun will again be overhead at Washington, having (apparently) passed westward around the earth 360° . In each hour, then, it passes over 15° . When it is noon at Washington, it is 1 p. m. at a place 15° east of Washington, and 11 a. m. at a place 15° west of Washington. If 15° cause a difference of 60 minutes of time, 1 degree will cause a difference of 4 minutes.

News of an event which occurred at 1 p. m. in Washington

might be bulletined by telegraph at about 10 a. m. in San Francisco and not earlier than 6 p. m. in London.

21. Standard Time. — It is evident that a traveler would find his timepiece always too slow or too fast according to

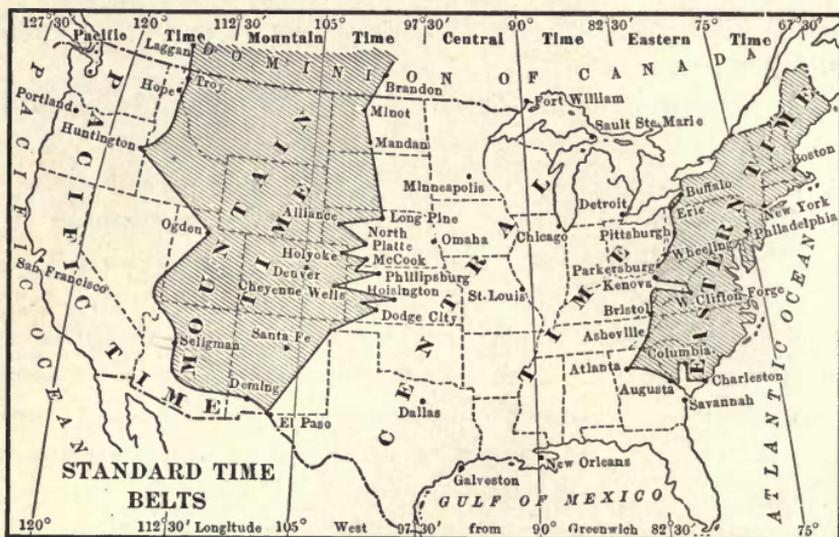


FIG. 7.—STANDARD TIME BELTS IN THE UNITED STATES

The meridians of 75°, 90°, 105°, 120° are standard meridians for the Eastern, Central, Mountain, and Pacific time belts respectively. If the belts were of uniform width, time changes would be made at meridians half way between these standard meridians. The time changes are, however, made at cities which are important railroad centers. The lines connecting these cities do not correspond exactly to meridians.

1. What is the widest time belt in the United States? 2. What is the difference between sun time and standard time at places on the 70th meridian? 3. On the 115th? 4. What is the difference between sun time and standard time at your meridian? 5. A man leaves Washington at 10 a. m. and arrives at Chicago the next day at 9 a. m. by his watch. He learns that the next train west leaves the same station at 8:10 a. m. Can he take it? Explain.

which way he journeyed, if each city regulated its time by the position of the sun. To avoid inconveniences which would occur in business, and in railroad and steamboat connections, the United States government in 1883 divided the country into belts about 15 degrees wide. Since that time,

all our government timepieces in any one belt have given the same time at any moment. When the government made the change in all post-offices, custom-houses, and naval stations, people had to make the same change for their own convenience, and now Standard Time is used everywhere in this country. A similar plan of time belts has been adopted in Europe also.

Only the middle of a belt has the true time by the sun; other parts of the belt differ from the sun's time by periods varying from one to thirty minutes. Most people do not know that Standard Time is not the same as sun time.

The United States is divided into four time belts, called the Eastern, Central, Mountain, and Pacific belts. Everywhere in a given belt the clocks are an hour ahead of those in the next belt west, and an hour behind those in the next belt east. When it is noon (Standard Time) at New York, it is 11 a. m. in Chicago, 10 a. m. in Denver, and 9 a. m. in San Francisco. It is then 5 p. m. in London.

EXERCISES

1. How are the south, east, and west points of the compass determined?

2. (a) How many degrees from the equator was Commodore Peary when he reached the north pole? (b) How many degrees, or what part of a circle, was the distance from his horizon to the North Star? (c) How many degrees above the north point on the horizon, is the North Star seen at the place where you live? At New Orleans? At Sitka?

3. What is meant by the earth's period of rotation?

4. (a) What fraction of the surface of the earth is illuminated by the sun at one time? (b) Why does the lighted space move to the westward? How many degrees per hour does it move? Why?

5. (a) If the sun rises at 6 a. m. at places on the 72d meridian W. longitude, at what meridian will it rise an hour later? (b) At what longitude will the sun be setting when it is rising on the 90th meridian W. longitude?

6. How many degrees north of the equator is the sun when it is visible for twenty-four hours at 70° N. latitude?

7. Explain the location of the tropic of Capricorn and the antarctic circle.

8. In what month of the year is it midsummer and continuous daylight at the south pole?

9. In what direction do windows of a house face, if the sun shines directly into them at noon in the United States? In Cape Colony, Africa? Why?

10. Which is the drier and warmer sidewalk in winter, that on the north or on the south side of a city street? Why?

11. At what season does the sun cast the longest shadows at noon in New England? In what direction do they lie? Name a country where, in both respects, the opposite is true for the same season.

CHAPTER II

THE EARTH'S NEAREST NEIGHBORS: THE MOON AND THE PLANETS

22. The Earth, a Planet. — It has been known for five hundred years that the earth moves around the sun once in about 365 days. It has since been learned that the earth is nearly spherical; that its orbit is nearly a circle; that it is kept in place by an attracting force, called gravitation; and that there could be no life on the earth if it were not for the light and heat which it receives from the sun. Besides the earth, there are seven other bodies of which nearly all these facts are true. These bodies are called **planets**.

23. The Motion of the Planets. — The star Regulus changes its position in the sky, but it is always at the end of the handle of the sickle in Leo. Similar statements may be made of all the stars we have studied. They do not change their position with relation to other stars. Among the stars, however, are seen a few bright bodies that shine with a steadier light and do *not* keep the same places in the constellations. At the end of a month, for instance, we may see that they have moved away from or nearer to some star in the same part of the sky. These are the planets (from a Greek word meaning "wanderer"). The brightest of the planets are Venus, Jupiter, Mars, and Saturn. It is very seldom that all four are seen at the same time in any evening, but two are often in the sky together, and sometimes three. The three other planets — Mercury, Uranus, and Neptune — cannot be seen well without a telescope.

If we could stand upon Venus and observe the earth, we should see that the earth changes its position with relation to the stars, just as the other planets do.

24. The Revolution of the Planets.— The other planets, like the earth, revolve around the sun, but not in the same

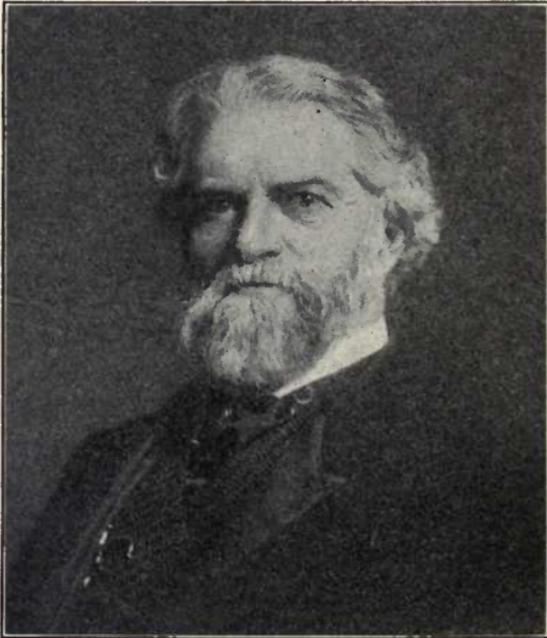


FIG. 8.— SIMON NEWCOMB: ASTRONOMER. 1835–1909

With his appointment to the United States Naval Observatory in 1861, his greater life work began. . . . The sun and the moon and the planets yielded their secrets to the call of his mighty intellect, and science has profited to the benefit of humanity in consequence of the life of Simon Newcomb. . . . They buried him in Arlington, where only those who have served their country are permitted to lie.—MARCUS BENJAMIN, in *Leading American Men of Science*.

period that the earth does. The earth's period of revolution is about 365 days, called one year or twelve months. That of Venus is seven and one-half months, of Mars one year and ten months, of Jupiter about twelve years, of Saturn nearly thirty years. The orbits are all nearly circular, like

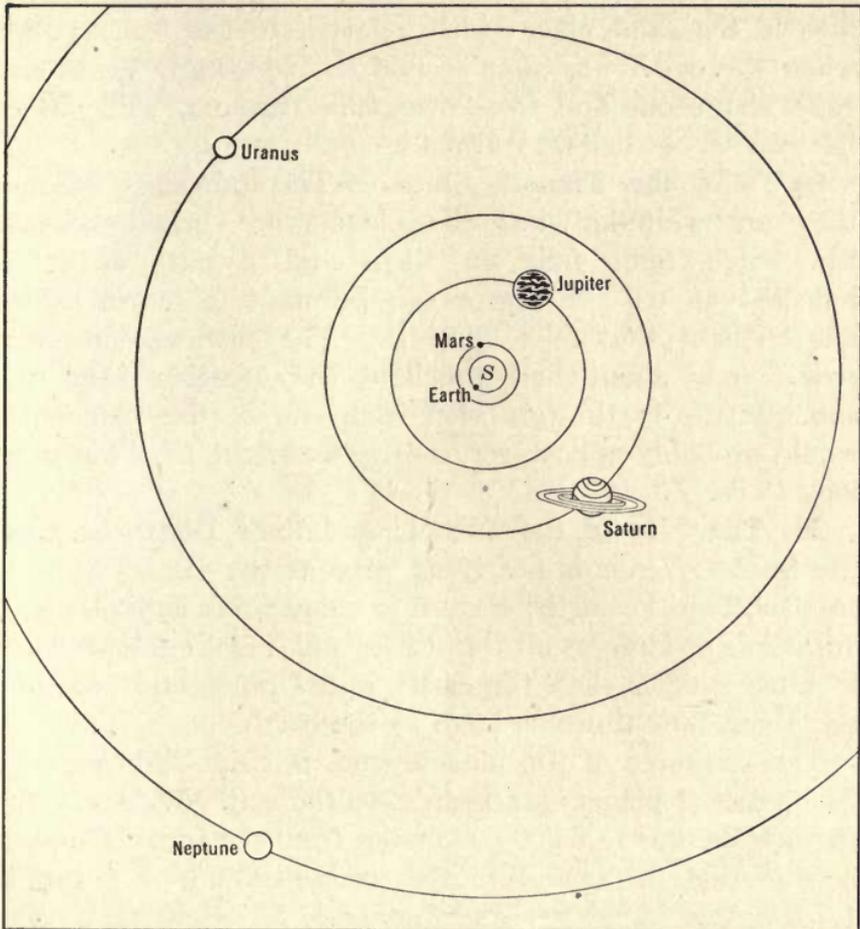


FIG. 9.—RELATIVE DISTANCES OF SOME OF THE PLANETS

1. Which of these planets comes nearest to the earth? 2. How far away is Jupiter when it is nearest to the earth? 3. Light passes from the sun to the earth in about eight minutes. How many hours does it take to reach Neptune?

the earth's, and they lie one outside another, with the sun almost at the center.

Planets are never seen in the northern part of the sky, but are always in the same belt from east to west in which the sun and moon are seen. If all the planets revolved about

the sun in the same period, each planet would always be seen in the same place, with relation to the others; but when the earth has gone around the sun once, Venus has gone about one and two-thirds times around, while Mars has gone about half-way around.

25. Why the Planets Shine. — The stars shine because they are white-hot, but the planets are bright because the sun's light falls on them and a part of it is reflected to us. A mirror can be made to reflect nearly all the light that falls upon it. The planets, however, reflect only about half the light they receive from the sun. If the earth were seen from one of the planets, it would probably appear very nearly as bright as the planets look to us.

26. The Size of the Planets and their Distances from the Sun. — Venus is nearly as large as the earth; Mars is smaller than the earth; Saturn is many times as large; and Jupiter is as large as all the others put together. Mercury is much smaller than the earth, and Uranus and Neptune are about four times as large as the earth.

The distances of the planets from the sun differ greatly. The smallest planets are nearest to the sun. We know the earth to be nearly 93,000,000 miles from the sun. Mercury is .4 of that distance from the sun and Venus .7. Mars is 1.5 times as far away; and Jupiter is 5, Saturn 9, Uranus 19, and Neptune 30 times as far from the sun as the earth is. Mercury is so near the sun that it is usually in the sky in the daytime. Uranus and Neptune, because of their great distance, seem like stars of the sixth and ninth magnitude respectively. (LABORATORY MANUAL, Exercise III.)

27. Venus. — Venus is so like the earth in size and distance from the sun that it is sometimes called the earth's twin planet. No one can tell whether it has continents and oceans, mountains and plains. Its surface cannot be clearly

seen because of its cloud-like atmosphere. This atmosphere reflects a great deal of the sun's light, and consequently Venus is the brightest planet.

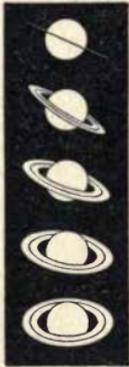
28. Mars. — Mars has been much studied and some astronomers think that light and dark markings upon its surface indicate the presence of land and water like the earth's; that the land is desert at some seasons and covered with vegetation at others; and that around the poles there are snow and ice which change in amount with the seasons. The seasons differ very much as ours do. Mars receives less than half as much light and heat as the earth, because of its greater distance from the sun, so that if there is life on Mars, it cannot be the *same kind* of life as on the earth. Mars has two moons or satellites, so small that they cannot be seen except through the largest telescopes.

29. Jupiter. — Jupiter is the giant planet, and if it were as near to us as the moon is, it would seem forty times as wide as the moon does. Jupiter has four moons as large as our moon, and five very small ones. Galileo, an Italian astronomer, discovered the four larger ones in 1610, the first time he looked at Jupiter with a telescope. They were the first heavenly bodies discovered. The five smaller satellites have been discovered, one at a time, since 1892. Four of them were discovered by means of photography. Heavenly bodies whose light is too faint to make an impression upon the eye, even through a telescope, can be photographed with a telescope-camera. By exposing the plate a long time — sometimes for many hours — it is possible to get an impression from the faint light of these distant bodies.

30. Saturn. — Saturn, as seen through the telescope, is a wonderful sight, because of the bright, thin, flat rings which revolve about the planet without touching it. When Saturn is situated so as to show the broad side of the rings (as it is once in fifteen years), it is much brighter than when we

see only the thin edges of the rings. Saturn has ten moons, some of which are very small.

31. The Moon.— Except the sun, the moon is the most important to the earth of all the heavenly bodies. It is



1907
1909
1911
1913
1914

our nearest neighbor, being less than a quarter of a million miles away. It is so familiar a sight that, except at the time of new or full moon, we scarcely remark upon it. The moon is the only satellite of the earth. Its diameter is about 2,000 miles, one quarter of the earth's diameter. No other planet has a satellite so large in proportion to its own size.

FIG. 10.—SATURN

1. From which position of Saturn should we receive the most light? Why? 2. How many years are there between the brightest and the least bright appearances of Saturn? 3. Does its brightness change suddenly?

Like the satellites of the other planets, the moon revolves in a nearly circular orbit. It takes almost twenty-eight days to go once around the earth and therefore makes about thirteen revolutions a year. While the moon makes one journey around its orbit, it rotates only once upon its axis. Because

the moon's period of revolution is the same as its period of rotation, it always turns the same side toward the earth. As the diagram shows (Fig. 11), when the moon has gone one quarter of the distance around the earth, it has turned upon its axis one quarter of the way. Thus, though each portion of the moon is in a different position with relation to the sun, the same side of the moon is always turned toward the earth, around which it is revolving. No one ever saw the other side of the moon.

32. Changes in the Apparent Form of the Moon.— The moon, like the planets and the other satellites, is nearly spherical in form, but it does not always appear so. At some times it looks like a disk and at others a half-disk, and

sometimes it is crescent-shaped. At certain times it is invisible. When it is on the other side of the earth from where we are, of course we do not see it.

The moon's light is reflected sunlight, and the sun shines upon half of the moon all the time, except during a lunar eclipse, that is, an eclipse of the moon. When the moon is in the same direction from us as the sun, the sun's light falls upon the half of the moon turned away from us, and the side toward us is dark and hence invisible.

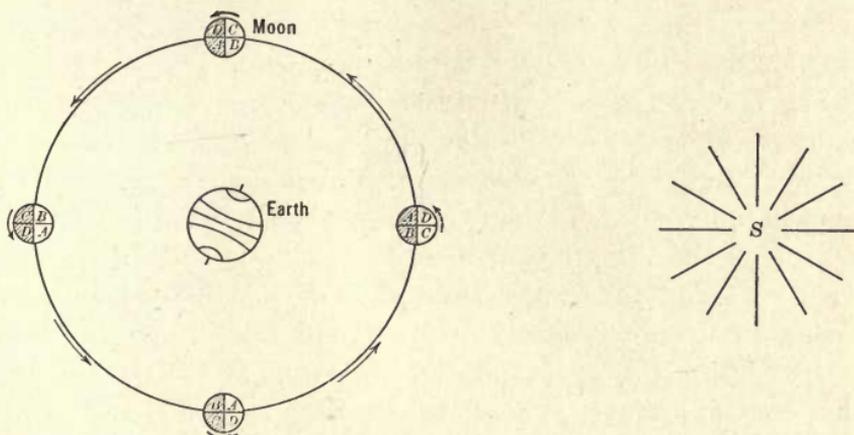


FIG. 11. — ROTATION AND REVOLUTION OF THE MOON

1. What quarters of the moon are turned toward the earth in position 1 shown at the left side of the diagram? 2. What quarters are lighted? Why? 3. What part of the moon's revolution is completed between positions 1 and 2 (at the bottom)? 4. What part of its rotation? 5. Name the quarters of the moon turned toward the earth in position 2. 6. Are they both lighted? Why?

In a day or two, as the moon changes its direction from us with relation to the sun, light strikes a small part of the half turned toward us and gives the crescent or "new moon," seen in the *western* sky soon *after sunset*. As the moon continues to move eastward around the earth, it is seen farther from the western horizon each evening, a larger portion of the half toward us is lighted, and the crescent changes gradually to a half-disk. This is called "first quar-

ter," because one fourth of the time from new moon to the next new moon has passed.

As the days go on, the half-disk grows to a whole disk or full moon, and this in another week has diminished to a half-disk called "third quarter." In about a week a small crescent, the "old moon," is seen in the *east before sunrise*. Then for a day or two the moon is again invisible because it is in the same direction as the sun. When next seen, it is a slender crescent in the western sky.

The time from new moon to the next new moon is about twenty-nine days. This was the period which the American Indians used in reckoning time by "moons."

33. The Time of Moonrise. — The moon rises, on the average, about fifty minutes later each day than the day before. It has moved eastward from the place where it was twenty-four hours before, and therefore the earth must turn a little farther on its axis before the moon is visible at the horizon. The full moon rises at the time of sunset, and about two weeks later the new moon rises at sunrise but is invisible to us. In a day or two, as it has moved eastward, it rises an hour or so after sunrise, but it is generally invisible to us while the sun is shining. People rarely speak of the rising of the new moon, although it actually rises at about the same time and place that the sun does.

34. The Moon's Surface. — Looking at the moon with the naked eye, we notice that some portions are less bright than others. With the telescope it is found that these darker portions are nearly level surfaces like plains. Around them are brighter elevations or mountains, some of which look like extinct volcanoes. In the summits of some of these mountains there are deep depressions or craters with smaller peaks in them. There is no air or water on the moon, so far as men have been able to learn by any scientific methods. No changes of importance have been observed

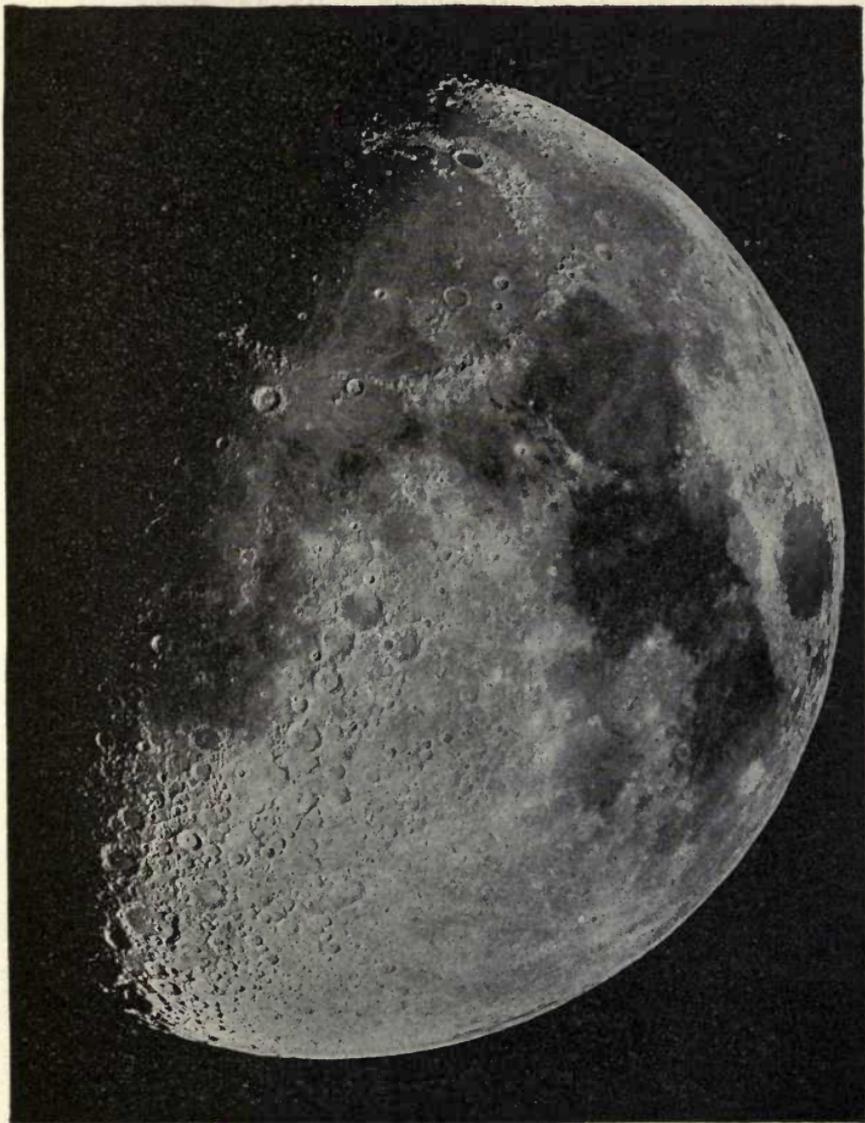


FIG. 12.—A PHOTOGRAPH OF THE MOON

This photograph was made about 10 days after new moon. One half of the moon is lighted, as it is always. 1. How much of the lighted half is visible in the picture? 2. The diameter of the moon is about 2,000 miles; estimate the width of the elliptical plain on the right. 3. How wide is the largest ring-shaped elevation that you can see?

since Galileo looked at the moon with his first telescope more than three hundred years ago.

35. Eclipses of the Sun. — As the light from the sun cannot pass through the moon, there is always a dark space or shadow stretching away from the moon on the side opposite the sun. When the moon comes *directly* between the sun and the earth, this shadow sometimes reaches the earth and a solar eclipse occurs.

As the moon is a sphere, the shadow is cone-shaped, and where it touches the earth, it makes a round or an oval shadow spot, just as a cloud between the earth and the sun casts a shadow on the ground. The shadow is less than 170 miles in diameter where it falls upon the earth. The sun is completely hidden from people who are on the part of the earth where the shadow falls.

When a total eclipse of the sun occurs, darkness comes on *suddenly*, for the daylight lasts as long as even a small portion of the sun is visible. When the last crescent of the sun has disappeared, it is as dark as night and stars are visible.

The outside gaseous portion of the sun, the corona, is never seen except at a solar eclipse, because its light is so much fainter than the light of the rest of the sun. During a total solar eclipse, the corona shines out around the dark moon with a beautiful, soft, pearly light, sometimes tinted pale green or rose color.

36. Eclipses of the Moon. — In a lunar eclipse the earth is between the sun and the moon. The shadow is then cast by the earth and it is much larger than the shadow made by the moon in a solar eclipse. Instead of making a dark spot upon the moon, it may cover the whole moon. As the moon enters the shadow space, a portion of the moon is darkened while the rest of the moon is as bright as usual. At this time the form of the earth is shown in the curved edge of the shadow. We “see our own shadow.” In a

total lunar eclipse the moon is in the shadow more than an hour, while in a solar eclipse the sun is hidden only a few minutes at the longest.

Eclipses of the moon are much more frequently seen than solar eclipses. The moon is visible to people on half the earth at one time, so when a lunar eclipse occurs, many of the earth's inhabitants may see it. In a solar eclipse, however, the shadow spot covers only a small portion of the earth and a solar eclipse is visible only to those within this small area.

Astronomers can predict with great exactness the times at

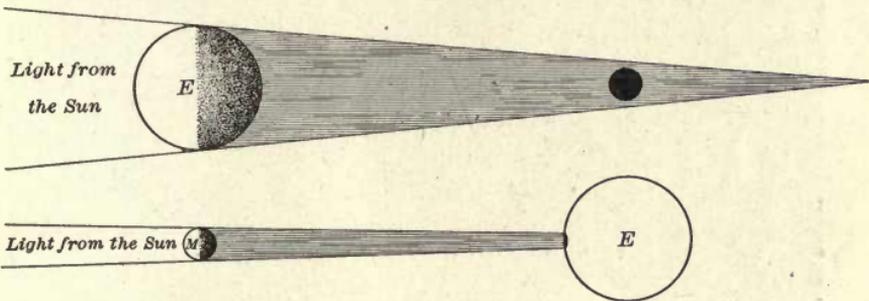


FIG. 13.—LUNAR AND SOLAR ECLIPSES

1. Compare the shadows cast by the earth and the moon. 2. Why is there this difference? 3. From what portion of the earth, as shown in this figure, is the lunar eclipse visible? 4. The solar eclipse? 5. In which of these portions do the larger number of people live?

which eclipses will occur, and almanacs give the dates of eclipses for the current year.

37. Telescopes. — There are two reasons why a telescope enables one to see an object better than is possible with the unaided eye. The light which makes a body visible is received through a small opening in the front of the eye, called the pupil. When the eye is placed at the eyepiece of a telescope, it receives all the light that falls upon a lens, some inches in diameter, at the other end of the telescope. Thus more light than usual is brought to the eye and the

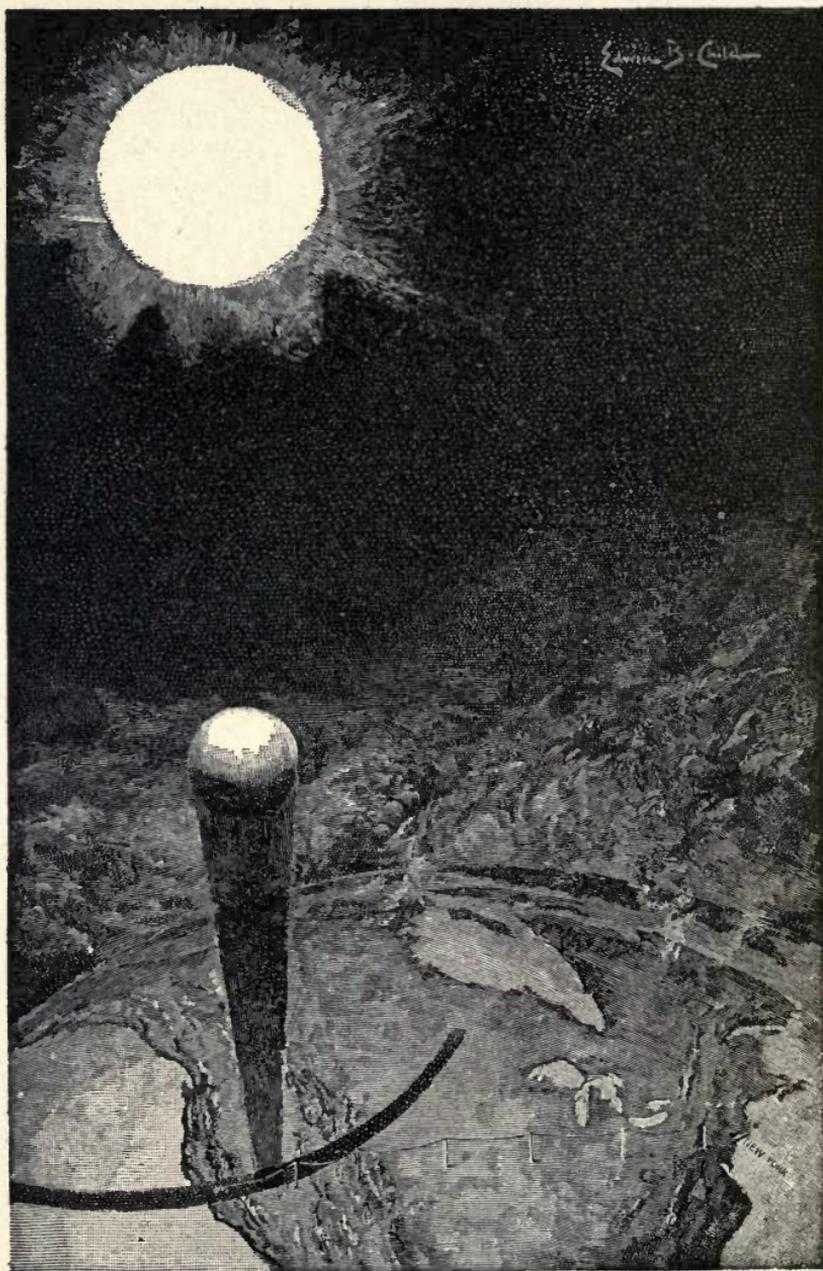


FIG. 14.—THE LUNAR SHADOW

image is brighter. Secondly, by its form the lens directs the light in such a way that the image is magnified.

The largest lenses used in telescopes in this country are the lens forty inches in diameter in the Yerkes telescope of the University of Chicago, and one of thirty-six inches in the Lick telescope of the University of California. Many colleges have telescopes with lenses from eight to twenty inches in diameter, and the great universities and national observatories have much larger ones. The largest telescope in the United States Naval Observatory at Washington has a twenty-six-inch lens.

Questions on Fig. 14. 1. What kind of eclipse does this picture represent? 2. Considering only the motion of the moon around the earth, in which direction would the shadow spot on the earth travel? 3. Does it travel more or less rapidly because the earth moves in the same direction? 4. If the moon were fixed and the earth rotated, as it does, in what direction would the shadow spot move?

EXERCISES

1. How may any observer distinguish the planets from stars? Could it be done in one observation? Why?
2. Which is more like a mirror, the surface of land or of water? Does the planet earth, then, reflect much or little light?
3. Why is it more reasonable to talk of the possibility of life upon Mars than upon any other planet?
4. Which receives more light and heat from the sun, Mars or the earth? Give the reason.
5. How many rotations does the earth make while the moon is making one?
6. What portion of the moon is lighted by the sun at one time? From what body does the moon receive light upon one half only?
7. Why does the moon have day and night? How long does daylight last at any one place on the moon?
8. In what direction is the full moon seen at sunset?
9. In what part of the sky, and at what time of the day, is the new moon first visible? What is its form?
10. Why is not the moon visible from the earth at the time of a solar eclipse?

CHAPTER III

MATTER AND ITS PROPERTIES

38. The Study of Science. — By constant observation and experiment, men have learned much about the earth on which we live. What they have learned has enabled them to do many things which would have seemed wonderful to people who lived even one hundred years ago. In order to understand the work going on about us and the effects of changes that have occurred in the earth and are still occurring, it is necessary to study the elements of science which men have learned in the centuries preceding.

39. Matter. — The heavenly bodies are so distant that we can use only the sense of sight in studying them; but to find out all that we can about things near at hand, we may use all our senses. We not only look at these things, but we may handle them, or smell of them, sometimes taste of them, or listen for sounds they may make. The name **matter** has been given to everything that takes up room and has weight. We learn about matter by use of the senses. The earth, the sun, bone, wood, brick, water, and air are all made up of matter.

There are two classes of matter, living and non-living. Ability to move of itself and to grow distinguishes living matter from non-living matter.

Matter is believed to be composed of minute, invisible particles called **molecules**. No one *knows* much about molecules, but some facts are best explained by believing that these invisible particles exist and that they are always

vibrating — that is, moving back and forth in their places — with great rapidity.

40. The Divisions of Matter. — Any separate portion of matter is called a **body**. A molecule, a book, a pebble, a boulder, a star, a fish, a tree are bodies.

A particular kind of matter is called a **substance**. Iron, sugar, salt, water, wood are substances of which bodies are made.

If the molecules of a substance are all of one kind of matter, that substance is called an **element**. Iron is an element, and nothing but iron has ever been made from iron alone. Gold and silver are elements.

41. Some Important Elements. — Of the eighty known elements, only about one half are of much importance at present. The elements most abundant in the sun and in the land upon which we live, in the air and water surrounding it, and in the bodies of plants and animals are:

Certain solid metals: aluminum, calcium, copper, gold, iron, lead, nickel, platinum, potassium, silver, sodium.

One liquid metal: mercury.

Certain solids which are not metals: arsenic, carbon, iodine, phosphorus, silicon, sulphur.

Certain gases: chlorine, hydrogen, nitrogen, oxygen.

These elements very seldom exist by themselves in the land, or in the water, or in our bodies. They are united with each other, forming another class of substances, called compounds.

42. Compounds. — If we heat a little of the element mercury (a heavy silvery liquid) and drop into it the right quantity of the element iodine (a bluish-black scaly solid), neither color remains. A new substance appears, not liquid like mercury, not in flat scales like iodine, but in the form of red powder. This is mercury iodide, a compound of mercury and iodine.

A **compound** is a substance made up of two or more elements combined in definite proportions by weight, and

having characteristics different from those of the elements which compose it. Sugar, salt, and water are compounds.

Considering that the eighty known elements may be combined in groups of two or more, and in different proportions, it is evident that many thousands of compounds may be formed from them.

If two elements, as mercury and iodine, unite to form a new and different substance, or if a substance separates into the parts of which it is composed and two or more elements result, such a change is a **chemical change**. No one of the resulting parts is like the original.

43. Mixtures. — Nearly everything that we eat or drink, the air we breathe, the substances of which our bodies are made, the paper and ink with which we write, — each of these things is either a compound or a mixture. With the exception of carbon, sulphur, and the metals, we rarely see or use anything that is an element. A **mixture** is formed when two or more substances (elements or compounds) are brought so closely together as to seem one substance and yet retain their original qualities. Sirup is a mixture of sugar and water; it is still sweet and a liquid. Air is a mixture of nitrogen, oxygen, and other gases; tincture of iodine is a mixture of alcohol and iodine; brine is a mixture of salt and water. It is often difficult for any one but a chemist to distinguish between mixtures and compounds.

The dissolving of salt or sugar in water is an example of a **physical change** because no new substance is formed. The resulting substance is liquid, as water is. It has a salt or a sweet taste, as salt or sugar has. Each substance could be recognized by a description of the mixture. The same salt or sugar could be procured in the solid form by allowing the water to evaporate.

44. Properties. — The word **property**, as it is used in science, means a quality or characteristic possessed by a

kind of matter. Hardness is a property of rock; magnetism is a property of iron; red color is a property of blood. To name the properties of a substance is to describe it. For example, water is a colorless, transparent liquid.

There are three properties which are possessed by *all* matter, living and non-living,—elements, compounds, and mixtures. These properties are extension, weight, and inertia.

45. Extension. — Every body has extension in three directions, i.e., it has length, width, and thickness or depth. Examples: a block, a pencil, a ball. The space which a body occupies is called its **volume**. A body 8 in. long, 3 in. wide, and 2 in. thick occupies 48 cu. in. of space, or has a volume of 48 cu. in.

A straight line drawn on a sheet of paper represents extension in one direction only, and a surface marked off on a table-top has extension in two directions only; therefore, the line and the surface are not bodies.

46. Systems of Measures. — The units used in measuring extension by the British system of measures (the inch, foot, yard, rod, and mile) have no common relation to each other. An inch is one twelfth of a foot; a foot is one third of a yard; and the relation of the foot or the yard to the rod involves a complex fraction. In the French or metric system, every unit of length is one tenth of the next higher, or ten times the next lower denomination.

So much time can be saved in computation by the metric system that the United States government has authorized its use in government work. In most colleges and many manufactories, scientific measurements are made in metric units. It is hoped that in time the metric system will come into general use in the United States, as it has now in most countries of Europe.

The decimal system of money was adopted in the United States more than a century ago, and some of its denomi-

nations will help us in remembering the units of the metric system.

10 mills make 1 cent.
 10 cents make 1 dime,
 10 dimes make 1 dollar.

We use the dollar as our unit and regard the smaller divisions as fractions which can always be expressed decimally. It is not necessary to write the names of the parts, for the dimes, cents, and mills are expressed decimally.

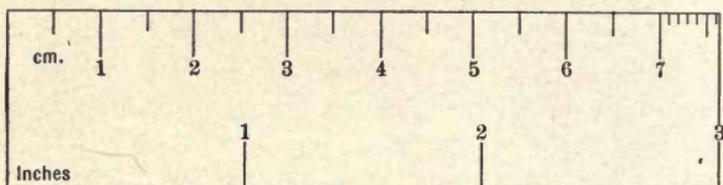


FIG. 15. — ENGLISH AND METRIC MEASURE

1. What is the equivalent of 1 in. in centimeters? 2. How many millimeters in 1 in.? 3. From the answer to 1, find which is longer, a yard or a meter.

47. Measurement of Extension. — In measuring length by the metric system, the meter is the unit. Its divisions are thus expressed:

10 millimeters (mm.) make 1 centimeter (cm.).
 10 centimeters make 1 decimeter (dm.).
 10 decimeters make 1 meter (m.).
 10 meters make 1 dekameter (Dm.).
 10 dekameters make 1 hectometer (Hm.).
 10 hectometers make 1 kilometer (Km.).

The prefixes *square* and *cubic* are used in measures of surface and volume respectively. A block measuring 5 centimeters on each edge has on each side a surface of 25 square centimeters, and contains 125 cubic centimeters.

The number of meters is more commonly written than the words *dekameter* and *hectometer*, but the kilometer (one

thousand meters) is the unit used in measuring distances. A meter is about $3\frac{1}{4}$ feet; a kilometer is about $\frac{5}{8}$ of a mile. Instead of describing a river as 1 dekameter deep, 3 hectometers wide, and 125 kilometers long, we should say it was 10 meters deep, 300 meters wide, and 125 kilometers long.

48. Weight. — When we have found out the volume of a body, we still do not know how much matter there is in it. The way to find out is to weigh it, and the amount of matter is called **weight**. Two bodies of the same volume may differ greatly in weight; as, a cubic foot of lead and a cubic foot of cork, a quart of kerosene and a quart of mercury, a cubic centimeter of ice and a cubic centimeter of stone.

49. Measurement of Weight. — The *gram* (about $\frac{1}{30}$ of an ounce or fifteen grains) is the metric unit for small weights; it is used by druggists, chemists, and dealers in gems and precious metals, and in all scientific work. The table of weights is similar to that of length, except that the unit is the gram. A *kilogram* (one thousand grams) is equivalent to about $2\frac{1}{2}$ pounds; it is the unit used in measuring large masses.

The weight of one cubic centimeter of pure water at the temperature of 39° Fahrenheit is accepted as the unit of weight, one gram (g.); and it is nearly correct to assume that one cubic centimeter of clean, cold water weighs a gram. Therefore one thousand cubic centimeters of water weigh one thousand grams or a kilogram (kg.). It is a simple matter to determine the weight of water in a tank or reservoir by measuring the capacity of the tank in cubic centimeters.

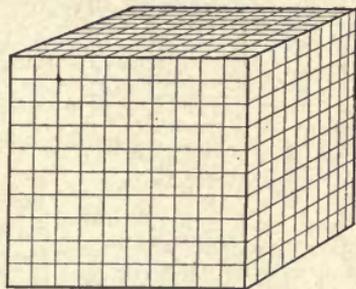


FIG. 16. — MEASURES OF VOLUME

1. How many cm. in 1 dm.?
2. How many sq. cm. in a surface 1 dm. on each edge?
3. How many cu. cm. in a block 10 cm. on each edge?
4. What name is given to such a volume?

If a tank is 50 cm. \times 40 cm. \times 30 cm., its capacity is 60,000 cu. cm., and the weight of water contained in the tank, when full, is 60,000 grams or 60 kilograms. If the liquid were twice as heavy as water, its weight would be 120 kilograms. (LABORATORY MANUAL, Exercise IV.)

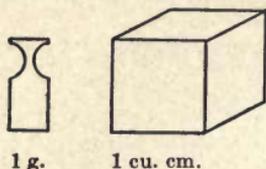


FIG. 17. — MEASURES OF WEIGHT

A small box 1 cm. on edge would have a volume of 1 cu. cm. and would hold 1 g. of water. A 1-gram weight made of brass or iron would not be so large as 1 cu. cm. 1. How many grams would 1 cu. dm. of water weigh? 2. What prefix could be used instead of the number of grams? 3. One pound is equal to the weight of about 450 g. How many pounds in 1 kg.?

50. Measurement of Capacity. —

A box measuring 10 cm. (or 1 dm.) on each inside edge has a volume of 1,000 cu. cm. (or 1 cu. dm.). The amount of liquid it will hold has been named the *liter* (pronounced *leeter*), which is about one quart. Liquids and gases in large quantities are measured by the liter. Fractions of the liter are usually expressed as cubic centimeters or as the decimal of a liter; as, 275 cu. cm. or .275 of a liter.

1,000 cu. cm. is always 1 liter, but 1,000 cu. cm. of a liquid does not always weigh 1 kilogram.

1,000 cu. cm. of water is 1 liter of water and weighs 1 kilogram.

1,000 cu. cm. of sea water is 1 liter of sea water and weighs about 1.025 kilograms.

1,000 cu. cm. of sulphuric acid is 1 liter of sulphuric acid and weighs 1.8 kilograms.

51. Inertia. — A book resting on a table will never change its own position; a ball thrown on smooth ice will go a long distance in a straight line before it stops. This inability of a body to change its own state of motion or rest is called **inertia**. If a body is at rest, it tends to remain at rest; if it is in motion, it tends to continue in motion in a straight line with unchanging speed.

Illustrations of this law of inertia are seen in moving cars.

People are standing, and while the car moves in a straight line with nearly uniform or gradually changing velocity, all is well. But if the car suddenly stops, people are thrown forward. Their feet stop when the car does, because the weight of the body presses the feet firmly to the floor. From

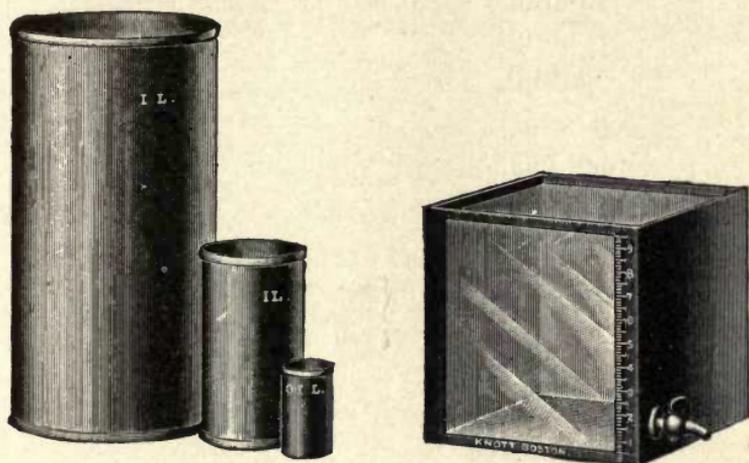


FIG. 18. — MEASURES OF CAPACITY

Measures of liquids and small solids are usually in the form of a cylinder. A cylinder which holds as much liquid as a cu. dm. box is called a liter (l.). It holds about 1 qt. 1. To how many cu. cm. is 1 l. equivalent? 2. 250 cu. cm. is what part of 1 l?

inertia, the upper part of the body continues in motion forward, as the result shows.

The effect of the sudden starting of a car in which people are standing shows the inertia of bodies at rest; that is, their tendency to remain at rest.

52. Special Properties. — Extension, weight, and inertia are the only properties which belong to *all* matter. Different kinds of matter have different special properties. Some of the special properties are:

Hardness, ability to resist being scratched. A diamond cannot be scratched by steel.

Tenacity, ability to resist being pulled apart. A steel cable bears a great strain without breaking.

Brittleness, capability of breaking under a sudden blow or shock. Glass is a substance having brittleness.

Elasticity, capability of regaining its shape and volume after the force which changes the form is removed. A rubber ball which has been flattened becomes round again.

Flexibility, capability of bending without breaking. A rope is flexible.

The terms *elasticity* and *flexibility* are sometimes confused. Rubber is flexible — it will bend; it is also elastic, for it unbends when the bending force is removed. A piece of lead is flexible — it will bend; but it is not very elastic, for it remains bent when the bending force is removed.

These properties, and many others, are *physical* properties.

53. Properties of Living Matter. — There are four special properties which belong to all *living* matter and do not belong to any forms of non-living matter. The properties or characteristics of living matter are called *physiological* properties. There are four physiological properties:

Irritability, the property of responding to influences from without. The tips of plant roots grow toward water.

Spontaneous motion, power to change the position of the body or a part of the body. Stems twine around a support; a snake glides along the ground.

Nutrition, the property of taking up certain substances to be used in constructing the body. Proper food and air are all that is necessary to make a chicken grow to be a fowl of twenty times its original weight.

Reproduction, the power to form other bodies like themselves. Plants form seeds and animals form eggs, from which grow new bodies like themselves.

54. Organisms. — Bodies having physiological properties are called **organisms**, and much of the matter of which they

are composed is called **organic** matter. The blood of an animal and the sap of a tree are organic matter. Grains of sand and drops of pure water are **inorganic** matter; they have none of the physiological properties.

EXERCISES

1. Name some bodies composed wholly or in part of silver; paper; stone; iron; rubber.
2. Name the principal substance in a book; a stove; a desk; a tumbler; a shoe.
3. By what words would you describe a piece of chalk?
4. What are the characteristics of salt?
5. Name the properties of lead. Tell why Ex. 3 and Ex. 4 are of the same kind as Ex. 5.
6. How many centimeters are there in 3 m. 4 dm. 5 cm.?
7. Write 1,246 cm. in terms of several different units.
8. (a) A tank is 1 m. deep, 1.5 m. long, .75 m. wide. Find its contents in cubic meters.
(b) Write the dimensions in decimeters and find its contents in cubic decimeters.
(c) What weight of water would fill the tank?
9. Why do people who are standing in a moving car tend to fall forward if the car stops suddenly?
10. What is the only safe way to alight from a moving vehicle? Give reasons.
11. Describe the effect on upright bodies in a wagon, when it suddenly turns a right angle.
12. Arrange under the two headings — *organic matter* and *inorganic matter* — the following substances: an apple, a pebble, silk, cotton, chalk, paper, salt, sugar, wood, brick, bread, granite, silver, milk, ice.

CHAPTER IV

FORCE AND MOTION; PHYSICAL STATES OF MATTER

55. Force. — A moving object attracts attention, and it is natural to ask, "What started it?" A single word is the answer: force. To the question, "What stops it?" the answer is the same: force. **Force** is that which produces or tends to produce motion, or change of motion. Force does not always produce motion. A man uses force when he pushes against a wall, but the wall may not move. A force is sometimes described as a push or a pull.

56. Gravity. — The force which causes an unsupported body to fall toward the earth is called **gravity**. The fall is explained by saying that the earth attracts or pulls the body toward itself. It is gravity which causes the air to remain near the earth and to move with it, instead of being left behind as the earth moves around the sun with the velocity of a cannon ball.

If a body does not fall toward the earth, it is because it is kept from moving by some opposing force. If the body is held in the hand, gravity is opposed by muscular force. If it rests on a table, gravity is opposed by cohesion, which holds the fibers of wood together. If it is suspended by a chain, gravity is opposed by the tenacity of iron.

57. Action of Two Forces. — The force of gravity acts vertically downward. Any force which opposes it must act vertically upward. If the opposing force is equal to gravity, the body remains at rest; if it is less than gravity, the body moves downward; if greater, the body moves upward.

The effect of two or more forces acting at the same point is called the **resultant**. For example, a body weighing 30

pounds is pulled upward by a force of 50 pounds. The effect will be motion upward as if a force of 20 pounds were acting alone. Forces and their resultants are described in terms of weight and may be represented by lines. A force of 10 pounds, for instance, may be represented by a line 1 inch long. In the same case, a force of 20 pounds would be represented by a line 2 inches long.

Forces also act horizontally and then produce motion in a horizontal direction. Two forces acting in the same direction produce an effect equal to the sum of the two forces. Acting in opposite directions, they produce an effect equal to the difference of the two forces, the resultant being in the direction of the greater force. For example, two horses working together can move as great a load as the two horses working singly. When a man rows a boat up stream, his muscular force acts in a direction opposite to the force of the current; he must therefore exert a force greater than that of the current.

If forces act obliquely or at right angles to each other, the resultant will lie between them. Suppose the current of a stream is directly east; a man in a motor boat sets out exactly south with the rudder set. He will arrive at a place down stream instead of opposite the point where he started. The direction of the resultant can be determined by a simple mathematical construction.

Let two lines at right angles represent two forces acting at the point *A*. If the horizontal line represents a force of 50 pounds acting east, and the vertical line a force of 25 pounds acting south, the resultant will be represented by the diagonal of a rectangular figure constructed on these lines. Its value can be found by measurement, letting each inch of the diagonal represent the same number of pounds as an inch in the other lines. (See Fig. 19, p. 58.)

58. Friction. — A ball is set rolling on a smooth floor; a boy runs upon a sheet of ice and then slides. Because of

inertia, the ball and the boy have a tendency to continue their motion in the same direction with the same velocity as at first. But they do not do so. They gradually roll or slide more slowly, until each finally comes to rest. Gravity caused them to press upon the surface below, and this rubbing of two surfaces, or **friction**, is a hindrance to motion. If two moving parts of a machine rub together, it takes more power to make them move. Oil or some other lubricant between the parts reduces the friction, because oil makes smoother surfaces. Friction may cause reduced speed or

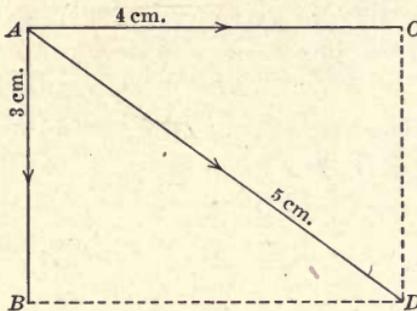


FIG. 19.—TWO FORCES ACTING AT RIGHT ANGLES

AC may represent a force of 100 kg. (1 cm. = 25 kg.) acting toward the east upon the point A. 1. What force and what direction does AB represent? 2. If the force AC acted alone, to what point would a body at A move? If AB acted alone? 3. With the forces acting together, the body moves to D. In what direction does it move, and as if acted upon by what force?

It is possessed by a moving body or by a body in such a position that it may be made to move. A baseball which has been struck has energy; it may overcome the resistance offered by a pane of window glass. In breaking the glass, the ball is doing work, and that requires energy as well as putting a new pane in place. Suppose that an iron beam is being lifted to its place in the framework of a building.

loss of motion, that is, rest. It is like an opposing force in its effect.

59. Work.—If, in spite of friction, a stone is moved along the ground, work is done. Overcoming resistance to force is **work**. Muscular work is done in lifting a body in spite of the resistance offered by the downward pull of gravity. The work of the steam in an engine is to push the piston rod which pulls or pushes other parts of the machine.

60. Energy.—The ability to do work is called **energy**.

The cable attached to the beam slips off and the beam falls downward, crashing through obstacles and doing great destructive work. While suspended and motionless, the beam had energy; it was capable of falling and doing work. The ordinary use of the word *work* implies necessary or useful motion, but in scientific use the act of overcoming any resistance is work.

61. Machines. — A **machine** is any instrument by means of which work is advantageously done. It may be very simple; as the *lever*, a stiff bar by which a man can move a much heavier weight than he could move without a machine. Another simple machine is the *pulley*, which consists of a wheel over which a rope, chain, or belt is moved, so as to lift a weight at one end when a force pulls on the other end. The *wheel and axle* consists of a cylinder and a wheel fastened together and moving upon the same axis. The cylinder, which is the “axle,” winds up a rope or cable that pulls or lifts heavy weights. The wheel is often furnished with a crank or spokes by which the whole machine is turned. Houses are moved by this machine, operated by horses.

Another simple machine is the *screw*, which is generally made of metal or wood. It is a cylinder having a ridge, called the thread, winding spirally around it. The screw works in a nut that has a groove to fit the thread of the screw. The screw is turned by hand or other power, and is used in small presses and in machines for raising weights. It is sometimes used to raise buildings. Several parts of the underpinning of a building are removed and a screw is put in each of these places. Every turn of the screw lifts the part above it by the width between the threads. The original screw propeller (1850) of a steamship really screwed its way through the water, pushing the water to one side as a small screw pushes wood. Later modifications have produced a propeller which does not resemble a screw in form.

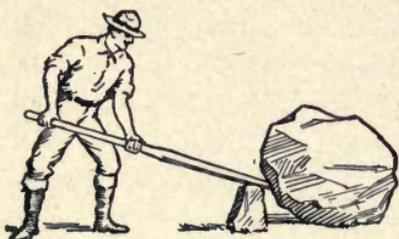


FIG. 20. — THE LEVER

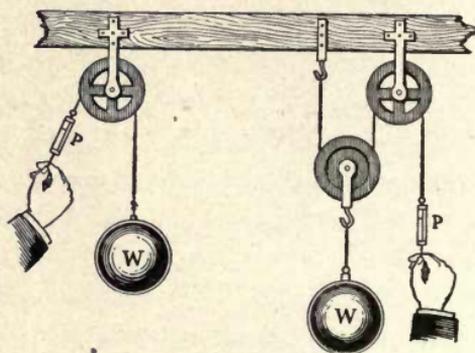


FIG. 21. — PULLEYS

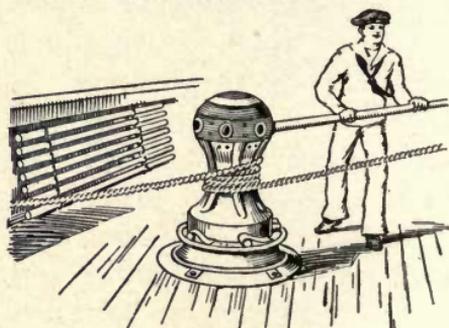
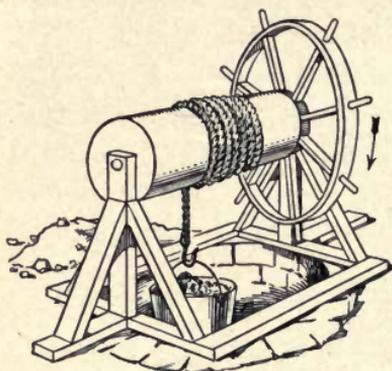


FIG. 22. — WHEEL AND AXLE

FIGS. 20-23. — SIMPLE MACHINES

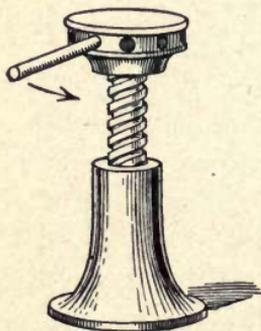


FIG. 23.—THE SCREW up?

Two advantages are derived from the use of simple machines: the power can be applied in various directions; and by the right adjustment, a small power can move a weight greater than itself. For example, to take a stone from its place requires lifting (that is, pulling upwards) by a force equal at least to the weight. By means of a stiff bar resting on a support, called the *fulcrum*, between the stone and the workman, he can move the stone by pushing down instead of lifting.

1. Why is it easier to push down than to pull up? 2. If the fulcrum is 1 ft. from the stone and P is applied 3 ft. from the fulcrum, the stone can be moved by applying only $\frac{1}{3}$ as many pounds of power as the weight of the stone. The distances of P and W from the fulcrum are as 3 to 1, which makes it possible for a given power to lift a weight three times as great as the power itself. If the stone weighs 450 lb., what power would be needed to move it?

The advantage in using the pulley at the left (Fig. 21) is simply change of direction. A 50-lb. weight is balanced by P , which = 50 lb. + enough to overcome resistance in the machine. There are two advantages in the use of the pulley at the right. W is supported by 2 cords, each of which bears half the weight of W + the weight of the pulley block. P must balance the weight supported by one cord. 3. Disregarding internal resistance, what P will balance 550 lb. in the first pulley? 4. What P in the second?

5. Where is P applied to the wheel and axle (Fig. 22)? In what direction and how far does P move? 6. In what direction does W move? How far does it move for one turn of the axle?

The thread of a screw fits a groove in the nut, which in Fig. 23 is the base of the screw. At the beginning of operation, the head of the screw rests upon the nut; spokes are thrust into the head of the screw by which to turn it. If used in lifting great weights, as in house moving, several men can be employed. As the head makes one turn, the screw and the weight upon it rise as much as the distance between the threads. 7. The threads of a set of jack screws are 2 in. apart; how many turns are needed to raise a building 1 ft.?

Complex machines, such as bicycles, sewing machines, egg beaters, or gas engines, are combinations and modifications of these simple machines and a few others. (See Fig. 24, p. 62.)

The force used in a machine is called the *power* (P), whether it is the muscular force of man or animal, the pull of gravity, or the push of steam. The resistance to be overcome is called the *weight* (W). It may be a block of stone to be lifted, a bale of hay to be compressed, or a building to be moved. Any resistance which the machine itself furnishes, on account of stiffness of ropes and friction between parts of the machine, is included in W .

62. Experiments. — An **experiment** is an attempt to find out the truth from observation of things themselves rather than from what others have learned and written about them.

When a piece of wood is placed on one pan of a balance, that side goes down. We place a piece of stone there with the same result. We exchange that for paper or feathers, and always that side of the balance goes down. We ask ourselves, "Why?"

If we conclude, after many experiments, that it is because there is more matter to be attracted toward the earth on

one side of the balance than on the other, we have answered the question. By repeating the same experiment in many ways and under various conditions, we may arrive at certain

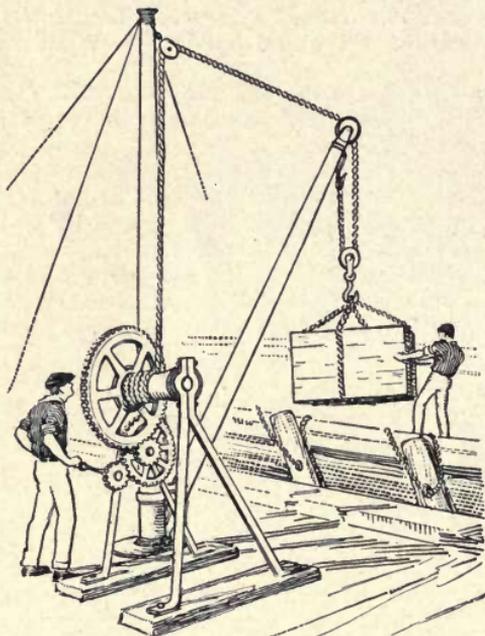


FIG. 24. — A COMBINATION OF SIMPLE MACHINES

This rotary crane is such as is used in unloading ships, and in constructing dams, bridges, and great buildings. It shows a combination of a lever, pulleys, and wheel and axle. The lever, called the jib, is fastened at one end to an upright post, with which it rotates, so that the load it supports can, after being lifted, be deposited elsewhere. The cable, which supports and lifts, runs over pulleys and is wound up on the drum of a wheel and axle. How much will the load rise if the cable is wound once around a drum 2 ft. in diameter?

should be handled with care, kept in good order, and returned to their proper places.

The weight of a body is determined by the use of a piece

conclusions which can be summed up as a definite law.

In an elementary course in science, we cannot expect to discover any new laws or even to prove any of the old laws. All that we can do is to satisfy ourselves that these great laws which others have discovered hold true as far as we have the means to observe them.

The place where experiments are made is called a **laboratory**. The word means "workshop."

63. Apparatus.—The things with which we work, such as balances, rulers, thermometers, microscopes, gas burners, and glass tubes, are called pieces of **apparatus**. They

of apparatus or machine called a balance, and the process of finding the weight is really an experiment with gravity as a force.

64. Weighing.—There are two common forms of machines for weighing: the spring balance and the equal-arm balance. In the spring balance, the body to be weighed is hung on a hook attached to a spiral spring. This causes the spring to extend, more or less, according to its stiffness and the weight of the body. By means of a scale near the spring, we can learn the pull which the earth exerts. We call this **weighing**; it is measuring the force with which gravity acts upon the body. Therefore **weight** is the measure of the earth's attraction for a body.

Another method of weighing is by the use of some form of an equal-arm balance. A horizontal bar is supported at the middle in such a way that it is free to swing up or down at either end. The bar will be horizontal if bodies of equal weight are placed on the pan or platform attached to each end. To weigh a body, we place it on one pan or platform, and on the other we place certain bodies of known weight that bring the bar to a horizontal position. (LABORATORY MANUAL, Exercise V.)

65. Density.—One of the important properties of a substance is its density. The term *density* has an exact meaning. We say that the weight of a body is the amount of matter which, however large or small, it contains. **Density** is the amount of matter in a *unit of volume*. For example,



FIG. 25.—THE SPRING BALANCE

1. When a body is suspended from the hook, the spiral wire to which it is attached is partially straightened. What straightens it?
2. When the body is removed, what property of the wire is shown?
3. Would steel or lead be the better wire for a balance? Why?

a block of stone weighs 1,500 kilograms; a piece of iron, much smaller, weighs 15 kilograms. The piece of iron is much lighter than the block of stone. But, on the other hand, 1 cubic centimeter of the stone weighs 3.5 grams; 1 cubic centimeter of iron weighs 7.8 grams. The iron has more matter in a cubic centimeter, or a cubic inch, or a cubic foot, than the stone has. The *density* of the iron is greater.

In the British system, in which the cubic foot is the unit of volume and the pound the unit of weight, the density of

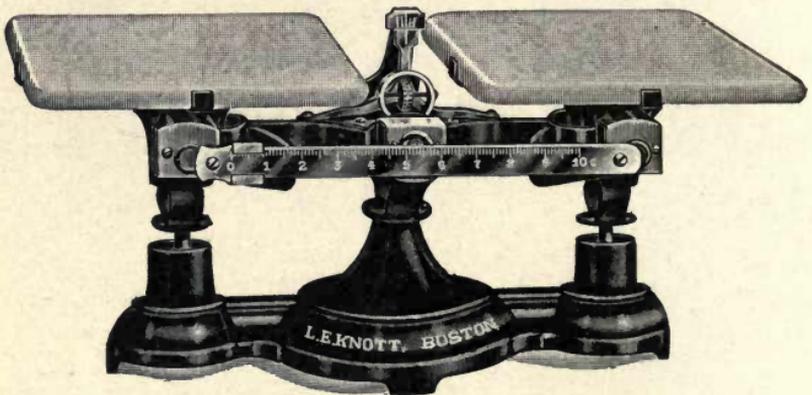


FIG. 26. — PLATFORM SCALES

This form of balance is an application of the lever. The pans or platforms are at the end of a bar which is supported at the middle. 1. With nothing on either platform, the bar is horizontal. Why? 2. Under what other conditions will the bar be horizontal? 3. What is its position with 100 g. on one platform and 90 g. on the other? Why?

a substance is the weight in pounds of one cubic foot of that substance. One cubic foot of water weighs 62.5 pounds; therefore the density of water is 62.5 pounds per cubic foot. One cubic foot of marble weighs 168.5 pounds; therefore the density of marble is 168.5 pounds per cubic foot.

In the metric system, in which the cubic centimeter is the unit of volume and the gram the unit of weight, the density of a substance is the weight in grams of one cubic centimeter

of that substance. One cubic centimeter of water weighs one gram; therefore the density of water is one gram per cubic centimeter.

66. Methods of Finding the Density of a Solid. —

It is not a difficult matter to find the density of a substance by experiment.

When the substance is in the form of a regular solid, such as a sphere, cylinder, or cube, the volume can be calculated from measurement of the dimensions. Determine the volume by measurement of dimensions, and the weight by use of balances. Then divide the number representing the weight in grams by the number representing the volume in cubic centimeters. If a block of iron containing 30 cubic centimeters weighs 234 grams, 1 cubic centimeter weighs 7.8 grams. Its density, then, is 7.8 grams per cubic centimeter.

When the substance has an irregular form, its density can be found in the following way, provided the substance will sink and will not dissolve in water. First find its weight. Then take a measuring glass, which has lines on the side to show the amount of liquid which it contains. Pour water into the glass, perhaps to the 200 cu. cm. line. Tie a thread about the body and let it down into the water. The water rises in the glass, because two bodies cannot occupy the same

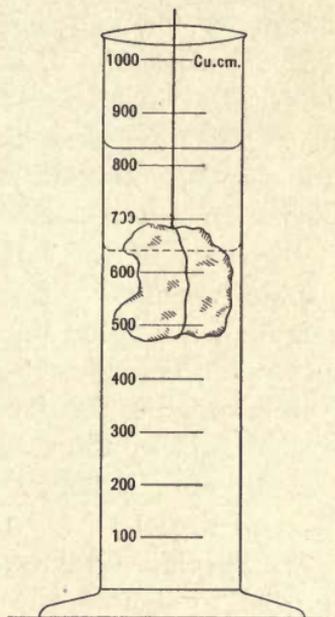


FIG. 27. — FINDING THE VOLUME OF A SOLID BY DISPLACEMENT OF WATER

A measuring glass contained 640 cu. cm. of water. A piece of stone was suspended in it and the water rose to the 830 cu. cm. line. 1. What was the volume of the stone? 2. How do you know?

space at the same time. If the water reaches the 230 cu. cm. line, the solid must have displaced 30 cubic centimeters of water. Therefore its volume is 30 cubic centimeters. If the weight is 96 grams, its density is 3.2 grams per cubic centimeter. (LABORATORY MANUAL, Exercise VI.)

67. Finding the Density of a Liquid. — The density of a substance in the liquid form may be found in the following way. Find the capacity of a flask or bottle by weighing it, first empty, and then filled with water. If the flask when filled with water weighs 75 grams more than when empty, the capacity of the bottle is 75 cubic centimeters, because 1 cubic centimeter of water weighs 1 gram. Then find the weight of the given liquid that is required to fill the same bottle; for example, 79 grams. Make the same calculation as in finding the density of a solid; that is, divide the weight of the liquid by the volume. $79 \text{ g.} \div 75 \text{ (cu. cm.)} = 1.05 \text{ g. per cu. cm., density.}$ (LABORATORY MANUAL, Exercises VII and VIII.)

68. Specific Gravity. — The expression **specific gravity** is used to denote the relation between the weight of a body and the weight of an *equal volume* of water. It is really a comparison of densities. Specific gravity can be determined by experiment without knowing the volume of a body.

It is well known that bodies seem to weigh less in water than in air. It has been proved by repeated experiments that this apparent loss of weight is always the same as the weight of the water displaced. The volume of water displaced is, of course, equal to the volume of the body immersed. Therefore the apparent loss of weight is the "weight of an equal volume of water." Hence, if we divide the weight of the body in air by its apparent *loss* of weight in water, we get the specific gravity.

For example, a piece of marble weighs 230 grams. When suspended from a balance so that it hangs in water, its

weight is 145 grams. The apparent loss of weight is 85 grams. $230 \text{ g.} \div 85 \text{ g.} = 2.7$ (specific gravity). Therefore, the weight in air is 2.7 times the weight of the water displaced, or 2.7 times the weight of a volume of water equal to that of the marble. (LABORATORY MANUAL, Exercise IX.)

69. Physical States of Matter. — There are three states or conditions of matter: solid, liquid, and gaseous. Most substances have been obtained in all three states.

Matter is said to be **solid**, or in the solid state, when it opposes any change in its shape. Much energy is required to separate the molecules of a solid. Wood, iron, nails, and sand are solids.

Matter is said to be **liquid**, or in the liquid state, when it has no definite shape of its own, but will take the shape of any vessel into which it is poured. It will oppose strongly, however, any change in its volume. Water, milk, kerosene, and mercury are liquids.

Matter is said to be a **gas**, or in the gaseous state, when it has no definite shape or volume of its own; if put into a vessel, it will distribute itself throughout all the space in the vessel, whatever the size or form. Air, hydrogen, illuminating gas, and steam are gases.

70. The Effect of Heat on Physical State. — Many solids, on being heated, are changed into liquids. Examples: ice, lead, lard. When these liquids are cooled, they change back to the solid state. Many liquids, on being heated, change into gaseous substances called vapors. **Vapors** are gases which condense at ordinary temperatures. Steam, the gas made by boiling water, is a vapor. The gas from boiling alcohol is a vapor. The gases of which the air is composed are not vapors.

The temperature at which a solid begins to be liquid is called the **melting point** of the substance. Every substance that can be melted has its own melting point. Iron melts

at a much higher temperature than lead, but at a much lower temperature than platinum.

If a liquid is sufficiently cooled, it returns to the solid state. The highest temperature at which it does this is called the temperature of solidification or the **freezing point**. The freezing point of water is 32° F.; of sea water, 28° F.; of sulphur, 240° F.; of copper, 2000° F.

The temperature of solidification and the melting point are the same for a given substance. If a thermometer is placed in cracked ice in a room of moderate temperature, it will show the temperature of the melting mass to be 32° F. If the thermometer were placed in water out of doors on a cold winter day, the temperature of the freezing water would be 32° F.

The temperature at which a substance changes from the liquid to the gaseous form, when heated in an open vessel, is called its **boiling point**. For water, this temperature is 212° F. On the other hand, if a gas is cooled sufficiently, it will **condense** or change into the liquid form. The highest temperature at which the gas condenses is the same as the boiling point of the liquid which it forms.

71. Distillation. — When water and other liquids are changed into the gaseous form by boiling, many of the impurities which were dissolved in the liquid do not change to a vapor. Hence, if the vapor is collected in a separate vessel and cooled until it condenses, a product purer than the original liquid may be obtained. This process is called **distillation**, and the product formed by the condensed vapor is called the **distillate**.

When a mixture of two or more liquids is heated, the ingredients become gases at different temperatures, because each substance has its own boiling point. The ingredient with the lowest boiling point escapes as a vapor first. If a mixture contains three liquids whose boiling points are 150° , 180° , and 212° respectively, the liquids can be sepa-

rated by **fractional distillation**. That is, if the mixture is heated to a temperature of 150° , the substance which boils at that temperature will change into vapor and can be cooled and condensed in a tube through which it passes off. Then if the temperature is raised to 180° , the liquid of that boiling point vaporizes. This is called fractional distillation.

72. Uses of Distillation. — It is sometimes necessary at sea to distill sea water in order to have water that contains

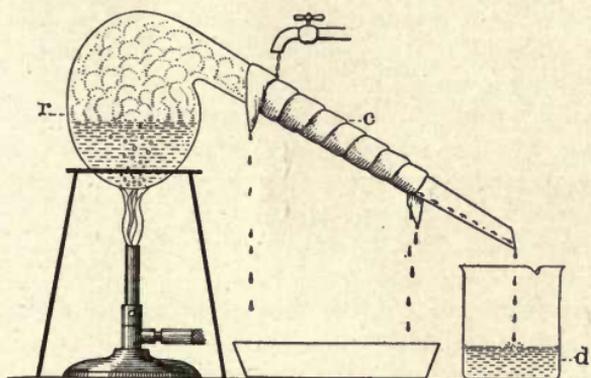


FIG. 28. — DISTILLATION

The glass retort might contain sea water, or a solution of blue vitriol, or molasses and water. 1. On being heated to 212° F., the same vapor would come out in each case. What vapor? 2. Why is water kept running over the neck of the retort?

no salt, for use in the boilers and for drinking. The distillate is fresh water.

Alcohol is distilled from liquids prepared from fruits, grains, potatoes, and other plant material.

Kerosene, benzine, gasolene, and other liquids can be separated from petroleum and from one another, because they have different boiling points. Gasolene has a lower boiling point than benzine; and benzine, a lower one than kerosene.

EXERCISES

1. A force of 50 kg. is acting toward the west, and one of 75 kg. toward the east. What is the resultant force and what is the direction of motion?

2. If the force of 50 kg. in Ex. 1 acted toward the east, what would be the resultant force and the direction of motion?

3. Represent a force of 100 lb. acting east by a line 2 in. long, and a force of 200 lb. acting north by a line 4 in. long at right angles to the first line. Draw with dotted lines two sides opposite and parallel to these, making a four-sided figure. Draw the diagonal line between the two force lines. That represents the resultant force. Measure it and compute its value, if 1 in. represents a 50-pound force. State the magnitude and direction of the resultant.

4. Represent a force of 25 g. acting southeast and one of 50 g. acting north. Draw the other two sides of the figure parallel to the first two. Measure the diagonal between the force lines and compute its value. Which force does it more nearly approach in direction? Why?

5. A block of stone $30 \times 25 \times 100$ cm. weighs 225 kg. (1 kg. equals 1,000 g.) Calculate its density.

6. A block of wood of the dimensions given in Ex. 5 weighs 54,625 g. Calculate its density.

7. The density of ice is .93 g. per cubic centimeter. What is its specific gravity? If put into water, will it sink or float? Why?

8. A rough piece of granite weighs in air 375 kg. In the water it weighs 250 kg. What is its specific gravity? What is its volume? From its specific gravity, determine the density.

9. An irregular piece of brass weighs 5 lb. 9 oz. in air; 4 lb. 14 oz. in water. Find its specific gravity.

CHAPTER V

HEAT: ITS DISTRIBUTION AND MEASUREMENT

73. Sources of Heat. — The principal sources of heat are:

Chemical action, as in the case of burning.

Friction, as when a match is rubbed on a rough surface.

Compression, as when the tube of a bicycle pump becomes hot because the air in it has been repeatedly compressed.

74. Effects of Heat. — In the study of the physical states of matter, it was shown that heat changes the physical condition from solid to liquid, and from liquid to gas; but the first effect of heat is to raise the temperature, the next to increase the volume. Heat is recognized as a form of energy because it overcomes the force which holds particles of matter together, and separates the molecules, causing expansion.

Many compounds, on being heated to a high temperature, separate into two or more substances (some of which are gases), without first melting. This is the case with wood, paper, and similar compounds. Charcoal is made by heating wood in a partly covered space, without burning it. During the process of heating, a heavy yellowish smoke comes from the wood, and a sticky dark substance, known as wood tar, collects on the inside of the charcoal kiln. The solid which remains is charcoal. (See Fig. 29, p. 72.)

75. The Thermometer. — Change of temperature is sometimes known by the sense of feeling, but it is more accurately shown by means of a thermometer. The sense of feeling often reports comparative temperature only. For example, if a person puts one hand into hot water and the other into cold water for a time, and then puts both hands into warm

water, the sensation is different in the two hands. The water feels cold to the hand which has been in hot water and hot to the one which has been in cold water. This shows that the body sense is not an accurate test of temperature.

An instrument for measuring the temperature of a sub-

stance is a **thermometer**. It consists of a glass tube with a bulb or enlargement at one end. To make a thermometer, the bulb and part of the tube are filled with mercury (sometimes called quicksilver), and then the air is removed from the upper part of the tube and the tube is sealed. The sealed tube and bulb are placed in melting ice and the point at which the mercury then stands is marked freezing point. On the Fahrenheit thermometer, commonly used in this country, the freezing point is at 32° .

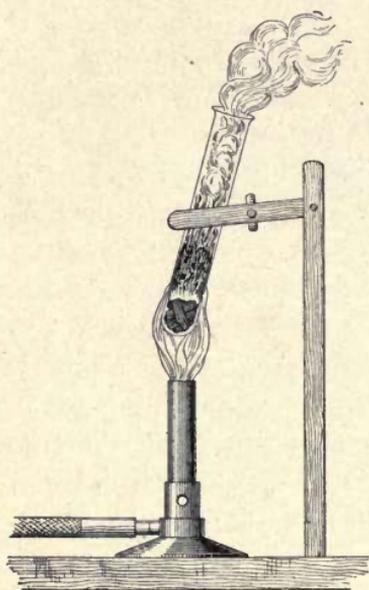


FIG. 29. — HEATING WOOD IN A TEST TUBE

Some dry pieces of wood are put into a test tube and heated until the tube is red hot. 1. What kind of change has occurred in the tube itself? 2. The wood does not melt; it does not burn because heat expanded the air so that nearly all of it left the tube; gas and smoke come from the wood, which grows black. What kind of change has taken place there? 3. Why do you think it was such?

If heat is then applied to the water around the thermometer, the mercury begins to rise in the tube as soon as all the ice is melted. The temperature does not change until the ice is melted, because the heat energy is used up in changing the solid to a liquid. The heat expands the mercury in the bulb and it must therefore rise in the tube. It continues to rise until the water boils and then the mercury remains stationary. The temperature will remain constant until

the water is all changed to steam, for the heat energy is now used in changing the liquid to a gas.

The temperature which indicates the boiling point of water is marked 212° on the Fahrenheit thermometer. The space on the scale between 32 and 212 is divided into 180 equal parts, each one of which is a degree.

On the scale of the Centigrade thermometer, the freezing point of water is marked 0° and the boiling point 100°. The change of temperature between 0° and 100° C. is, of course, the same as between 32° and 212° F., and the change of temperature of one degree C. is therefore greater than of one degree F. The Centigrade thermometer is used in most laboratories and in general scientific work, and for all measurements of temperature in many countries.

To change degrees Centigrade to degrees Fahrenheit: multiply the number of degrees by 1.8 (or $\frac{9}{5}$) and add 32. Example: $(100^{\circ} \text{C.} \times 1.8) + 32 = 212^{\circ}$.

To change degrees Fahrenheit to degrees Centigrade: from the number of degrees subtract 32 and divide the remainder by 1.8 or $\frac{5}{9}$.

Example: $\frac{212^{\circ} \text{F.} - 32^{\circ}}{1.8} = 100^{\circ} \text{C.}$

Since mercury becomes solid at about 40° below zero, mercury thermometers are not used for very low temperatures. Alcohol has a much lower freezing point than mercury and for this



FIG. 30. — LABORATORY THERMOMETER

1. In what respects is a laboratory thermometer different from an ordinary house thermometer?
2. Why are these differences necessary ones?

reason alcohol thermometers are used in cold climates. Because alcohol is cheaper than mercury, colored alcohol is much used in ordinary thermometers. (LABORATORY MANUAL, Exercise X.)

76. Conduction. — Whenever the temperature of a body is higher than that of its surroundings, it gives out some of its heat. There are three methods by which heat is distributed: conduction, convection, and radiation.

If two bodies of different temperatures are in contact, after a time the temperature of the colder body will rise

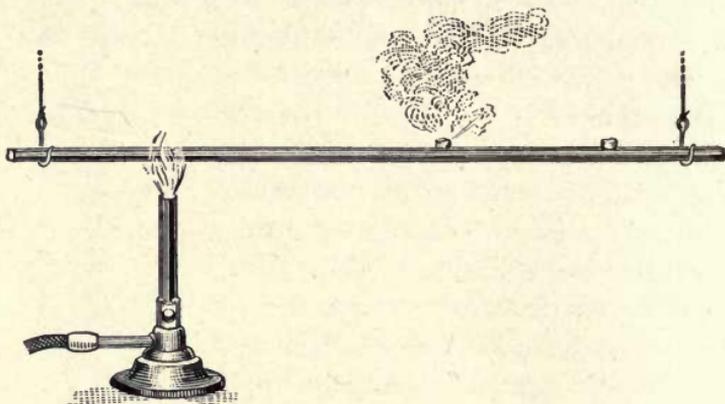


FIG. 31. — CONDUCTION OF HEAT

Phosphorus takes fire at a low temperature. 1. If a piece of phosphorus is placed on a strip of metal and the metal is heated at a distance from it, the phosphorus soon burns. Why? 2. Why in Fig. 31 do not both pieces ignite at once?

and that of the warmer will fall. If one end of a cold iron rod is heated in a fire, the end in the fire will soon become red-hot and the other end warm. The end farther from the fire is heated by **conduction**. Heat has passed from molecule to molecule until the one farthest from the source of heat has received it. After the source of heat is removed, the distribution continues until all parts of the bar are of the same temperature. The iron is said to be a **conductor**. All the metals are heat conductors.

If the hand touches an object having a temperature lower than the hand itself, the object feels cold because it conducts heat *from* the hand. If the object has a higher temperature than the hand, it feels warm because it conducts heat *to* the hand. Bodies which have been for a long time in the same room have the same temperature, but the good conductors feel cold, the poor ones less cold.

Metals are the best conductors of heat; stone, hard wood, silk, and linen are very good ones; asbestos, wool, paper, and air are poor conductors. Because of the layers of air between articles of our clothing, several thin garments are warmer than one thick layer of the same weight as all the thin ones. Clothing does not *make* us warm but *keeps* us warm if heat is not conducted away from the body.

77. Convection. — Heat is distributed through liquids and gases by moving currents. This method is called **convection**. It may be illustrated by studying a kettle of water over a fire. The bottom of the kettle becomes heated, and the layer of water in contact with it is heated by conduction. This rise in temperature causes expansion in the bottom layer and therefore a smaller density. One gram of cold water occupies one cubic centimeter of space; when the water is warmed, a gram occupies more than one cubic centimeter. One cubic centimeter of warm water weighs less than one gram. The lighter, warmer water in the kettle is pushed away by the colder, denser water and rises. This process is continued until the liquid at the top as well as at the bottom has reached the boiling point.

In convection, there is a downward movement of the colder liquid or air and an upward movement of the warmer. The air of a room is always warmer near the ceiling than near the floor.

78. Radiation. — Besides conduction of heat through matter in contact with a source of heat, and convection in currents of liquids and gases, there is another method by

which heat is distributed more rapidly and through greater distances. Heat passes through air and some other substances in straight lines in every direction. This is **radiation**. It is by this method that heat passes from the sun to the

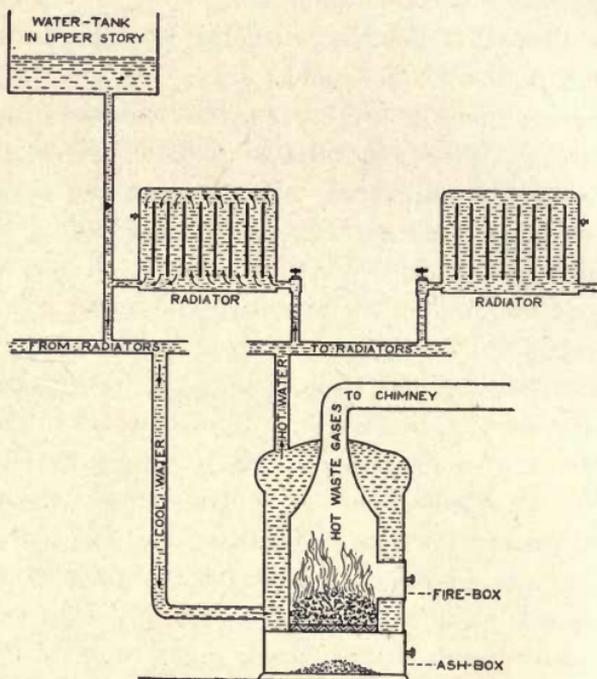


FIG. 32. — HOUSE HEATING BY HOT WATER

1. Why does water rise from a heater in the basement to the second floor? 2. Why is it rising in one part and falling in another, in the radiator at the left? 3. Make a diagram like the right-hand radiator; connect it properly with the rest of the system and indicate the direction of hot and cool water currents.

earth and to other planets; and from stoves, radiators, and lamps to objects around them.

If this radiated heat falls upon a body through which it cannot pass, it is absorbed and the temperature of the body rises. The sun's radiations pass through the air, with very little absorption, to the earth, which absorbs the heat and is warmed by it.

79. How the Air is Warmed. — The air in contact with a stove is warmed by conduction. Being lighter, it is pushed away by cooler air and moves upward (convection). In a similar way, the atmosphere surrounding the earth is warmed by heat from the earth. Besides distributing heat by conduction and convection, the earth radiates heat. This radiated heat passes through the air, if it is dry, without raising its temperature; but if there is much vapor in the air, the vapor prevents the passage of radiated heat and the air retains the heat. A layer of cloud near the earth at night is like a blanket keeping the earth warm.

80. Intensity of Heat. — The intensity of heat is stated in terms of degrees of a thermometer. Water, oil, air, and iron at a given degree (as at 10° C. or 50° F.) have the same temperature or intensity of heat.

Very high temperatures cannot be measured with an instrument made of glass because the glass would melt, but they are sometimes determined by the amount of expansion of a metal rod. For such measurements, a rod is fastened at one end to a frame, and the other end is supported but free to move. As the rod becomes heated, it lengthens and pushes against a movable pointer. This pointer indicates, on a scale, the increase in temperature. Such small differences as degrees are not indicated, but a change of a hundred degrees or more is shown. Red-hot iron has a temperature of $1,000^{\circ}$ F.

81. Quantity of Heat. — A teacupful of water and a pailful may have the same *temperature*, but the larger amount of water would have the greater *quantity* of heat. It would melt a greater weight of ice or raise the temperature of a larger mass of matter a given number of degrees.

82. The Calorie. — The metric unit used in measuring the quantity of heat in a body is called the *calorie*. It is the quantity of heat required to warm one gram of water through one degree Centigrade. For example, to warm one gram of

water from 15° C. to 25° C. requires 10 calories; to warm 50 grams of water from 30° C. to 100° C. requires 50×70 or 3,500 calories. A body in cooling gives out heat. A gram of water in cooling one degree Centigrade gives out one calorie.

83. The Quantity of Heat Absorbed by Water. — If equal weights of water, copper, and mercury are warmed through the same number of degrees, very unlike amounts of heat energy are required. The quantity of heat required to raise the temperature of a pound of water one degree will warm a pound of copper ten degrees or a pound of mercury about thirty degrees. That is, one tenth as many calories are required to warm a pound of copper one degree, and one thirtieth as many to warm a pound of mercury one degree, as to warm a pound of water a single degree. No solid, and no other liquid, absorbs so much heat in a given rise of temperature as water does. (LABORATORY MANUAL, Exercise XI.)

84. Influence of Bodies of Water upon Climate. — Water has a much greater quantity of heat to distribute to objects around it than other substances at the same temperature, because it absorbs more heat than the other substances do, while gaining the same number of degrees. Water is not so good a conductor of heat as metals, rocks, or other solids, and for this reason does not distribute its heat so rapidly to the surrounding air. As it is commonly expressed, "water keeps warm longer."

These facts have a very important bearing on the subject of the climate of islands and of land near a large lake or an ocean.

A great lake or an ocean, having been slowly heated through the summer to a temperature of 75° F. or 24° C., has a great quantity of heat to transfer and will do it slowly. The land *loses* heat rapidly after sunset, but near a lake or ocean the air *receives* heat from the water during the night

and so does not have a freezing temperature when the ground does. This delays the season of frost in the fall at places near the water. Grapes and other fruits which ripen late are more successfully grown near the lakes in New York State than at a distance from them.

85. Heat and Energy. — Heat is a form of energy; it can do work. As the temperature of a body rises, its molecules vibrate more rapidly and, in so doing, separate farther apart; that is, the volume of the body is increased. Thus pressure is exerted upon surfaces in contact with the body.

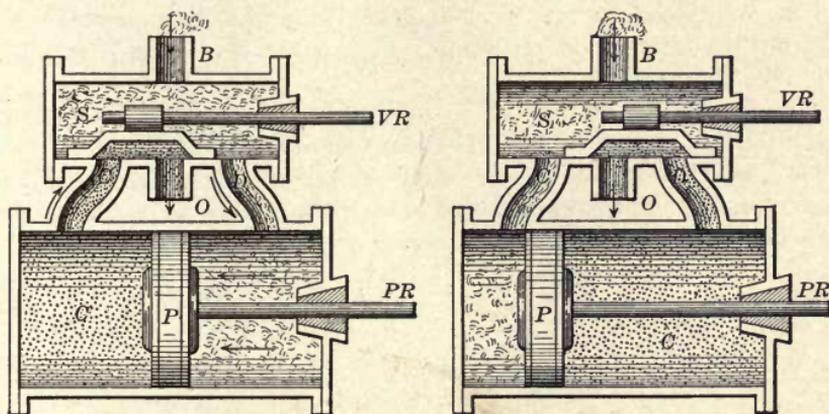


FIG. 33. — THE STEAM CHEST OF AN ENGINE

In the left-hand figure, steam is shown entering from the boiler at B, passing through D to the cylinder. It exerts pressure on P, pushing it to the end of the cylinder. Steam passes out through C and O to the condenser. The valve rod VR is moved by other machinery so as to close the entrance to D when the cylinder is filled with steam. C is then open to S. Trace the path of the steam from B to O in the right-hand figure.

When water is changed to steam, the vapor, if unconfined, occupies about 1700 times as much space as the liquid did. The force of this expansion is used to exert a push on the piston in the cylinder of an engine. When the steam is admitted first into one end of the cylinder and then into the other, the piston is pushed back and forth. By means of a connecting rod, other parts of the machinery are kept in motion.

The use of steam for this kind of work about the year 1770 was the beginning of great progress in rapid travel on land and sea and in the manufacture of cloth, tools, and food. Electric power has recently displaced steam in many kinds of work; but unless natural water power is available, steam is still relied upon to turn the machinery that is necessary to make electric currents.

EXERCISES

1. Describe changes in the physical state of matter produced by changes in temperature.

2. Why does the mercury rise in the tube of a thermometer when you put your finger on the bulb? How could you make it fall considerably in a short time?

3. How many Fahrenheit degrees are there between the freezing and boiling points of water? How many Centigrade degrees?

4. Which shows a greater change of temperature, one Fahrenheit degree or one Centigrade degree? State the arithmetical relation between the value of a Centigrade degree and a Fahrenheit degree.

5. How many degrees above 0° F. is 9° above freezing? How many degrees above 0° C. is 5° above freezing? Which is the higher temperature? Why?

6. Show why 32 is added in one case and subtracted in the second case, in changing the readings of one thermometer scale to the other. (See § 75.)

7. 68° F. is a comfortable house temperature. What is the equivalent in degrees Centigrade?

8. Which is the greater rise in temperature, from 32° F. to 50° F. or from 0° C. to 12° C.? Prove your answer.

9. (a) Which has the higher temperature, 1,000 g. of water at 40° C. or 500 g. at 82° C.?

(b) Which has the greater amount of heat, 1000 g. of mercury or 500 g. of water at the same temperature. Explain. Give the answer in calories.

10. Why is there greater probability of a frost on a clear night than on a cloudy night?

CHAPTER VI

LIQUIDS AND THEIR PROPERTIES

86. Properties of Liquids. — The special characteristics of liquids are:

Mobility, or freedom to change form, as liquids do when poured from a pitcher into a cup.

Incompressibility, or resistance to pressure which tends to reduce the bulk. A bottle, when full of water, may be burst by putting in a cork.

Viscosity, or tendency of the particles to cling together. The form of a drop is due to viscosity.

Volatility, or tendency to change to a vapor. Ether on the skin disappears very quickly.

Water, the most familiar liquid, is used as a standard in comparison of liquids. Alcohol is less dense and more volatile than water; tar is a very viscous liquid; molasses, while less viscous than tar, is more so than water. All liquids are practically incompressible.

87. Hydraulic Presses and Elevators. — We make use of the incompressibility and mobility of liquids in running certain machines, like presses and elevators. In both presses and elevators, a platform is placed upon a piston or plunger in a water-tight cylinder. Water is forced into the cylinder, and as the water pushes up the plunger, the platform rises. In the press, the object to be compressed is placed upon the platform, which moves up until it meets an immovable surface. Great pressure is then exerted against the substance on the platform. Bundles of cotton, hay, or paper are thus made into compact bales.

Passenger elevators are constructed with a strong cage or frame-work above the platform. When the operator stops the elevator, he closes a valve so as to prevent more water coming into the cylinder. When the elevator descends, he opens a valve and allows water to escape from the cylinder;

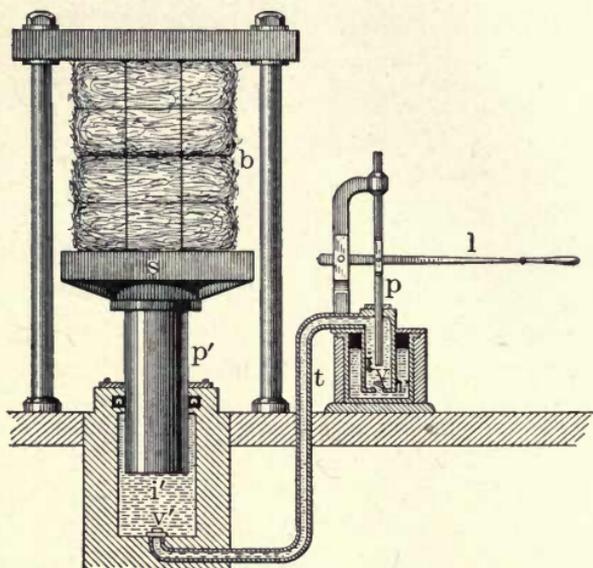


FIG. 34.— A HYDRAULIC PRESS

1. By means of a small pump p , water is forced from i through t , into the cylinder i' . The pressure exerted by one square inch of the surface of the piston p is transmitted to each square inch of the surface of p' . If the pressure of p is 25 lb. and p' is 100 times the area of p , what is the pressure upon p' ? 2. Why does not p' sink back after being pushed up? In a passenger elevator, the valves V and V' are opened or closed by the operator in the elevator. 3. Learn from a dictionary the meaning of *hydraulic*.

the elevator then descends by gravity, checked by the resistance of the water as it moves slowly out of the cylinder.

88. Solution.—Liquids have the power of **dissolving** other substances, that is, of absorbing particles of other substances between their molecules. The absorbed solid, liquid, or gas disappears and the result is a liquid mixture called a **solution**. The solution may have a different taste, odor, or color from the original liquid, which is known as

the **solvent**. The substance has dissolved and is thus shown to be **soluble**.

Water is a solvent for many substances, but not for others, such as fat, wax, and gum. Alcohol dissolves many solids which are not soluble in water. Benzine is another solvent. It is their ability to dissolve grease, gums, and such substances that makes alcohol and benzine useful as cleansers.

Metals are not soluble in water or in alcohol, but disappear after a time in acids. In such a case the product is not a mixture, as in the case of sugar and water, but a new compound. If a solution of sugar and water is boiled until the water has all evaporated, sugar will remain in solid form. But the liquid formed by the action of the acid upon the metal, on being evaporated, will not leave the original metal but a very different solid in the form of crystals.

89. Natural Waters. — Raindrops are nearly pure water; but while the rain water soaks through the ground, various minerals become dissolved in it. These minerals in very small quantities are found in the water of wells, springs, and rivers. Water also dissolves gases and some organic matter from the ground. Many of these dissolved impurities are harmless, but some are sources of disease. It is best, therefore, not to drink well-water or brook-water which has passed near houses and barns. Such water can be made safe for drinking by boiling it for ten minutes or more and then cooling it. Injurious organisms, such as disease germs, are destroyed by *long continued* heat.

Natural waters are not pure, though they may be harmless. Nearly pure water can be obtained by distilling the water of springs, rivers, and even the sea. The dissolved mineral matter does not vaporize but remains as a solid after all the water has evaporated. The distillate may contain some of the gases which were dissolved in the water, and so it is not *perfectly* pure.

90. Mineral Springs and Salt Lakes. — Many springs contain dissolved mineral matter in sufficient quantities to be detected by the taste. Some mineral springs are medicinal in character and their water is recommended by physicians in the treatment of some diseases. It does not follow, however, that these waters are beneficial to every one.

Salt lakes, which contain dissolved salt and other minerals, are found in dry regions where evaporation goes on rapidly. Pure water is continually evaporating from the lakes, while streams are constantly bringing in minerals in solution. When such lakes have no outlet, they become more and more salt.

91. Gravity, the Cause of Streams. — Water, like all other matter, has weight; that is, it is attracted by the earth. Hence, unless restrained, it falls to the lowest possible level. This falling, due to gravity, is the cause of flowing water in streams. The water seems to slide or roll along over the surface of the earth, but in reality streams fall, some a few feet in a mile of their course, others hundreds of feet. Rapids, cascades, and waterfalls are names given to parts of a stream where the fall is considerable within a short distance.

The headwaters of the Connecticut River are nearly a thousand feet above sea level, so in its journey of four hundred miles to the sea the water falls one thousand feet. In a few places the fall is twenty or more feet at one place and there the energy of the falling mass is utilized in turning machinery.

92. Water Power. — Long before steam was used to run machinery, men placed large water wheels where the water could fall upon them, turning them as it fell. Connected with these wheels was the machinery to grind grain, to saw logs, and later to weave cloth. At the present time water is used to run dynamos, which are machines for producing the electric currents that furnish both light and power.

The trolley cars of many cities are run, lighted, and warmed by the energy of waterfalls in distant rivers.

93. Springs and Wells. — Since water seeks low places, the rain which falls upon the earth flows down a slope, or settles into the soil and finds its way lower still through porous rocks or through cracks. When the water reaches a layer of rock through which it cannot pass, it may follow the rock to some place where the layer comes to the surface,

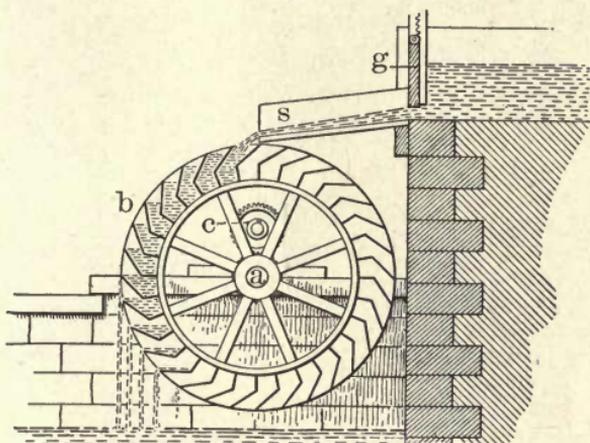


FIG. 35. — POWER FROM FALLING WATER

Water flows from some height through the sluiceway into a bucket on the water wheel. 1. Suppose that the buckets are empty and the wheel is at rest; water enters the bucket nearest to *s*. What force sets the wheel in motion? 2. Why does the wheel move faster when two buckets are filled? 3. Why is this form of bucket better than one with straight boards?

perhaps many miles from where the water started. Many hillside springs are formed in this way.

A stratum of porous rock often contains much water. If the rock is inclined, as in a hilly region, some parts of the stratum are much lower than the source of the water. From the lower levels, water rises through fissures, or cracks, to the surface of the ground, by pressure of the water behind it. Such springs are fissure springs. They bring water often from a great distance as well as from a great depth.

By digging or drilling to the underground water-level, it is possible to bring water to the surface by its own pressure or by pumps. Wells of one or the other of these types furnish water for domestic and agricultural purposes in many districts.

Many springs and wells have a uniformly cool temperature at all seasons. This is because the absorption and radiation of heat by the earth change the temperature for only a short

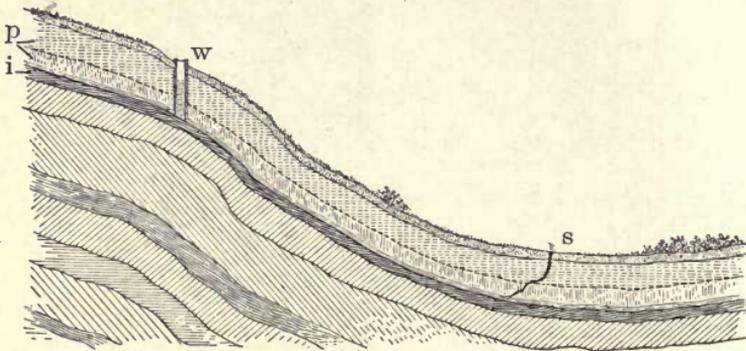


FIG. 36. — FISSURE SPRING AND WELL

If *i* is a layer impervious to water, the water which has passed through the porous layers (*p*) must rest there, or follow down the inclined layer *i*. A fissure through the upper layers may deliver the water at *s*. 1. Why is such a spring usually a "bubbling" spring? 2. If a tube were sunk there, how high might the water rise in it? (Make no allowance for friction.) 3. Would making a well at *w* have any effect upon the spring? 4. Is there any better place for a well? Why?

distance below the surface. The cooler the water of a spring is in summer, the deeper one would have to go to find its supply.

94. Pressure in Liquids. — As a diver descends below the surface of water, he is conscious of a pressure which steadily increases with the depth. If he is to remain some time below the surface, he puts on a loosely fitting rubber suit, provided with a metal helmet and a rubber tube through which air can be forced down to him from above. It is necessary to force the air down for two reasons: first, to

supply the diver with oxygen for his lungs; and second, to overcome the pressure exerted by the water against his suit. For example, if the diver is working at a depth of seventy feet under water, the pressure upon his body is about three



FIG. 37. — A DIVER PREPARING TO GO INTO THE WATER

On his shoulders the diver carries a cylinder of compressed air connected by a tube with a machine for supplying the air. What pressure is there upon every sq. dm. of his body at 100 dm. depth?

times as much as at the surface. As long as he is provided with air at a pressure sufficient to balance the pressure of the water, his suit will fit loosely. A greater pressure of air will tend to burst the suit; a smaller pressure will allow it

to collapse and press against his body. As fast as the diver uses the air, it escapes through a valve into the water, fresh air being pumped to him all the while.

95. Laws of Pressure in Liquids. — Experiments prove three things about the pressure of liquids:

First, that the *pressure varies directly with the depth*. The pressure of the water upon a body ten feet below the surface is twice as great as upon a body five feet below.

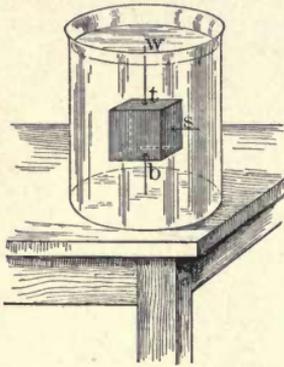


FIG. 38. — PRESSURE UPON A SUBMERGED BODY

1. Which is greater, the upward or the downward pressure upon this block? 2. Would the block remain (naturally) in this position: (a) if its density were greater than that of water? (b) if it were less? (c) if it were the same as that of water? 3. Give the reasons for one of these answers. 4. Explain from these answers why a body apparently weighs less in water than in air.

Second, that the *pressure varies with the density of the liquid*. The pressure upon a body ten feet below the surface of the *ocean* is greater than upon a body ten feet below the surface of a *pond*, because the salt water of the ocean is more dense than the fresh water of the pond.

Third, that at any given point in the liquid the *pressure is the same in all directions*. At any point upon a body under water, there is the same pressure from above, below, and from each side.

96. Direction of Pressure. — Pressure in a liquid is exerted at right angles to the surface of the body upon which it is acting. Suppose a cubical block, two centimeters on each edge, is placed under water so that its top is three centimeters below the surface of the water. The bottom of the block is five centimeters below the surface and the average depth of each side is four centimeters.

In accordance with the first law of pressure in liquids, the pressure on all six sides can be found. The total downward

pressure upon the top is equal to the weight of $(2 \times 2 \times 3)$ 12 cubic centimeters of water. The total upward pressure on the bottom of the block is equal to the weight of $(2 \times 2 \times 5)$ 20 cubic centimeters of water. The total pressure upon each side of the block is equal to the weight of $(2 \times 2 \times 4)$ 16 cubic centimeters of water.

The third law of pressure is applied in the construction of hydraulic presses and elevators. Water enters, or is pumped into, the small cylinder with a force, for example, of 100 grams to the square centimeter of area. The water at the bottom of this cylinder has that pressure upon it. Because the pressure is exerted in every direction, the water at the same level in the large cylinder receives a pressure of 100 grams to the square centimeter. This pressure, in turn, is exerted upward as well as horizontally upon the water and upon each square centimeter of the piston in the large cylinder. If the area of the large piston is 900

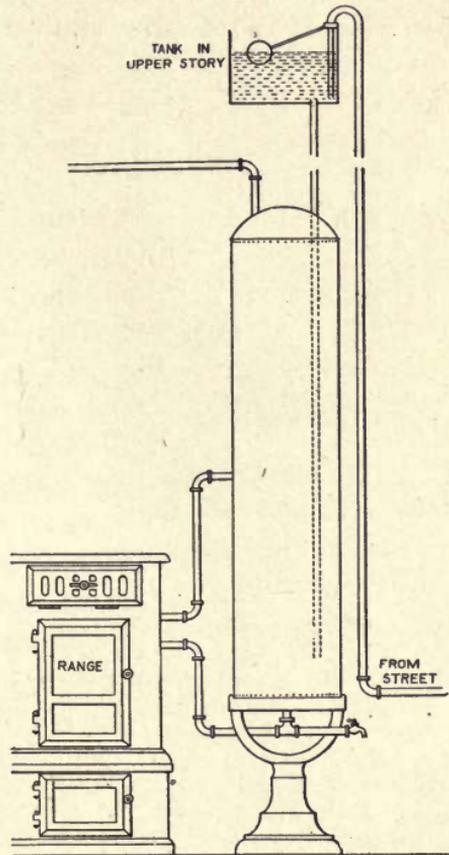


FIG. 39. — GRAVITY PRESSURE IN A HOT-WATER BOILER

1. Under what conditions is an elevated water tank necessary to a hot-water system?
2. If a tank is not needed, where does the water enter the boiler?
3. From which pipe does it enter the stove?
4. Trace its course from the water-front of the stove to a story above the boiler.
5. Name in order the changes of direction of pressure from the street to the stove. (Use upward, horizontal.)

square centimeters, the total upward effect will be a pressure of 900×100 grams.

97. Buoyancy in Liquids.— Careful study of the diagram (Fig. 38) will show that the horizontal pressures on opposite sides of the submerged block are equal, but

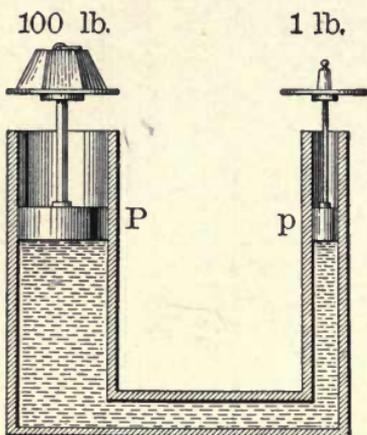


FIG. 40.—TRANSMISSION OF PRESSURE

1. The area of the piston p is 1 sq. in.; what is the pressure exerted upon the surface of the water beneath?

2. This pressure is transmitted in every direction: what is the pressure in the horizontal tube? 3. In what direction is pressure exerted in the large cylinder? 4. What is the pressure upon each square inch of P ? 5. From the weights indicated here, what must be the area of P ? 6. If more weights were placed upon p , and it went down 1 in., would P rise 1 in.? Why?

are acting in opposite directions, so that the block will not tend to move in either direction sidewise. But as the upward pressure upon the bottom of the block is greater than the downward pressure on the top, the block will be buoyed up in the liquid by a force equal to the difference between the upward and downward pressures. This is the reason that a body seems to lose weight in water; part of its weight is supported by upward pressure of the liquid.

98. Capillarity.— If water is put into a glass, it is seen to rise a little higher where it touches the glass than elsewhere at the surface. If a glass tube is placed upright in water, the water stands higher in the tube than around it. This rise of liquids in tubes, or on the side of a solid placed in the liquid, is called **capillarity**. It is due to the attraction of the solid for the liquid.

Capillarity can be shown with all liquids which wet—that is, adhere to a solid. Mercury does not adhere to glass; it will roll off from clean glass and leave no trace. Mercury

does not rise higher in tubes than in the surrounding liquid, as water does, but is slightly depressed.

Small spaces between threads close together, as in a wick or cloth, have the effect of tubes in which liquid rises. If a dry cloth is placed with one end in water, the liquid rises in the spaces, as in tubes, and the cloth is soon dampened throughout. Water sometimes rises through the cloth over the edge of a bowl and drops from the other end of the cloth. Kerosene rises between and upon the threads of the lampwick to the top, where it burns. Blotting paper takes up ink between the fibers of the paper. In plants, capillarity aids in the rise of liquids from the roots through the stems to the leaves. In soil, it aids in the rise of water from lower levels to the surface of the ground.

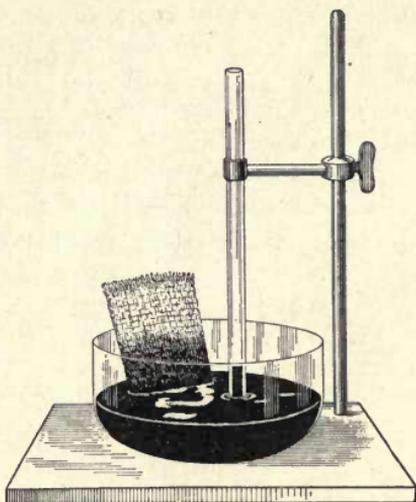


FIG. 41. — CAPILLARITY

The smaller the bore of a tube, the higher a liquid will rise by capillarity. The diameter of the tube shown here is 2 mm., which is much larger than that of many plant cells. Liquids pass from cell to cell by osmosis, and rise in the cell by capillarity.

EXERCISES

1. Which would be likely to furnish cooler water, a hillside spring or a fissure spring? Why?
2. At what depth in fresh water will the pressure be 75 g. per square centimeter?
3. Why is pressure in the ocean greater than at the same depth in a pond?
4. Which apparently loses more weight, a body partially immersed in water or a body wholly immersed? Why?
5. A cubical block 5 cm. on each edge is immersed in water to a

depth of 25 cm. above the top of the block. State (a) the depth of the bottom of the block; (b) the average depth of each side; (c) the pressure in grams on the top; (d) the pressure in grams on the bottom; (e) the pressure in grams on each side; (f) the difference in pressure on the bottom and the top. Illustrate by a diagram.

6. (a) How many cubic centimeters of water are displaced by the block described in Ex. 5? (b) Compare this with the answer to Ex. 5, f.

7. If the block described in Ex. 5 weighs 280 g. in air, what is its weight in water?

8. If the downward pressure on the tube admitting water to the cylinder of an elevator is 100 lb. to the square inch, what will be the upward pressure on the large piston, if it is one square foot in area?

9. Why is it easier to float in salt water than in fresh water?

10. Why is a cloth better than a newspaper to wipe up water?

11. Describe the surface of good blotting paper and tell why such a surface is required.

CHAPTER VII

PROPERTIES OF GASES; THE ATMOSPHERE; ATMOSPHERIC PRESSURE

99. Properties of Gases.— Since gases are a form of matter, they have weight and occupy space. Some gases are elements, such as oxygen, hydrogen, and nitrogen. Some are compounds, as ammonia and carbon dioxide. Some are mixtures, as illuminating gas and air.

Gases have some of the same physical properties as solids and liquids, but in different degrees. The special properties of expansibility and compressibility belong to gases in a greater degree than to solids or liquids. A cubic foot of air on being heated becomes more than a cubic foot, although its weight remains the same. By pressure it can be made to occupy much less than a cubic foot of space, but its weight is still the same. If some gas is removed from a vessel containing one cubic foot, the weight of the remaining gas is diminished, but it expands to fill the space and its volume is still one cubic foot.

100. Molecular Motion.— The expansibility of gases is a result of the action of molecules. The molecules of gases, as well as of other bodies, are in very rapid vibration. As they strike one another, they rebound and thus set other particles in more rapid vibration and are separated farther and farther. They strike the walls of the vessel that contains the gas, and if the space is enlarged, or an opening is made, the gas expands to fill the larger space or finds its way out.

101. Solubility of Gases.— Many gases will dissolve in water and remain more or less permanently dissolved, ac-

ording to conditions of temperature and pressure. What is commonly called "ammonia" is the gas ammonia dissolved in water. Air dissolves in water and in this way the oxygen necessary to life is furnished to fishes and other water animals. If a tumbler of drinking water is left standing for a time, small bubbles may be seen clinging to the inside of the glass. These bubbles contain air, and the water is not so agreeable to drink as it was before the air left it. All natural

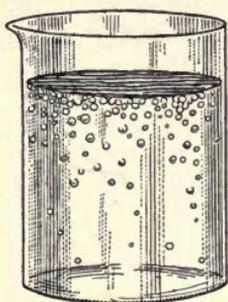


FIG. 42.—SOLUTION OF AIR IN WATER

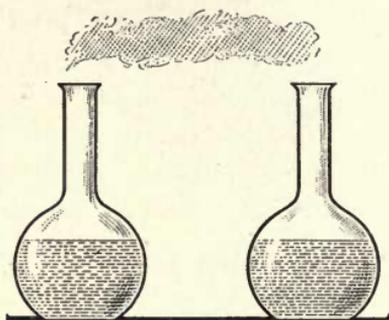


FIG. 43.—DIFFUSION OF GASES

FIG. 42. The water here represented has been growing warmer while standing for some hours. Air which was dissolved in the water has separated and appears as bubbles on the glass. 1. What did the change of temperature have to do with the change in the water? 2. How does air become dissolved in water?

FIG. 43. One of these flasks contains an invisible acid gas dissolved in water; the other contains invisible ammonia gas, also in solution. If these two gases come together, they form a new compound in the form of a fine white solid. 1. What shows that they have diffused? 2. Suppose that one of the bottles were removed; what change would occur?

waters contain dissolved air, and much spring water contains the gas carbon dioxide. If water is heated, the dissolved air and other gases expand and escape. Such water tastes stale or flat, even after it is cooled.

102. Soda and Carbonated Waters.— Large quantities of carbon dioxide dissolved in water give the pungent, slightly acid taste familiar in plain soda water. The name "soda water" was given because the carbon dioxide was

formerly prepared from soda, but there is really no soda in soda water. The tanks containing soda water are made of metal and are very strong. They are partially filled with water, and carbon dioxide is then forced into the water with great pressure. As long as the tank is closed, the gas remains dissolved in the water. If the valve is opened, the gas escapes with violence, bringing with it a little water in the form of a spray.

There are many manufactured liquids, called by the names of celebrated medicinal springs, which contain carbon dioxide. Minerals are dissolved in the water and then carbon dioxide is added. The waters are much more agreeable to the taste after they are "charged" with the gas. Such waters are called "carbonated" and are close imitations of natural waters.

A great number of "soft drinks" owe their effervescence to compressed carbon dioxide.

103. Diffusion. — Gases are soluble in other gases. This dissolving of one gas in another is usually spoken of as mixing or **diffusion**. If ammonia gas escapes from a bottle of ammonia solution or from ammonia smelling salts, its odor is soon evident to a person some distance away. The gas has been dissolved in the air and has spread quickly. Some gases diffuse more rapidly than others; diffusion is assisted by movement of the air.

Diffusion of gases, and also of liquids, occurs even when they are separated by a thin membrane of plant or animal tissue. Diffusion through a membrane is called **osmosis**. It plays a very important part in the distribution of gases and liquids in living bodies. Oxygen from the air we inhale passes, by osmosis, through the membranes of the lungs into the blood vessels, to be carried to all parts of the body.

104. The Pressure of the Air. — The atmosphere, which envelops the whole earth and moves with it as it rotates, is held in place, like other movable bodies, by

gravity. The pressure of the air due to its weight is nearly fifteen pounds on a square inch of surface at sea level. This means that the column of air directly above this square inch of surface would weigh about fifteen pounds.

As one rises to higher levels and leaves some of the air beneath, the pressure becomes less. One of the ways of

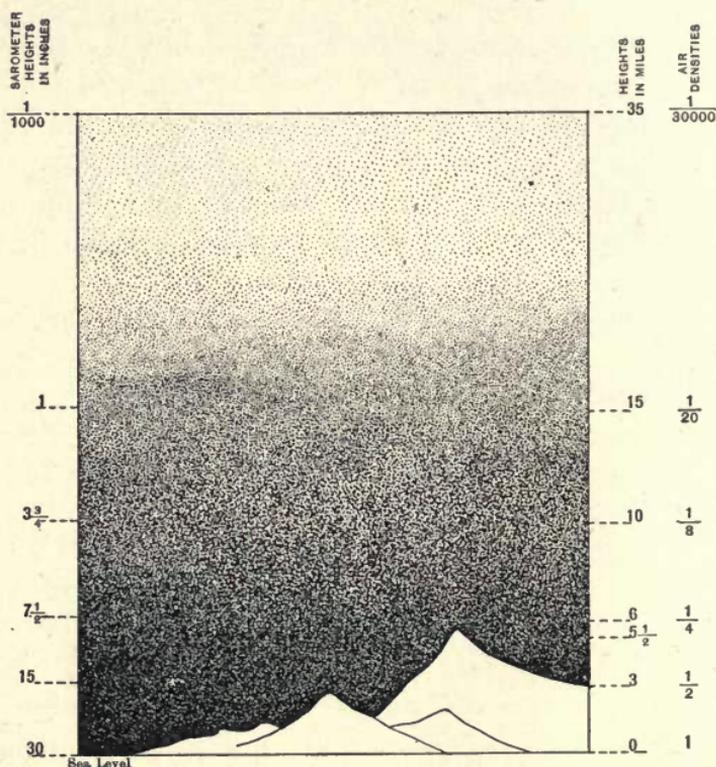


FIG. 44. — DENSITY OF THE AIR AT DIFFERENT ELEVATIONS

1. What is the reason that the air is more dense at sea level than at high elevations? 2. What is the density of the air at the highest mountain known (about $5\frac{1}{2}$ mi. high)? 3. Why would the mercury stand at 1 in. at a height of 15 mi.?

determining the altitude of a mountain is by measuring the pressure of the atmosphere. Scientists estimate that there is some atmosphere at a height of two hundred miles, but

at that height it exerts very little pressure. About half the weight of all the air is within three miles of the earth. This is because the lower part of the atmosphere, having the weight of all the upper air resting upon it, is compressed and therefore has greater density.

105. The Barometer. —

An instrument for measuring the pressure of the air is called a **barometer**. In a simple form, it consists of a glass tube about three feet long closed at one end; the tube contains mercury and stands inverted in a cup of mercury. The mercury in the tube stands at the height of about thirty inches above the level of the mercury in the cup.

As the tube is open at the bottom, the mercury is free to leave it, but does not do so because the air is pressing down upon the mercury in the cup. The pressure is transmitted through the liquid both horizontally and upwards, and thus the downward pressure of the air holds the column of mercury in the tube.

We know that the weight of thirty inches of mercury in a tube one square inch in area is nearly fifteen pounds. The

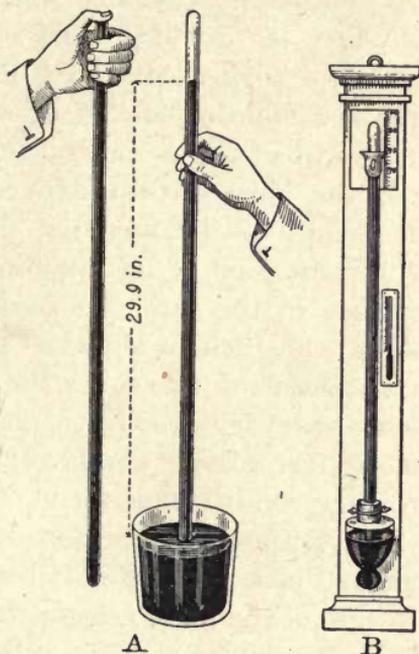


FIG. 45. — TORRICELLI'S EXPERIMENT

In 1643 an Italian named Torricelli observed, in using apparatus like this, that mercury would remain in a closed tube to the height of 30 in. if the tube were inverted with the open end in mercury. 1. He discovered the reason. What is it? 2. Why will the mercury remain at the height of only 30 in.? 3. Suppose that both ends were open; why would the mercury not remain in the tube?

downward pressure of the air which supports this column of mercury must be equal to the weight of the column — that is, nearly fifteen pounds on a square inch.

A complete barometer, which is to be carried from place to place, is provided with a metal case to protect the glass and to keep the tube upright. At the back of the tube is a scale of inches, or centimeters, by which to read the height of the mercury column.

At sea level the world over, under ordinary conditions, the height of the mercury in the tube of a barometer is 29.9 inches, or 76 centimeters, above the surface of the mercury in the cup. In ascending to higher elevations, a fall of one inch is observed during the first 900 feet, but in an ascent of two miles the fall of mercury averages one inch for every 1,000 feet of ascent. Leadville, Col., is 10,600 feet above sea level; its barometer reading under ordinary conditions is about 20 inches.

106. Differences in Air Pressure. — If at sea level the mercury in a barometer is higher than 76 centimeters, the pressure of the air is greater than under ordinary conditions. If the barometer reading is lower than 76 centimeters, the pressure is below the normal. These differences in air pressure are due to one, or both, of two causes: variation in the amount of water vapor in the air, and variation in the temperature. To illustrate: if the temperatures are the same, a cubic foot of dry air has a greater density, and therefore a greater pressure, than a cubic foot of moist air. If the moisture is the same, a cubic foot of cold air has a greater density, and therefore a greater pressure, than a cubic foot of warm air. These two conditions may counteract each other or they may tend to produce the same effect on the barometer, sending the mercury up or down.

107. Pressure upon our Bodies. — We are not conscious of the weight of the atmosphere because there is equal pressure on all sides of the body. We are not crushed by this

pressure because of the elasticity of the fluids of the body, which exert a similar outward pressure. When travelers rapidly ascend mountains of great height, or airmen reach high levels in the air, blood sometimes bursts through the thin membranes of the nose and eyes. This is because the pressure outside the body has diminished while the

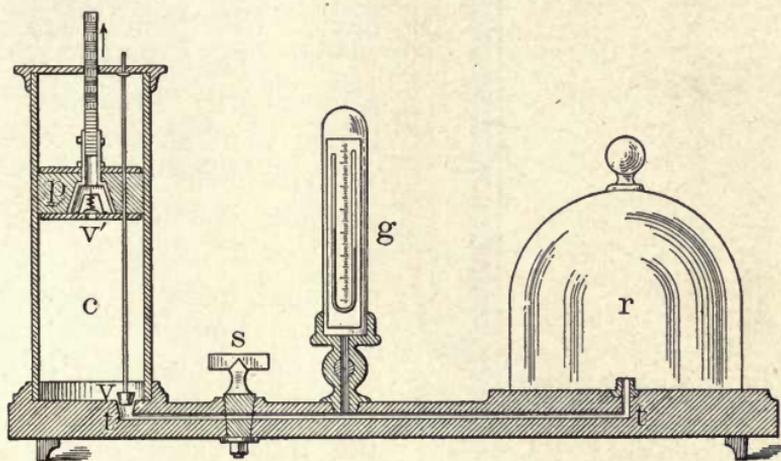


FIG. 46. — AN AIR PUMP

A receiver (*r*) fits closely upon a metal plate. A tube (*t*) connects the space in the receiver with the cylinder of the pump. When the piston (*p*) is lifted, the space *c* is enlarged and air moves into it from *r*, equalizing the pressure. When the piston goes down, *V* closes and *V'* opens and allows air to pass through. A part of the air originally in the receiver is removed. A gauge (*g*) connected with *t* shows that the pressure in the receiver is now less than normal. 1. If one half of the air of the receiver is removed by one double stroke of the piston, how much of the original amount will be left after two such strokes? 2. How much after four strokes?

internal pressure has not had time to change during the rapid ascent.

108. The Air Pump. — The air pump is a machine for taking air out of a closed space, in somewhat the same way that water is pumped from a well. An inverted jar, called the *receiver*, is placed upon a brass plate, which has an opening into a tube connected with the cylinder of the pump. The receiver fits the plate air-tight, and at each

stroke of the piston a portion of the air in the receiver is removed.

A space from which all air has been removed is a **vacuum**. With an air pump it is impossible to produce a *perfect*

vacuum, but from experiments with a partial vacuum much can be learned about the behavior of the atmosphere.

109. The Direction of Atmospheric Pressure. — It is easy to understand, without an experiment, that air exerts pressure downward, because all matter has weight. The air pump makes it possible to show that air also exerts pressure upward and in a horizontal direction. Suppose that a thin sheet of rubber is tied closely over the mouth of a bottle filled with air. The molecules of air in the bottle are in the same rapid motion as those outside, and the rubber remains flat, because the pressure above and below it is the same.

If now the bottle is placed under the receiver of an air pump, and some of the air is removed from around the bottle, the rubber bulges upward. The air in the bottle is pressing in every direction, but the rubber is the only

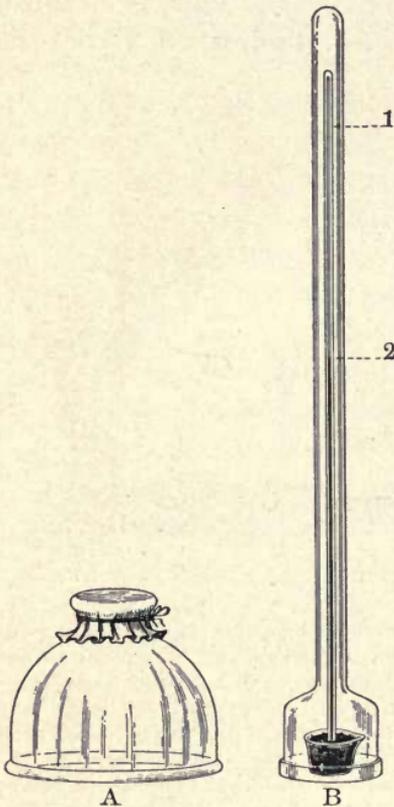


FIG. 47.—APPARATUS TO BE USED WITH AN AIR PUMP

1. The glass dish *A* is placed on the plate of an air pump and one double stroke of the piston is made. What is the effect on the rubber cover? Why?
2. What is the effect of continued pumping?
3. If *B* is placed on the plate while the mercury is at 1, and the pump is worked, the mercury falls to 2 in the tube. Explain its position at 1, and at 2.

part that can show the pressure. When air is allowed to go back into the receiver, the rubber becomes flat again. If the bottle is placed in a horizontal position and the experiment is repeated, the rubber bulges out in a horizontal direction.

The laws of pressure in gases are similar to those in regard to liquids.

110. Relation between the Pressure and the Volume of a Gas. — Gases are very compressible and highly elastic. If pressure is applied to compress a gas into a smaller volume and is then removed, the gas returns to its original volume. As it expands, the gas may be made to do work, by pushing back the body that compressed it. Air guns, air springs for closing doors, air brakes, and other devices make use of the energy of compressed air.

When a gas has been compressed into half the space it originally occupied,

it exerts twice as great pressure as before compression. This relation between the volume and the pressure of a confined gas continues as long as the substance remains a gas. Under a very great compressing force at low temperature, gases — even air — become liquids.

Steam at high temperature in a confined space exerts hundreds of pounds of pressure to the square inch. This pressure does an immense amount of useful work if properly controlled

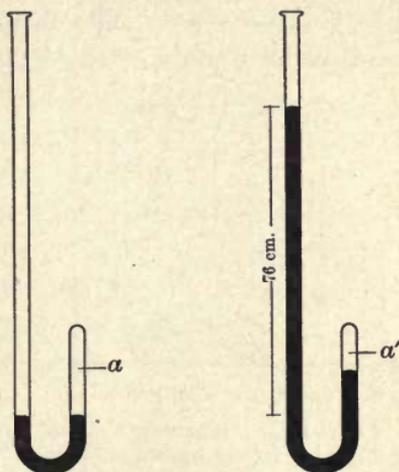


FIG. 48. — RELATION BETWEEN PRESSURE AND VOLUME OF GASES

1. What is the pressure upon the mercury in the long arm of the left tube?
2. What shows that the downward pressure of the gas in the space *a* is equal to the downward pressure in the long arm of the tube?
3. How great is the downward pressure in the long arm of the second tube?
4. Why has the volume of the gas in *a'* decreased?
5. How much pressure does the gas in *a'* now exert?

and directed, and great destructive work otherwise. When the steam boiler in a factory bursts, parts of the boiler are sometimes thrown against the walls of the building, knocking down the walls and often causing loss of life.

In the process of "charging" the steel cylinder from which the tank of a soda fountain is filled, a very great amount of

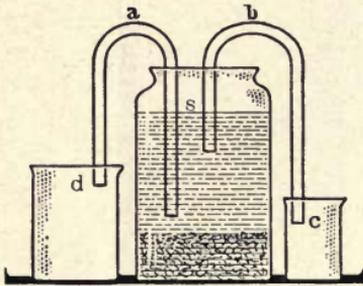


FIG. 49. — SIPHONS

The figure represents a jar of liquid with sediment in the bottom and two siphons. The short arm of *b* is the vertical distance *sb*. The long arm of *b* is the vertical distance *bc*. 1. Which is the short arm of *a*? 2. What is its length? 3. Under what condition will the liquid stop flowing through *b*? 4. Through *a*? 5. Which siphon will remove more water? 6. Why is *b* the better one to use in this case?

flexible material. It is used to carry liquids from a higher to a lower level over an elevation, as in transferring from one tank or barrel to another. One advantage in its use is that sediment in the bottom of the tank need not be disturbed during the removal of the liquid.

To set a liquid flowing through a siphon, the air must first be removed from the tube. To do this, fill the tube with the liquid or with water, then cover both ends and invert the tube. Place the shorter arm in the liquid to be transferred and the long arm over the vessel which is to receive the

compressed carbon dioxide is forced into it. A cylinder that holds five gallons at ordinary pressure may have forty gallons of gas forced into it. This makes a pressure of one hundred and twenty pounds on each square inch of the inside of the cylinder, while on the outside the pressure of the air is only fifteen pounds. If there is a defect in the metal, this tremendous inside pressure may cause an explosion of the cylinder.

111. The Siphon.—A siphon is a tube in the shape of an inverted U but with unequal arms. It may be made of glass or of rubber or some other

liquid. The end of the long arm must be lower than the surface of the liquid that is to be moved. When the ends of the siphon are uncovered, liquid falls from the long arm. This would tend to cause a vacuum above, but the pressure of air upon the surface of the liquid causes it to rise in the short arm, as soon as the pressure is lessened at the other end. The flow continues until the liquid reaches the same level on both sides, or until the surface of the liquid is as low as the end of the short arm of the siphon.

112. Pumps. — We are all familiar with the operation of taking lemonade through a straw. We say we “suck it up.” What we do is to draw the air from the tube, creating there a partial vacuum. (An old saying is that “Nature abhors a vacuum.” This means that in natural conditions a vacuum does not exist.) Just as soon as the pressure is diminished in the tube, the pressure of air upon the liquid pushes it up through the tube to the mouth. If air is allowed to come into the top of the tube for an instant, the liquid falls back into the glass.

This method of drawing lemonade from a glass is similar to the method used in drawing water from a well by a pump which is sometimes called the **suction pump**. This consists of a pipe of metal or wood placed upright, with the lower end near

the bottom of the well. A piston works up and down in the upper and larger part of the pipe (called the cylinder), fitting it water-tight. An opening through the piston is closed by a hinged cover, (called a valve) which opens upward. There is also a valve opening upward in the pipe below the piston.

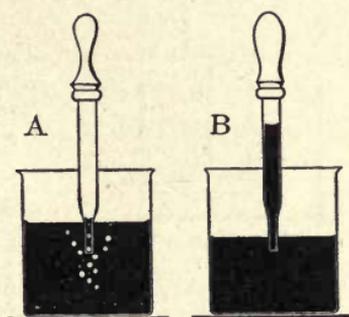


FIG. 50. — A PEN FILLER

1. Compare the situation in A with the first step in the process of sucking liquid through a straw.
2. Compare B with the next step.
3. Under what conditions would ink rise to the top of the tube?

By means of a handle attached to the piston rod, the piston is raised and lowered. As the piston goes down, the air in the cylinder pushes up through the valve in the piston, while the valve in the pipe below remains closed by its own weight. Conditions in the cylinder are now just as at first, except that the piston is as far down as the length of its rod allows. There is air above and below the piston.

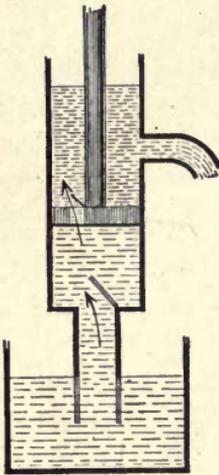


FIG. 51.—THE LIFT PUMP

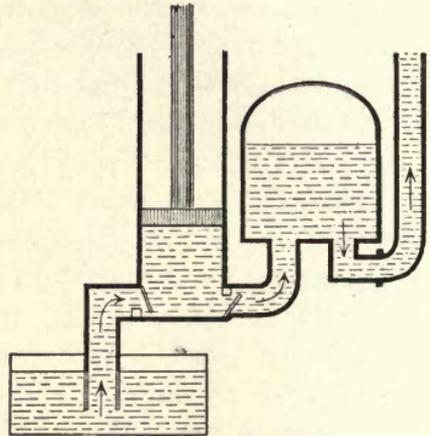


FIG. 52.—THE FORCE PUMP

FIG. 51.— This diagram shows the essential parts of a common lift pump. 1. What relation must there always be between the area of the piston and the cylinder? 2. In what direction does the piston valve open? 3. What opens it on the first downward motion of the piston? 4. Why is 30 ft. the greatest *practicable* distance between the surface of the well and the valve in the pipe?

FIG. 52.— 1. Why is there no valve in the piston of a force pump? 2. Why, if there were no air chamber, would water be delivered in spurts from the side of the cylinder? 3. For what use is a constant stream necessary? 4. In Fig. 52, what shows that the air in the chamber is compressed?

The water in the lower end of the pipe is at the same level as the water in the well.

When the piston is raised, its valve remains closed by its own weight and pressure of the air above. As the piston rises, the air space beneath becomes larger and therefore the pressure of the air within this space is decreased. The air in the pipe below, at the same pressure as that outside,

pushes open the valve and enters the cylinder. The pressure on the *water* in the pipe is thus decreased, and water is pushed farther up in the pipe, by the air pressure on the surface of the water in the well. Atmospheric pressure, which must be depended on to push the water from the well through the pipe into the cylinder, can sustain a column of water about 30 feet high. The distance, therefore, between the surface of the water in the well and the bottom of the cylinder must not be more than 30 feet.

When after several strokes the water has reached the cylinder, if the piston is pushed down, the water presses the valve in the piston open and passes above it. The water is then *lifted* to the outlet, by few or many strokes, according to the length of the cylinder.

The suction pump or, as it is better named, the lift pump is used, not only to raise water from wells and cisterns, but to remove gasoline and kerosene from barrels and tanks, to pump out sea water which has leaked into the hold of a ship, to pump river and lake water for use in factories, and for many other similar purposes.

113. The Force Pump. — There are two important differences between a lift pump and a force pump. The force pump has no valve in the piston, and it has an opening near the bottom of the cylinder, into a tube, out of which the water is forced to levels much higher than the pump. Water is raised from a cistern or well to the bottom of the cylinder by atmospheric pressure, just as it is in the lift pump. It is then forced out of the exit tube by pressure of the solid piston in its down stroke. The water is thus sent out in a spurt, through the exit tube, with every stroke of the piston.

In order to furnish a steady stream and to avoid successive shocks to the pipe, the force pump of a fire engine is provided with an air chamber through which the water passes from the cylinder. Here the water compresses the

air, as it enters the chamber faster than it can go out. While the piston is lifted for another stroke, the elastic air expands and forces out the remaining water, thus giving a moderately steady stream.

In parts of the country where there are no elevated regions, many towns and cities have their water supply in lakes or rivers lower than some sections of the town. Such places have a pumping station where machine-power pumps work constantly to fill elevated reservoirs or stand-pipes and privately owned tanks. From these the water is delivered under pressure to buildings and fire hydrants. Both lift pumps and force pumps may be worked by wind-mills or gas engines.

EXERCISES

1. Explain the difficulty of filling an "empty" bottle held in a stream of water.
2. Why is a bottle still full of air when some of it has been removed?
3. Why is there physical discomfort at high elevations?
4. In an inverted closed tube, water is supported by atmospheric pressure to a height of 34 ft.; mercury, to a height of 30 in. Why is the mercury column shorter? What is the relation of the density of mercury to that of water, as shown by this fact?
5. A vertical open tube 40 in. long is placed with its lower end in a cup of mercury, and its upper end is connected with an air pump. If some of the air is removed from the tube, what will happen? Give the reason.
6. What adjective is commonly applied to air under more than ordinary pressure? How is it used?
7. A mass of gas under ordinary atmospheric pressure occupies 3,000 cu. cm. How many cubic centimeters will there be, if the pressure is doubled? If halved?
8. Will a balloon filled with gas expand or contract as it rises?
9. Explain how the height of a mountain can be calculated from barometric readings.
10. How many meters high is a mountain, if the barometric readings at the same time at top and bottom are 564 mm. and 754 mm. respectively? (A fall of 1 mm. corresponds to an ascent of 12 m.)
11. If the mercury in a barometer stands at 76 cm. at sea level, what would be the length of a column at an elevation of 3 miles?

CHAPTER VIII

WEATHER; WINDS AND STORMS; CLIMATE

114. Variations in the Composition of the Atmosphere.

The only way in which the *composition* of the air varies is in the amount of water vapor it contains. The air contains nitrogen, oxygen, and carbon dioxide in practically the *same* proportion everywhere and all the time. Water vapor is present in *varying* quantities, according to the location. The air is never without water vapor even in deserts.

It is therefore more correct to speak of the **humidity** — that is, moisture — than of the dryness of the air. The air is said to be **saturated** when, at a given temperature, there is as much vapor in the air as it can hold *at that temperature*. The higher the temperature, the more vapor the air is able to hold. If the air contains $\frac{6}{10}$ as much vapor as would saturate it, its condition is expressed as **relative humidity** 60 per cent, which means that it contains 60 per cent as much vapor as there could be at that temperature.

When the relative humidity is high, if the air is cooled, a part of the vapor is condensed and rain falls, or dew is deposited. Blades of grass cool earlier in the evening than stones or earth; therefore the vapor is condensed upon the grass first. Dew is often seen on the outside of a pitcher of ice water. The cold pitcher cools the surrounding air to the temperature at which dew is deposited — the **dew point**. This is not a uniform temperature like the freezing point, but varies with the relative humidity.

Change in relative humidity and change in temperature are the two principal causes of change in the pressure of the atmosphere. Cold, dry air is of the greatest density and

therefore highest pressure. Warm, saturated air is of the least density and lowest pressure.

115. Weather. — The condition of the atmosphere as regards temperature, humidity, and motion determines the **weather**. “Cold, dry, and windy” may describe the weather of one day. “Warm, moist, and still” would describe the other extreme. (LABORATORY MANUAL, Exercise XII.)

116. The Weather Bureau. — The conditions of temperature and wind are of such great importance to farming and navigation that the United States government has es-

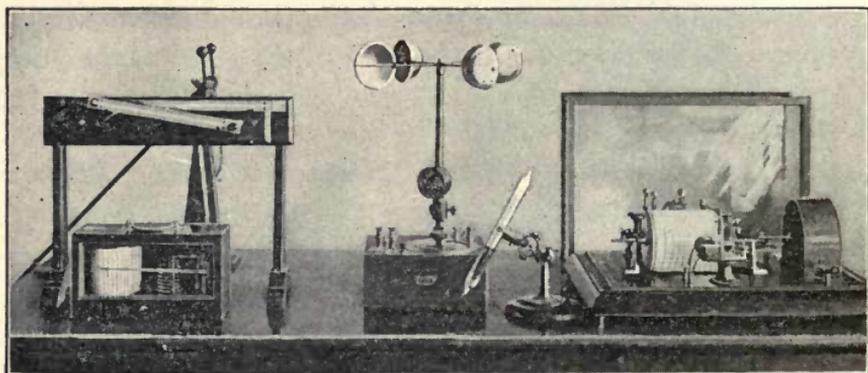


FIG. 53. — INSTRUMENTS USED BY THE UNITED STATES WEATHER BUREAU

At the left are self-registering thermometers, which show the maximum and minimum temperatures since they were last adjusted. Below is a *thermograph*, which records, by a pen upon a slowly revolving paper cylinder, the changes in temperature during 24 hours.

In the center is an *anemometer* to measure the velocity of the wind. The cups are exposed in an elevated place and their revolutions, as they catch the wind, are recorded by a mechanism similar to that of a gas meter.

At the right is a self-registering barometer, a *barograph*.

Which one of these instruments would give practically the same record in the house as out of doors? Why?

tablished a Weather Bureau as a division of the Department of Agriculture. A central office at Washington receives, three times a day, reports of the weather from more than a hundred stations scattered over the country. These reports include the degree of cloudiness, direction and

rate of the wind, humidity, amount of rainfall, and the readings of thermometer and barometer. Men of experience interpret the reports and make up forecasts of the weather for the next twenty-four hours or more. By long study it has been learned that weather conditions follow certain rules and move in regular paths across the country. Consequently, from the conditions of the atmosphere to-day experts can predict what will probably result to-morrow.

The forecasts of the Weather Bureau are telegraphed to all sections of the United States and are reported by daily papers and by weather maps and cards posted in public places. The advantages in making use of such information can scarcely be estimated. Farmers and sailors, especially, may take precautions which greatly reduce the dangers from a sudden fall in temperature or from high winds. For instance, if a frost is predicted, a farmer may often save the delicate buds on his young fruit trees by the use of small kerosene heaters placed at frequent intervals in his orchard. A few dollars' worth of kerosene may thus save thousands of dollars' worth of fruit. Masters of sailing vessels, too, may often escape danger to life and property by remaining in port when storms have been predicted.

117. Weather Records. — The records of the Weather Bureau extend over only about fifty years, but in that short time statistics of great importance have been secured. Many people have records of the weather in their own locality for a longer period. Observations that were recorded at the time they were made are the only reliable information as to weather in the past.

From such records it is possible to learn the average amount of rainfall and the average number of days of sunshine for ten or twenty years. This *average* gives a standard by which to judge the weather of any particular year. By such standards only can it be determined whether a season was a "remarkably hot summer" or a "very rainy

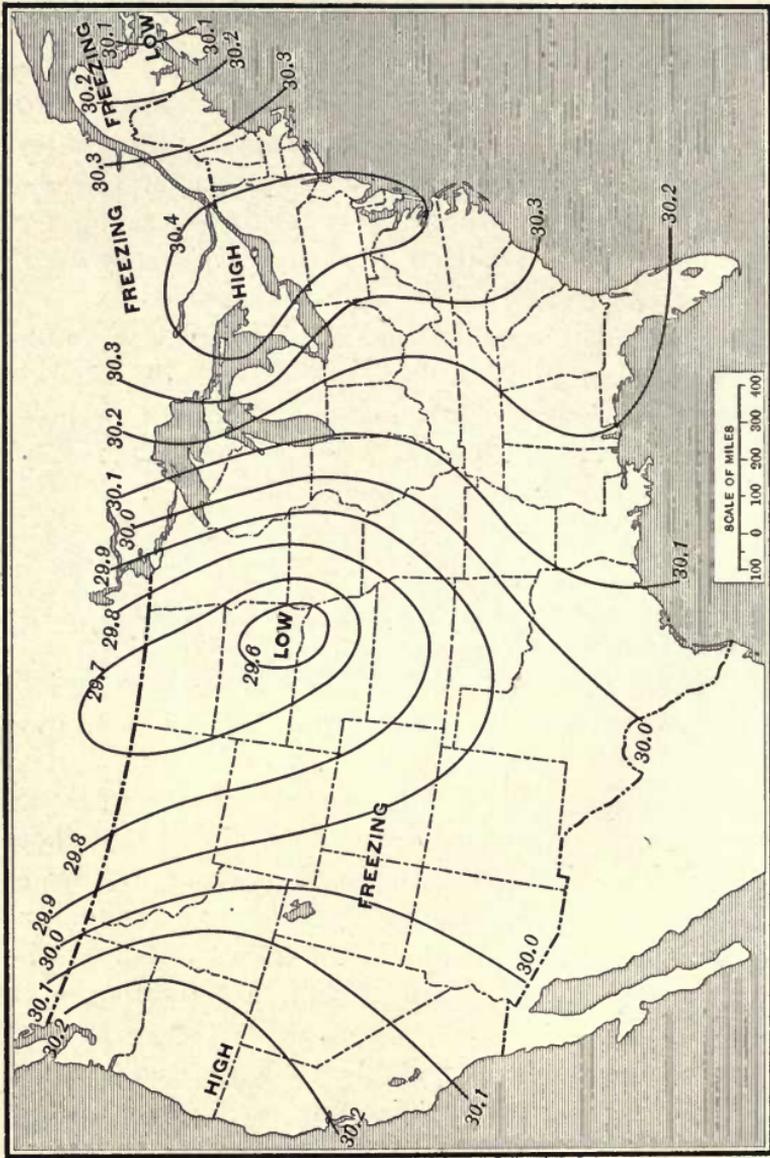


FIG. 54 (1). — WEATHER MAP, APRIL 24. 1. What state has the lowest barometer reading? 2. What other conditions of the atmosphere probably prevail there? 3. Are these conditions usually the cause or the effect of low pressure?

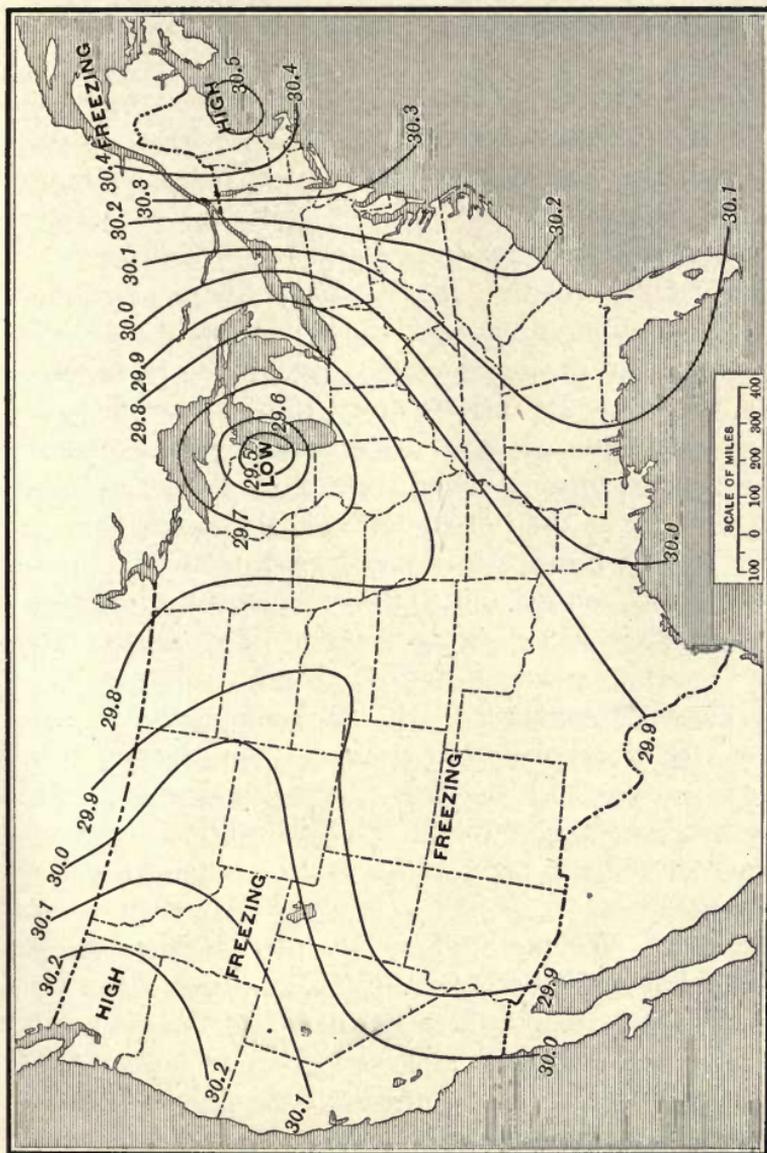


FIG. 54 (II). — WEATHER MAP, APRIL 25. 1. What differences do you notice in the location, form, and extent of the "low" studied on map 1? 2. What other changes do you notice? 3. How do these maps explain the remark, "We have to-day the weather of yesterday at Chicago" (or some other region)?

spring." Our memories of the weather often mislead us, for the impression made upon our minds by one hot week or many days of rain is likely to be recalled as describing a whole season.

118. Wind. — Wind is air in motion. Its strength is designated by different expressions, such as light or stiff breeze, if the velocity is from two to ten miles an hour; strong wind, twenty to thirty miles; gale, forty to sixty miles; and tornado, one hundred to two hundred miles.

All winds result from the same condition, though the condition may have different causes. This one condition is the difference in pressure of the atmosphere over adjacent regions.

Just as water always moves down hill in obedience to gravity, so air moves out from a region of high pressure to one of lower pressure. If over New York State and the Province of Ontario the barometer indicates a pressure of 30.2 inches (or 768 mm.), while over New England the pressure is 29.7 inches (or 755 mm.), the air moves toward New England and it is called a west wind. The greater the difference in pressure, the stronger the wind.

119. Cyclonic Movements. — If the low-pressure area is surrounded by areas of higher pressure, the air moves in from all directions, and the currents, as they meet, unite in an upward whirling motion. This is called a cyclone. It may vary in violence from a dust whirl in the street to a destructive gale.

120. Constant Winds. — There are certain parts of the world where winds blow all the time in the same direction. The air in the equatorial belt is warmer than the air north or south of it and contains much vapor, on account of the great extent of ocean there. For these reasons, air in this belt is lighter than the air outside, and the heavier air pushes its way into the region of lower pressure. This causes constant winds to blow toward the equatorial belt from both north and south.

121. The Belt of Calms. — The heated air within the equatorial belt rises slowly and its vapor condenses in the cooler, upper layers of air. Consequently there are frequent rains, but not much wind, as there is very little horizontal motion of the air. Because of this condition, the region is named the belt of calms.

During the year the belt of calms shifts its position north and south across the torrid zone, according as the positions of the sun and of the region of greatest heat change. The rainy season in the torrid zone changes according to the movements of the belt of calms. It comes in the northern half of this zone during the northern summer and in the southern half during our winter.

122. The Trade Winds. — If the earth were stationary, the air moving into the equatorial belt would give rise to constant north winds blowing north of the equator, and south winds on the other side. The great velocity of rotation at the equator, however, gives the constant winds a northeast and southeast direction. This is explained by the fact that, owing to the greater circumference at the equator, the rotation of any equatorial point is faster than that of any point north or south of the equator. Hence the wind that moves toward the equator does not reach the point toward which it started, but a point farther west. As a result, the wind in the northern half of the torrid zone seems to come from the northeast, and in the southern half from the southeast.

These constant northeast and southeast winds are called trade winds because of their help to navigation and to trade.

123. Storms. — Though the term *storm* is usually applied only to rain or snowfall, any marked disturbance of the atmosphere is, properly, a storm. A storm occurs when there is a great difference of pressure over different regions, and the air moves *rapidly* from the high-pressure area to the re-

gion of lower pressure. This disturbance of the atmosphere is often accompanied by a precipitation of rain or snow. As the rain inconveniences us more than does the wind, we often make the mistake of thinking that the precipitation alone constitutes the storm.

If an atmospheric disturbance prevails over a large area, the storm is said to be general. Such storms are cyclonic



FIG. 55. — AFTER A TORNADO, OMAHA, NEBRASKA

That the wind had a whirling instead of a direct motion is shown by the position of the beams of this house with respect to the foundation. The house was lifted away from its foundation and turned, before it dropped back.

storms. As the whirl moves, the wind may change in direction and velocity and the amount of precipitation may vary at different places, but the same general conditions continue for hours or even days and then pass away. In the eastern part of the United States cyclonic storms travel generally in a northeast direction. Reports to the Weather

Bureau, for instance, may show that the atmospheric disturbance occurs first, perhaps, in the lower Mississippi Valley, then in the Ohio Valley, then in New York State, and finally in New England. It is not so easy to trace the course of storms in the western part of the country. The great variations in altitude in that region cause irregularities in pressure which modify the course of the storms. Their general direction is easterly.

The study of storms requires a thorough understanding of barometric conditions and humidity, as well as the relative position of mountains, plains, and oceans. It is, therefore, beyond the range of an elementary course in science. But careful observation of changes in the weather leads, in time, to a good judgment in regard to local probabilities, so that one may learn to forecast the weather with considerable accuracy, without understanding the laws that govern the changes.

124. Tropical Storms. — Violent storms called hurricanes sometimes start near the Gulf of Mexico and travel northward along the Atlantic coast. These storms are greatly feared because of damage to shipping. When the Weather Bureau receives information of such storms, it directs that storm signals be displayed, warning shipmasters to remain in port. Much life and property are saved by these warnings.

125. Local Storms. — The term *local storm* usually refers to precipitation which occurs in a small area and for a short time. Such storms generally follow a change in temperature. After a hot sultry day, as the air rises from the heated surface of the earth, the vapor which it contains may condense rapidly in meeting the higher, cool air. Rain may then fall for a few minutes or perhaps hours.

If the condensation is very rapid, electricity may be developed upon the clouds and flashes of lightning will show its passage through the air. The thunder which follows has the same cause as the sound which results from tearing a

piece of paper; viz., the vibration of air particles that have been disturbed.

After a shower, the atmosphere is usually free from clouds, and hence the earth is cooled by rapid radiation of heat. It is cooled also by the evaporation of rain water, for the heat required in evaporation is taken from the surface of the ground. From one or both of these causes, it is often true that "a shower cools the air."

126. Climate. — Climate may be said to be the average of weather for a long series of years. It is not correct to say that the *climate* is much more severe in a given place this year than last year, for it requires many years of observation to determine the climate of a place. It could properly be said that a *winter* was severe or a *season* rainy. A drouth may prevail one year, but the next year conditions may be normal or there may be an excess of rain.

A single word is not sufficient to describe climate. The climate may be hot and dry with certain prevailing winds, or cold and dry with some other winds. It is customary to speak of an island climate, or a coast or inland climate, according to the situation of a place, because various physical conditions have an important effect on climate.

Variations in temperature, rainfall, and wind cause all the differences in climate.

127. Conditions Affecting Temperature. — There are three conditions which determine the temperature of a place. The *first* condition we are accustomed to call "distance from the equator," as if the equator were the source of heat. The source of most of the earth's heat is, of course, the sun, and because of the nearly spherical shape of the earth different latitudes receive different quantities of heat. Where the sun is directly overhead, as it is *somewhere* in the torrid zone all the time, every square mile of the earth receives more heat than an equal area where the rays are slanting. At the tropic of Cancer on June 21, the heat is received ver-

tically, that is, at right angles to the earth's surface. On the same day at the arctic circle heat is received in slanting lines, at about half of a right angle. The same amount of heat spreads over a larger surface when it falls obliquely than when it falls vertically. Therefore any given area at the arctic circle receives less heat than an equal area at the tropic of Cancer.

The *second* condition affecting temperature is altitude, or the elevation of a place above sea level. We use sea level as a convenient uniform basis from which to reckon altitude, even though the place considered may be thousands of miles from the sea.

The farther one rises above the earth, the less heat is found. This is because the earth warms the air. A high mountain, rising above the great mass of the earth, is surrounded by cool layers of air. The mountain receives less heat and likewise gives out less heat to the surrounding air than land on the lower levels of the earth.

The *third* condition affecting the temperature of a place is nearness to a great body of water. The ocean, or any other large body of water, absorbs more heat and warms more slowly than the land at the same temperature. When the ocean, for instance, has become warmed to 80° F., it has absorbed more heat than

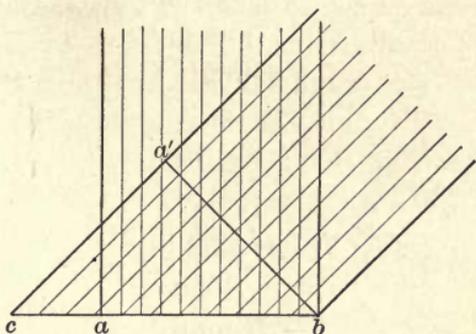


FIG. 56. — VARIATIONS IN THE AMOUNT OF HEAT AT DIFFERENT LATITUDES

If each vertical line represents the same number of rays of heat as each oblique line, then the surface *ab* receives the same amount of heat as *cb*. 1. Compare the amount of heat received on $\frac{1}{4}$ of *ab* with the heat on an equal surface of *cb*. 2. In what month does Cuba receive vertical rays? 3. Name some part of the world upon which rays would fall obliquely (as on *cb*) in the same month. 4. In which case would a square mile of the earth receive more heat?

the land has absorbed at 80°. The water also retains its heat longer than the land.

At the beginning of the warm season, a large body of water remains for some time cooler than the land, and "sea breezes" temper the heat along its shores. At the close of the warm season, on the other hand, the sea or lake cools more slowly than the land. The general effect of a large body of water is to make the climate of coast or island, both summer and winter, less extreme than the climate of the interior at the same latitude. The *difference* between the average winter temperature and the average summer temperature of a coast or island is smaller than the difference in the interior of a continent. The climate of Bermuda or Hawaii, for instance, is much more equable than that of the interior of the United States in the same latitudes. (LABORATORY MANUAL, Exercise XIII.)

This third condition — nearness to the ocean — has an important relation to rainfall, which is another great factor affecting climatic conditions. The amount of rainfall is largely dependent upon the direction of winds, whether coming from an ocean or from an arid region.

Water on the surface of the ocean is constantly changing to vapor and passing into the air. As this vapor-laden air spreads over the continent and meets cooler air, or rises over high lands, the vapor condenses and rain or snow falls. Air from the ocean always carries vapor; the amount varies, inasmuch as cool air absorbs less vapor than warm air. Winds from the desert, on the other hand, contain so little vapor that they bring no rain.

128. Changes in Climate. — Elderly people sometimes remark, "The climate has changed since I was young." The climate is doubtless the same, but the circumstances under which people live and travel have changed so greatly that it is natural that people should think there have been changes of climate.

The history of people who lived in Asia Minor, Greece, and Italy twenty-five hundred years ago shows us that the same native fruits, grains, and trees grew there then as now; that the country people lived in the same kind of dwellings and wore the same amount of clothing as to-day; and that they raised flocks and herds of the same domestic animals as are raised now. It is evident that the climate of that part of the world has not changed materially in over two thousand years. It is not likely, then, that the climate on our continent has changed within a lifetime.

EXERCISES

1. A pitcher of ice water at a temperature of 40° becomes covered with dew on a day when the relative humidity is 75 per cent. Explain why the same effect is not produced with water at 60° .

2. An area in Kansas has, on a given day, a barometric pressure averaging 30.2 in.; another area has a pressure of 29 in. State the direction of air movement between these regions and explain.

3. Two other regions have pressures of 31 and 29 in. respectively. Compare the velocity of wind with that in the case of Ex. 2.

4. Why does sprinkling the streets and sidewalks cool the air?

5. Describe the weather of yesterday.

6. Describe the climate of the state you live in.

7. Name a distant state or country, in about the same latitude as yours, which has a climate differing in any respects from your local climate. Tell what you think is the reason for the difference.

8. In what ways does climate influence people as regards dwellings, food, occupations, and material for clothing?

CHAPTER IX

LIGHT

129. Sources of Light. — People are now living who can remember when candles and whale-oil lamps were the ordinary means of lighting houses and streets. Later kerosene oil and gas came into use, and now electricity is very generally used for lighting streets, public places, and houses. Light from gas, candles, and oil lamps is caused by particles of carbon made red-hot in the flame. The *heat* of the flame is due to combustion of gas and vapors from the heated wax or oil. Thus the origin of the light is the heat of combustion. In the case of an electric lamp, the conductor is heated to a glowing heat or **incandescence** by the resistance which is offered to the current.

Besides combustion and electricity, there is another source of light: friction between two bodies. Here it is resistance to motion which produces heat. Often a small particle of metal or stone is heated to light-giving temperature, as when a spark is struck by a horse's shoe on the pavement. Meteors are made red-hot by the resistance of the air, through which they pass with immense velocity.

130. Intensity of Light. — The rapid vibration of molecules, from whatever cause, produces heat; and if the vibrations are sufficiently rapid, heat causes the body to become incandescent. The brightness or intensity of light increases with the temperature of the luminous body. The cause of the vibrations is not always known. This is the case with the sun and the stars.

In stating the amount of light given from a luminous body, the term **candle power** is used. One candle power is the

light given by a sperm candle burning about 8 grams of wax an hour. A common type of incandescent electric light is the 16-candle-power light, which gives about as much light as 16 standard candles.

131. Vision. — It is often said that we “see light,” but that is not strictly true. The fact is that we see an object which gives light, or we look into a room which is lighted. We see bodies which send light to the eye.

Air, clear water, and glass are the ordinary **mediums** through which light passes. Such substances are called **transparent**. Horn, celluloid, and ground glass are semi-transparent or **translucent**. An **opaque** substance is one through which light does not pass; as brick, wood, and stone.

132. Light, a Form of Energy. — Light, like heat, is a form of energy, for it does work, although the work is not always immediately observed. The change or loss of color called fading, with which all are familiar, is due to light. We know that the exposure of a photographic film to the light for a small fraction of a second, makes the film different in some way. It is possible to produce a picture from it afterward by the application of the proper solutions. The energy of light has rearranged molecules on the film and formed new compounds.

The important work of starch making is carried on in the green leaves of plants only in sunlight. The light energy used in that process is later transformed into heat energy or muscular energy in the animals using the plants as food. *Energy is never lost or destroyed*, though often it is so changed that the ordinary observer does not recognize it.

Light which falls upon a body from any source may be **transmitted**, passed through the body; **reflected**, turned away; or **absorbed**, taken in. Absorption of light raises the temperature of the absorbing body; that is, light energy is transformed into heat. Sunlight is transmitted through

glass without warming it; but if sunlight falls on an opaque surface, part of the light is absorbed and changed into heat.

133. Reflection. — No one expects to see around a corner any more than through a wall. The reason why one cannot do this is because *light travels in straight lines*. This is true of reflected light as well as of light coming directly from its source. A polished surface of metal or glass makes the best reflector of light, but all surfaces reflect a part of the light which falls upon them. It is by this reflection of light that we see bodies that are not themselves luminous.

Vision is partly a process of the mind. We are accustomed to the fact that objects are visible by means of light passing

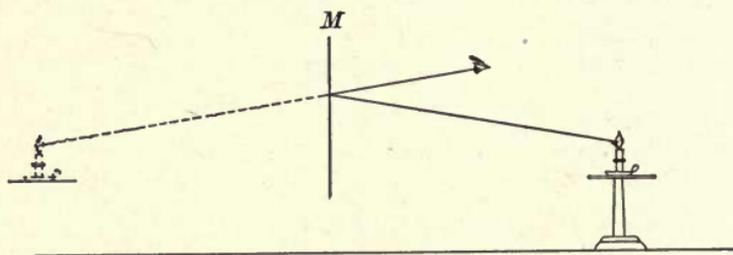


FIG. 57. — A MIRROR

1. Explain how a person, by aid of a mirror, can know what is at one side or back of him. 2. Why does a kitten placed before a mirror try to look behind it? 3. Explain the use made of a mirror in the front of a motor vehicle.

in straight lines to the eye. Therefore we mentally follow the lines back to the place from which they seemed to start. The reflection seen in the mirror seems to come from an object at the mirror or behind it, because the light comes to us from that direction. A mirror is usually so placed that objects behind or at one side of the observer can be seen while he is looking straight ahead. Careful arrangements of mirrors may reflect images of images of objects. One object may have several images if the mirrors are placed parallel, or at an angle to each other. Some

apparently mysterious phenomena which are produced on the theater stage are caused by adjustment of mirrors.

134. Refraction. — Light is **refracted** (that is, bent) in passing *obliquely* from one medium into another, as from air into glass or water. It is this refraction that causes an oar held partly under water to look bent at the place where it leaves the water. Light from the oar blade is bent—and therefore its direction is changed—when it passes from water into air. The light seems to come from a different position.

The apparent change of position of an object caused by refraction can be shown by an experiment. Put a button on the flat bottom of an opaque dish and place yourself in such a position that the top of the dish just conceals the button from view. Pour water into the dish without moving the button or yourself. The button seems to rise into view over the edge of the cup. This is because light from the button which passed above your eye when the dish contained only air, has been bent away from the eye and has entered your eye.

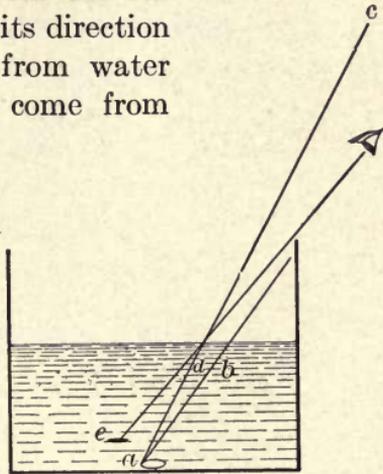


FIG. 58. — REFRACTION CAUSING APPARENT CHANGE OF POSITION

1. Why could not the eye receive light from the coin *a* if the basin were empty? 2. *Ab* and *ac* show the direction of two rays of light from one edge of the coin. The direction of *ac* is changed just above the point *d*. Why does light seem to have come from *e*? 3. Through what mediums does light pass from the coin to the eye?

direction in which it started

135. Refracting Bodies. — Prisms and lenses are transparent bodies which refract light. A prism has three or more flat surfaces. If light passes obliquely through any one of the surfaces of a prism, two effects may be produced

The light may be bent from the direction in which it enters; and it may be separated into the rainbow colors of which white light is composed. An object seen through a prism held horizontally seems to be above or below its real place, and the image is fringed with a band of colors.

Raindrops act like prisms in separating sunlight into rainbow colors, and the colored light reflected to the observer from many drops at once, makes a rainbow. The rainbow is always seen in the part of the sky opposite the sun.

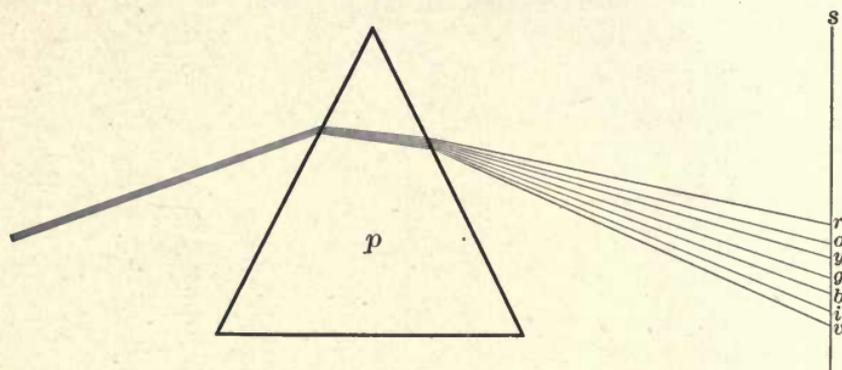


FIG. 59. — A PRISM

Glass prisms used in the study of light have generally three faces. 1. If a beam of light falls perpendicularly upon one face, it will not be bent on entering the prism; why will it be bent on leaving the other side? 2. In Fig. 59 the beam enters obliquely, is bent, passes out obliquely, and is bent again. How many changes of medium are there? 3. What happens to the rays composing the beam, besides change of direction? (The names of the colors are violet, indigo, blue, green, yellow, orange, red.)

A lens is a transparent body having two curved surfaces or one curved and one plane. If a surface is like the inside of a hollow sphere it is a *concave* surface; if like the outside, it is a *convex* surface. When the surfaces are so combined that the lens is thinner at the middle than at the edges, it is a concave lens; if the lens is thicker at the middle than at the edges, it is a convex lens. A convex lens can be used as a magnifying glass. When it is held a short distance from the object examined, the eye of the observer receives light from

an image apparently larger than the object. Combinations of lenses are used in telescopes, opera glasses, and compound microscopes.

136. The Eye and the Camera. — The photographic camera is constructed upon the same principle as the eye. Light is admitted to the camera through a small opening; it enters the eye through a similar opening called the pupil. In both the camera and the eye, the light then passes through a convex lens into a dark space and there the light produces an image. In the camera, the image is formed upon a plate or a film coated with a sensitive substance upon which light energy causes a chemical change. In the eye, the image is

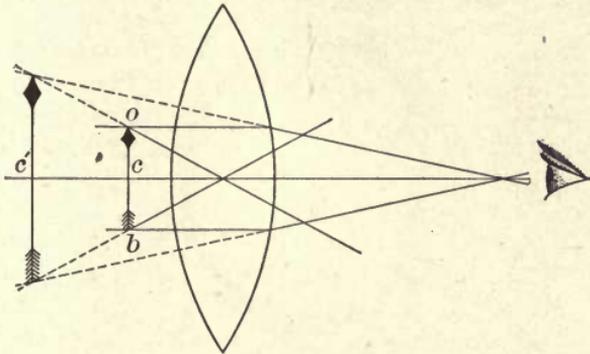


FIG. 60. — A MAGNIFYING GLASS

1. Follow three parallel rays of light *o*, *c*, *b*, from the small arrow through the lens; how is their relation changed after leaving the lens? 2. They pass into the eye and fall upon the retina; where do they seem to come from? 3. What is the difference in appearance between the object and the image?

formed upon the **retina**, which is a membrane upon which the ends of the fibers of the nerve of sight are spread out.

By means of further chemical change which takes place outside of the camera, the image on the film is developed and is made permanent. From the eye, the nerve of sight transmits to the brain the effect of the light energy and we are conscious of an image; we "see" the object.

137. Eye Glasses.— Defects of vision, such as near-sightedness, farsightedness, or unlike vision of the two eyes, can generally be remedied by the use of spectacles or eye

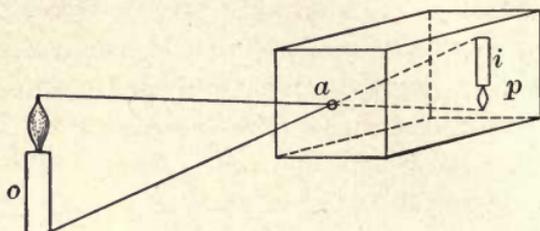


FIG. 61. — A CAMERA

o is a candle from which two rays of light are represented. *a* is the opening in front of the lens of a camera. *p* is a plate or film. *i* is the image upon the plate. Why is the image inverted?

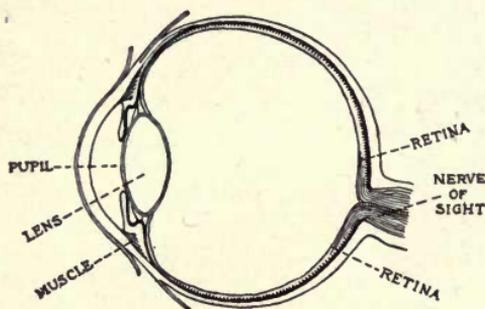


FIG. 62. — THE EYE

In Fig. 62 the *pupil* is the opening through which light enters the eye; the *lens* bends the rays of light and brings them together near the *retina*, where the image is made. The muscles change the shape of the lens as the distance of objects varies: other muscles make the pupil larger or smaller according to the brightness of light. 1. Comparing Fig. 62 with the camera (Fig. 61), tell why the image formed upon the retina is inverted? 2. Why does it not seem so to us?

glasses, which are often lenses, sometimes convex and sometimes concave. These, in combination with the lens of the eye, bring the image in the right position with regard to the retina. Without these external lenses, eye strain may be caused by the effort of the muscles to change the shape of the lens constantly. These muscles in the eye are adapted only for occasional use, as when we look from a

distant object to one near at hand. They readjust the lens of the eye according to the distance of the objects viewed.

One should consult a trained oculist before wearing glasses. There is great danger of serious injury to the sight in using glasses which are not suited to the eye. Glasses which one person has found in every way beneficial may be quite the reverse for another. Traveling peddlers of eye glasses should not be patronized any more than street venders of medicines which "cure everything."

EXERCISES

1. What heavenly bodies are sources of light?
2. What heavenly bodies shine by reflected light?
3. Is the earth a source of light?
4. Light travels through space with a velocity of 186,000 miles per second. How many times would it pass around the earth in one second?
5. Why, considering the statement in Ex. 4, do we use "instantaneous" in speaking of the passage of light from one place to another on the earth?
6. Arrange the names of twelve substances in tables headed *transparent*, *translucent*, *opaque*.
7. What weather conditions are necessary in order that we may see a rainbow?
8. What is your position with relation to the sun when you see a rainbow? Why must it be so?
9. If a rainbow is visible at 5 p. m., in what part of the sky must it be? Why?
10. What important differences are there in the operation of the camera and the eye?

CHAPTER X

ELECTRICITY AND MAGNETISM

138. Frictional Electricity. — Twenty-five hundred years ago a Greek discovered by experiment that if a piece of amber is rubbed with wool or fur, it will attract very light bodies, such as bits of dry paper, lint, or pith. These light bodies cling to the surface of the amber for a time and then fly off as if repelled by it. Similar effects can be produced by rubbing a piece of sealing wax or hard rubber with fur, or by rubbing glass with silk. The rubber, glass, or similar body is said to be charged with electricity by the friction. The bits of paper or pith by contact become charged with the same form of electricity as the rubber or the glass, and they are then repelled.

139. Positive and Negative Charges. — The electricity upon the surface of glass is called positive electricity; that upon rubber is called negative. The body causing the friction receives an opposite charge at the same time. The silk, causing friction on the glass, received a negative charge; and the fur, rubbed on wax or rubber, received a positive charge. A body which is positively charged is attracted by one negatively charged and repelled by one positively charged.

A ball made of pith suspended at the end of a silk thread shows very well the behavior of a charged body. If an electrified glass rod is brought to the ball, the ball flies to the glass and clings to it for a time. But the ball receives from the glass a positive charge of electricity. Then it jumps away, and instead of hanging vertically, seems pushed away from the glass by an invisible agent. A second ball,

treated like the first and brought near it, is repelled by the first. But if one ball is charged from the glass and one from wax, they attract instead of repel each other. The silk thread prevents the electricity from passing off, so that the balls remain charged for a long time if the air is dry.

140. Conductors and Insulators. — If, after an object is charged with electricity, the hand is drawn over its surface, the electricity disappears. It has been conducted away through the hand and the body to the earth. We call the human body a **conductor** of electricity. Many of the metals are much better conductors. Moist air and damp wood are also conductors, but not such good ones as metals. Hard rubber, glass, dry wood, dry air, porcelain, and sealing wax are non-conductors or **insulators**.

Frictional electricity is also called **statical** electricity, from a Latin word which means "to stay." This electricity remains for a long time upon the surface of insulated bodies.

Machines have been constructed that will produce very strong charges of statical electricity. Some electrical machines will cause a spark to pass through several feet of air. Statical electricity is used by physicians in electrical treatment of diseases and in X-ray work. It was useful in the study which led to the developments of wireless telegraphy.

141. Lightning and Thunder. — If a sufficiently large charge of electricity accumulates upon an insulated conductor

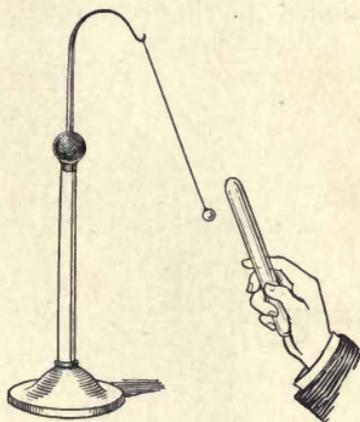


FIG. 63. — An ELECTRIFIED PITH BALL

1. The pith ball is attached to a metal frame by a silk thread; why not by a wire?
2. The glass rod has been rubbed with silk; how does it affect the ball?
3. How does the position of the thread show that electricity acts like a force?

in an electrical machine, it finally discharges itself — that is, it passes through the air to the nearest body. When the discharge takes place, a sound is heard, varying from a slight snap to a loud cracking sound. If a sheet of paper is held between the conductors, a hole like a needle prick shows where the electricity tore its way through the paper.

A flash of lightning is a great electric spark. Electricity, having accumulated upon cloud particles, passes

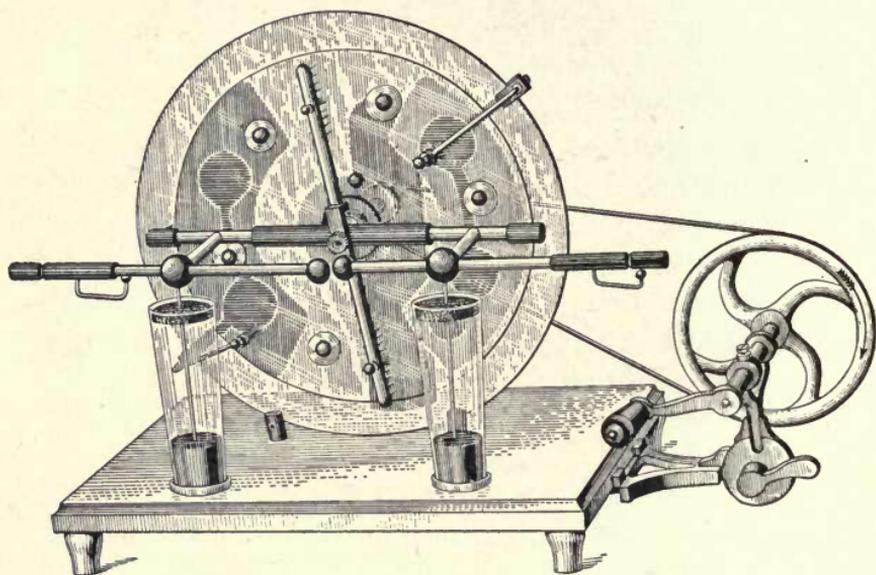


FIG. 64. — AN ELECTRICAL MACHINE

Electricity, which is on the surface of revolving glass plates, passes by metallic conductors to knobs at the front of the machine. If these knobs are near together, a succession of sparks crosses the space between them so rapidly as to seem continuous. If they are several inches apart, the discharges are less frequent and more violent. They are like flashes of lightning in miniature.

from cloud to cloud or from clouds to the earth. As it tears its way through the air, it causes a noise whose echoes reverberate, making a succession of crashes or rolling sounds which we call thunder. The flash of the electric discharge

reaches the eye instantly. The noise it makes travels more slowly. The velocity of sound in air is about 1,100 feet per second. If one second elapses between the flash



FIG. 65.—JOSEPH HENRY: PHYSICIST. 1797–1878

He was a born experimentalist: one who knew how to cross-examine Nature as an astute lawyer would cross-examine a witness and thus bring out her inmost secrets. He was one of those men by whom it seems as if Nature loves to be cross-examined.—SIMON NEWCOMB in *Leading American Men of Science*.

and the report, the discharge is 1,100 feet away, or more than one fifth of a mile. (One can count five in one second.)

142. Current or Voltaic Electricity.—About the beginning of the nineteenth century, it was learned that if two different metals, such as copper and zinc, are placed in a weak acid and connected by a wire fastened securely to the metals, a current of electricity will pass through the wire. Carbon, and a metal upon which the solution acts chemically,

may be used instead of two metals. There must be chemical action between the liquid and one metal, or there will be no current. Such a combination is called a **cell**, and two or more cells make a **battery**. Electricity produced in this way is called current electricity or Voltaic electricity, from Volta, one of its discoverers. (LABORATORY MANUAL, Exercise XIV.)

The two pieces of metal, the liquid between them, and the wire connecting them make a **circuit**, or path for the current of electricity. The ends of the metals where the conducting wire is attached are the **electrodes**. If this circuit is broken

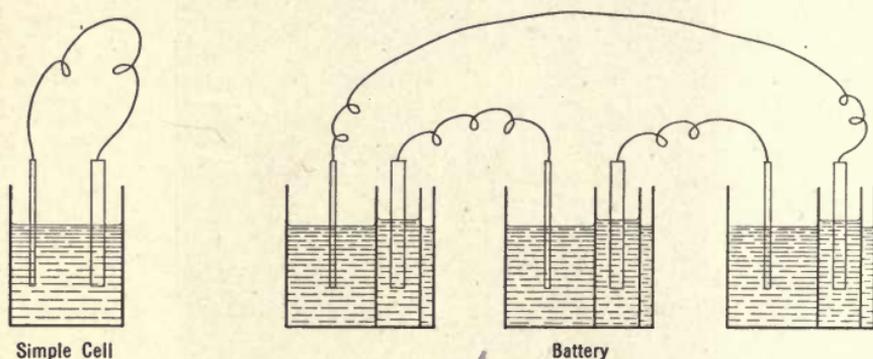


FIG. 66. — A SIMPLE CELL AND A BATTERY OF THREE CELLS

The wider piece of metal represents zinc, the other copper. Weak acid acts more strongly upon zinc than upon copper. The current starts with the zinc, is conducted by the acid to the copper, and thence by wire back to the zinc. 1. How many substances are there in the circuit? 2. What change would be produced if the wire were broken?

This *battery* contains two different liquids as well as two metals. The zinc in weak acid is in a porous cup, which stands in a jar of blue vitriol solution. The current passes in the same direction as in a simple cell, but its quantity and intensity vary with the number of cells and the connection of the plates.

by separating the conductors at an electrode, or by taking one metal from the liquid, no current passes.

At the instant of breaking the circuit, and of connecting it again, a little spark at the electrodes shows the presence of electricity. The heat of this spark is sufficient to light the gas at a burner constructed for "self-lighting." An

electric spark, also, ignites the vapor of gasolene in the gas engine of a motor boat or an automobile.

One of the commonest forms of cells is the **dry cell**, which is very convenient to handle because it contains no liquid which might be spilled. It is filled with a paste containing moist substances which act chemically upon one of the metals. Liquid cells, when used up, must have one of the electrodes or the liquid replaced by new materials; but the dry cell, when used up, must be replaced by an entirely new cell. Dry cells are much used in operating doorbells and in automobiles.

Statical electricity accumulates in charges on various bodies, and as soon as proper connections are made, it discharges instantly. Current electricity, on the other hand, has a continuous, steady flow. It is used in the wires of telephone and telegraph systems, whereas a charge of statical electricity is useless for such service, because it is gone in an instant.

143. Effects of an Electric Current.—Some of the effects of current electricity are similar to those of statical electricity, but since its

quantity and intensity can be better regulated, current electricity is of much greater use. The effects of electricity are heat, light, and magnetization, all of which can be produced with a battery of a few cells. Electricity from a battery is, however, seldom used to produce any of these effects for practical purposes. Such effects are produced by a method which is described later.

A simple way to determine whether a current is passing

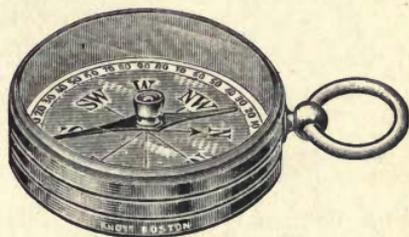


FIG. 67. — A MAGNETIC COMPASS

1. The box surrounding the magnetic needle is usually made of brass; why not of iron? 2. Should the box rest in a vertical or horizontal position when used to determine direction? Why? 3. Why are pipes in a magnetic laboratory made of brass or copper?

through a wire is to wind the wire from north to south around a magnetic compass. If no current is passing, the needle will keep its north and south position just as if no wire were present; but if a current passes through the wire, it causes the needle to turn from its north-south position toward the east or west, according to the direction of the current above the needle.

144. Magnetism. — The power to attract pieces of iron or steel (which is a form of iron) is called **magnetism**. Bodies having this property are **magnets**. Iron and steel are more strongly magnetic than any other metals. If a light piece of

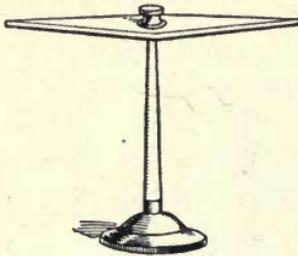


FIG. 68. — A MAGNETIC NEEDLE

The needle is free to move around a pivot upon which it is supported. 1. It is at rest, pointing north and south. What would be the effect of holding a piece of iron to the east of either end? 2. Would a copper rod produce the same effect?

iron is placed near a magnet, it moves to the magnet and clings to it; but if the magnet is the lighter of the two bodies, it moves toward the piece of iron.

Not all pieces of iron are magnets, but the property of magnetism may always be given to iron. This may be done by striking an iron bar while it is held in a north-south position, or by rubbing the iron with a magnet. In either of these cases, a bar of *iron* becomes a temporary magnet, but a *steel* bar retains its magnetism and becomes a permanent magnet.

There is an ore of iron called magnetite that is naturally magnetic; it does not have to be magnetized. It is found in veins in rocks.

The needle in a compass is a slender piece of magnetized steel which, if balanced on a pivot, will swing from any other position until it lies in a north and south direction. It is upon such an instrument that the pilot of a ship or a surveyor depends to determine the points of the compass when the sun or stars are hidden.

145. Electricity and Magnetism. — The construction of telegraph and telephone instruments depends on the fact that an electric current can produce magnetism and that magnetism can produce an electric current. When an electric current is passed around a bar of iron, the bar becomes a magnet, but it remains one only as long as the current is passing. A temporary magnet is the important part of a telegraph instrument.

If a current passes around a bar of steel, the steel becomes a magnet, and does not lose its magnetism after the current ceases. A permanent magnet is a part of every Bell telephone receiver.

If a magnet is put into a coil of wire, a momentary current of electricity passes through the wire. When the magnet is removed, a current starts in the opposite direction. These facts are made use of in producing electricity by machines

called dynamos. They furnish powerful electric currents for electric lights, electric furnaces, and for motors which are used in running trolley cars, elevators, and all kinds of machines in factories.

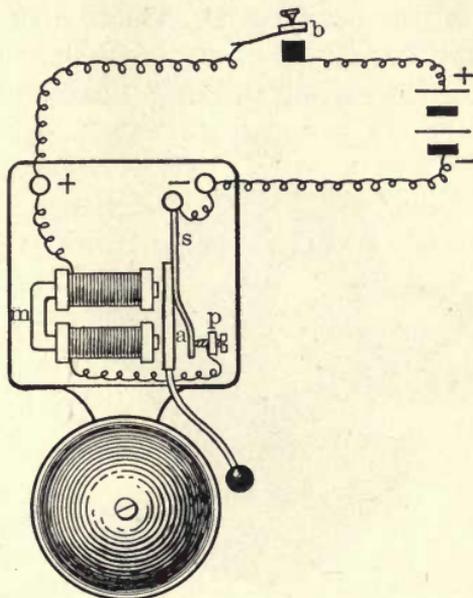


FIG. 69. — THE ELECTRIC BELL

In the figure, *m* is an electro-magnet, consisting of pieces of iron around which insulated wire is wound. When *b* is pressed, a current can pass from the battery through the coils of wire and back to the battery.

1. What is the effect on the pieces of iron?
2. At *a* there is another piece of iron on a spring connected with the hammer of the bell. What is the effect of *m* upon *a* when the button is pressed? 3. Why does not this effect continue when pressure is removed from *b*?

Electric lights are of two kinds, incandescent and arc lights. In the incandescent light a thread-like conductor, called the filament, is heated white-hot by its resistance to the electric current passing through it. This filament is enclosed in a bulb, which is either a partial vacuum or is filled with nitrogen. The filament would be burned if the bulb contained air. Arc lights are caused by a powerful electric current passing between two carbon rods slightly

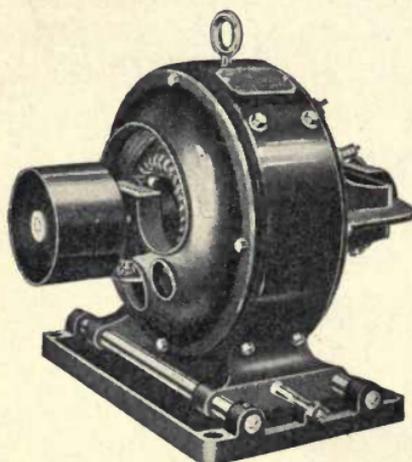


FIG. 70. — AN ELECTRIC GENERATOR OR DYNAMO

Such a machine as this is a dynamo. It consists of a revolving core of electro-magnets within a great permanent magnet. The magnets set up currents of electricity, first in one direction and then in the opposite direction, so rapidly that they seem continuous. The currents pass off by wires connected at the axle. The revolution of the core is caused by power transmitted by a belt over the axle at the side. What power might be used?

separated from each other. This separation causes a resistance which heats the ends of the carbons white-hot. These white-hot carbon ends give the brilliant light. The hot carbon vapor, which fills the space between the ends, conducts the current.

146. Transformation of Energy. — Whenever an electric motor is used, it must be run by power furnished by a dynamo, which in turn is run by water power or by steam. In the former case, the force of gravity gives energy to the falling water; in the case of steam, the energy is produced by the chemical action between fuel and the oxygen of the air.

There are several steps in the transformation of chemical energy into electrical energy. Chemical energy from oxidation of coal becomes *heat energy*; heat causes the expansion of steam which produces *energy*

of motion in a piston; this motion, transmitted by the parts of an engine to a dynamo, produces *electrical energy*.

The waterfall and the steam boilers may be many miles away from the motor and the machines. The electricity can be conveniently carried by wires, properly insulated, underground or overhead. Current is thus supplied to towns which have no water power or railroad facilities for bringing coal by which they could produce electricity. Streets and houses in rural districts are now better lighted than were those of a large city fifty years ago. Cars run by electricity furnish cheap and rapid conveyance which brings the city and the country nearer together, to the advantage of both.

EXERCISES

1. What kind of electricity is developed by stroking a cat's fur?
2. Explain the spark that passes from the hand to the cat's body after the stroking.
3. Which is a better conductor, dry or moist air?
4. Why does a body retain a charge better on a dry day?
5. How far away is an electric flash if one can count twenty between the moment of seeing the flash and hearing the thunder?
6. Name all the parts of the circuit of a simple cell whose metal plates are connected by a copper wire.
7. Why is it necessary to cover telephone and electric light wires?
8. Why are glass or porcelain coverings used where telegraph wires are supported on poles?
9. What is meant by a "live wire"?
10. Name changes in the form of energy between a waterfall which is used in producing electricity and a trolley car run by electricity.

CHAPTER XI

HOW MATTER CHANGES

147. Physical Changes. — A small bar of iron rubbed upon a magnet becomes a magnet itself; that is, it acquires the property of attracting pieces of iron or steel. Left untouched for a time, it loses its new property; but the iron was iron and nothing else all the time. Mercuric iodide, a red powder, on being heated becomes yellow. When cooled again, it returns to its original red color; it is the same substance as before. If a piece of wood is changed to sawdust, or a piece of stone crushed to powder, the wood and stone retain their former characteristics though they may never again become a single body. If sugar or salt is dissolved in water and the solution is exposed to the air, the water evaporates and the sugar or salt reappears unchanged. Such changes as these are physical changes. Condensation and evaporation, freezing and melting, expanding and contracting, are all physical changes.

A **physical change** is one that does not permanently change the properties of a substance nor produce any change in its composition.

148. Chemical Changes. — A lump of sugar placed on a hot stove melts. A cloud of white smoke rises from it and after a time a crisp, black solid is all of the sugar that remains on the stove. This residue looks like charcoal; it does not dissolve in water; it has no sweet taste. It has permanently lost its characteristic properties of whiteness, solubility, and sweetness. It is not sugar.

A **chemical change** is one that causes a loss of characteristic properties because of a change in the composition of the substance.

If mercuric oxide, a red powder, is heated slowly in a tube to a high temperature, it does not behave like the red powder described in §147. If a stick with a spark on the end is held in the tube while the mercuric oxide is being heated, the spark bursts suddenly into flame. This shows that there is now something besides air in the tube. When the tube is allowed to cool, a gray shining substance appears on the inside. This does not return to the form of a red powder, no matter how long it stands. The mercuric oxide was a compound that, on being heated, gave off a gas and mercury. The gas made the wood blaze, and the mercury remained in tiny globules on the inside of the tube. This change was a chemical change called decomposition. In **decomposition**, a compound separates into two or more different substances.

If the end of a thin piece of magnesium is heated in a flame, it burns. When it is cooled, the substance remaining is quite different from the original magnesium in color, texture, and composition. There has been a chemical change. Oxygen from the air has united with the magnesium, making a new substance, magnesium oxide. When two or more substances unite to form new substances, there is a chemical change called **combination**.

Decomposition and combination include all kinds of chemical changes. Burning, decay, separation of metals from ores, and digestion of food are chemical changes, and all involve either decomposition or combination, or both.

149. Oxidation. — The most abundant element in the earth is oxygen. It is a gas which exists as an element mixed with other gases in air. The union of any other element with oxygen is called **oxidation**, and the new substance or product is always an **oxide**. Oxidation is the most common chemical change.

When a substance burns, it is because one or more of its elements combines with the oxygen of the air. If the combi-

nation takes place rapidly, noticeable quantities of heat and light are given off, and the process is called **combustion** or burning. If the change takes place slowly without any flame, the process is called simply oxidation or slow combustion. The compounds formed in both cases are oxides.

The burning and the decay of wood are both oxidation and form the same compounds. In the case of burning, the heat is intense for a short time. In decay, the change in temperature is too slight to be detected by ordinary observation, and the process may take many years.

150. Spontaneous Combustion. — The slow oxidation of oily rags or paper is often the cause of accidental fires. The oil slowly unites with the oxygen of the air and heat is produced. If the rags are loosely placed, the heat may be given off as fast as it is made and no harm is done. If the matter is packed closely or is in a small space like a closet where there is little change of air, the temperature rises until it is high enough to set the combustibles on fire. This is called spontaneous combustion.

151. Explosions. — A little gunpowder spread upon a stone and set on fire burns quickly but quietly, making a large amount of smoke. A smaller quantity of gunpowder in a firecracker burns quickly and bursts the firecracker, making a loud noise. In both cases the powder burns; in the second case it results in an "explosion." The noise produced in this way and the bursting are both called explosions. In both cases of burning, a large amount of gas is formed quickly; in the second case the gas is confined and makes room for itself by pushing away the confining walls.

Explosives are made for the purpose of pushing the projectile from a gun, the rocket from its fastening, the rock from the side of a mountain. An explosive always contains two things: (1) a substance which, on being struck or heated, sets free oxygen to insure rapid combustion; and (2) a combustible material which, when united with oxygen,

makes a large volume of gas. The rapid expansion of this gas produces the desired explosion. Gunpowder, the explosive longest in use, contains saltpeter to furnish oxygen, and charcoal and sulphur for combustibles.

152. The Relation of Oxidation to Life. — The unfolding of a flower bud, the turning of a leaf toward the sun, the lifting of the foot or the hand, the beating of the heart, are all forms of work and therefore require energy. Energy in living things is the result of oxidation, and all living things use oxygen to produce energy. Part of the energy shows itself as heat or increase in body temperature — a temperature which is higher in many animals than in plants.

Life ceases when no energy is produced. That is why **suffocation**, or lack of air, produces death. Drowning is a form of suffocation. The loss of life in a burning building is not always the result of burning to death; it is often due to suffocation. Irritating, suffocating gases are made by the burning of wood, as we all know if we have ever sat near a smoking fireplace. Such gases in a burning building may fill rooms and stairways not touched by fire. One of the first effects of suffocation is unconsciousness. If the victim is rescued and supplied with fresh air, fatal results may be prevented.

When injurious gases, as coal gas or illuminating gas, are mixed with air, the result is not simply suffocation but a poisoning. This is called **asphyxiation**.

153. The Ignition Point. — The temperature which a substance must have before it takes fire, or ignites, is called the **kindling point** or **ignition point**. The kindling point of gasoline vapor is so low that it is not safe to use gasoline in a room where there is a fire or flame of any kind. Alcohol also has a very low ignition point. Hot alcohol is sometimes recommended for treatment of bruises, but the alcohol cannot safely be placed in a dish on the stove; it may, however, be heated over a dish of hot water.

154. The Law of Conservation of Matter. — A body may be destroyed by burning, or may disappear by evaporating, but the matter of which it was composed still exists — perhaps in some different state or united with other matter to form a new substance. This is known as the Law of Conservation of Matter. The law, briefly stated, is this:

the quantity of matter in the universe is constant; or in other words, matter is indestructible.

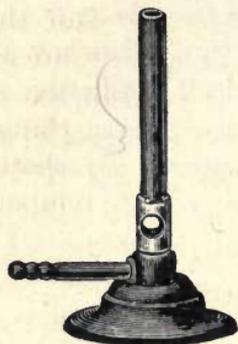


FIG. 71. — BUNSEN BURNER

Inside, at the bottom of the upright tube, is a small tube with a narrow slit. The gas comes through this slit and is pushed up to the top, where it is lighted. When the holes at the base of the upright tube are open, air enters and mixes with the gas before it reaches the top. 1. How does that affect combustion? 2. If the holes are open, the flame is pale blue; if closed, it is luminous. Which is like the flame of a gas stove?

When an element is completely burned, or oxidized, the **product** (that is, the new substance formed) weighs more than the original. To the weight of the element that was burned is added the weight of the oxygen. Twelve grams of carbon completely burned give forty-four grams of carbon dioxide.

If a solid, in burning, forms chiefly gases, the **residue** (that is, the solid remaining after combustion ceases) weighs less than the original, because a part of the matter has passed off as gaseous oxides. Wood is a fuel which illustrates this fact. The ashes weigh less than the original wood.

155. The Law of Definite Proportions. — *Any given compound is always made up of the same elements in the same definite proportions by weight.* In combustion 12 grams of carbon will unite with 32 grams of oxygen, or 6 grams of carbon with 16 grams of oxygen, and there will be no remainder of carbon or oxygen. But if there are 13 grams of carbon and only 32 grams of oxygen, one gram of carbon will remain uncombined. The same law holds true for

other combinations. This is called the Law of Definite Proportions.

If the proper weights of the given substances are well mixed, so that each small particle is near those with which it will unite, chemical combination takes place more rapidly. Gases mix most readily, and liquids next; finely powdered solids mix less readily than gases and liquids, but better than large masses of solids.

The burners of gas stoves and Bunsen burners, such as are used in laboratories, are provided with holes for the admission

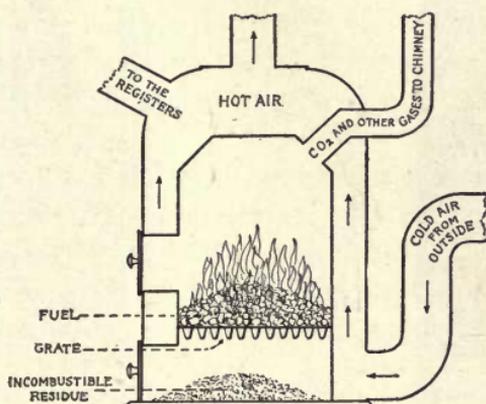


FIG. 72. — THE FIRE BOX OF A FURNACE

1. Why is a grate, and not a sheet of metal, provided for the coal to rest upon? 2. At which door does air enter for the process of oxidation? 3. What is such an opening called? 4. How does the amount of air affect combustion? 5. Explain the effect upon the fire when the other door is left open.

of air near the place where the gas enters. Thus air and illuminating gas are mixed and come to the opening together, and when a flame is applied, every particle of illuminating gas is in contact with the oxygen of the air and burns rapidly. Each particle of gas, however, will unite with only a *certain amount* of oxygen, no matter how much is furnished. (LABORATORY MANUAL, Exercises XV, XVI.)

Stoves and furnaces have an opening below the firebox. Air entering there mixes with the hot fuel and helps to produce rapid combustion. If the opening is closed, the current of air does not pass through the fuel, combustion is less rapid, and the fire is "checked."

156. Extinguishing Fires. — Two conditions are necessary to produce a fire: a temperature at or above the ignition point, and the presence of oxygen. There are consequently



FIG. 73. — A CHEMICAL FIRE EXTINGUISHER

When the cylinder is turned "upside down," according to directions, acid runs out of a loosely stoppered bottle inside, into a strong solution of sodium carbonate or sal soda. This causes a large quantity of carbon dioxide to be made in a small space. Under its own pressure, the gas is pushed out of the small hose attached, bringing some liquid with it.

two methods of extinguishing fires: first, by cooling the burning material below its ignition point; and second, by preventing air from coming in contact with the burning material. In the first method water is used. The second method may be successful when the fire is confined to a small area; for instance, blankets or a suffocating gas may be

used to cover the flames and keep out the air. If the clothing of a person takes fire, the quickest and safest method of extinguishing the flame is to wrap the body closely in a woolen rug or blanket. This excludes the air. If the accident occurs out of doors, the victim may be rolled in soft earth or covered with earth.

157. Chemical Engines. — Chemical engines and hand extinguishers furnish a spray of water and carbon dioxide, a gas in which combustion will not take place. Carbon dioxide is a heavy gas and spreads over the fire in much the same way that a wet blanket might, thus shutting out the air and preventing combustion until the combustible substance has cooled. It would take a great quantity of water to produce the same effect, and much injury to goods would be caused by the water.

If kerosene is spilled and burning, carbon dioxide is a better extinguisher than a stream of water. As kerosene is lighter than water, the water would go under the burning kerosene, leaving it still exposed to the oxygen in the air. Carbon dioxide, however, would cover the kerosene and extinguish the flames.

EXERCISES

1. Arrange the following occurrences under the proper heading, as *Physical Change* or *Chemical Change*: melting of glass, burning of paper, magnetizing of iron, boiling of water, rusting of iron, dissolving of salt, drying of clothes, explosion of a torpedo, formation of ice, tarnishing of silver, lighting the gas, extinguishing a fire, evaporation of water.

2. What is meant by the statement that the kindling point of coal is higher than that of wood?

3. Which gives a higher temperature, slow or rapid burning?

4. A given weight of carbon unites with $2\frac{3}{4}$ times its own weight of oxygen, in case of complete combustion. (a) How much oxygen will 15 g. of carbon require? (b) What weight of carbon dioxide is made from this combination?

5. 1,000 cu. cm. of carbon dioxide weigh 2 g. In Ex. 4, how many thousand cubic centimeters of gas would be made?

6. How does water act in putting out a fire?

7. Why is prompt action with a limited amount of water more successful in extinguishing a fire than a larger amount of water after the fire is well started?

8. Why does not the carbon dioxide formed by combustion extinguish the flames which produce it?

9. If some kerosene were spilled and burning, why would sand be a better extinguisher than water?

10. Compare suffocation with the process of putting out a fire.

11. Why is oxidation the commonest change in matter? Give three illustrations of oxidation not mentioned in the text.

CHAPTER XII

THE COMMON ELEMENTS OF THE EARTH

158. Oxygen. — Oxygen is the most abundant as well as the most important of all the elements. Without it, there could be no life. It has no color, odor, or taste. It does not burn, but causes other substances to burn. It is a part of the air we breathe, of the water we drink, and of almost everything we use for food. As a pure element, however, we have almost no practical use for oxygen. Physicians

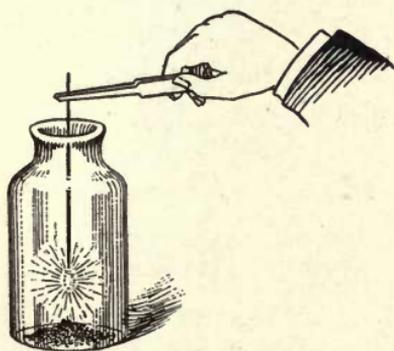


FIG. 74. — BURNING IRON WIRE

FIG. 74.—The end of a piece of iron wire tipped with a bit of burning sulphur is put into a bottle of oxygen. The sulphur burns very brightly and heats the end of the wire, which becomes *dazzlingly* bright and throws off bright sparks. After the burning ceases, the inside of the jar is found covered with a brown powder. 1. What could the powder be? 2. Why does the burning stop before the iron is used up?

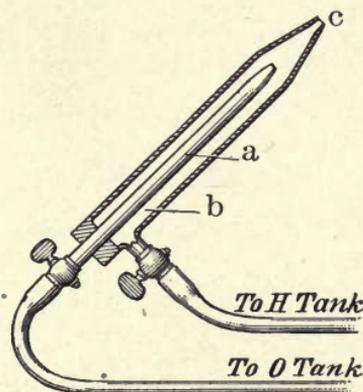


FIG. 75.—OXYHYDROGEN LAMP

FIG. 75.—Acetylene, another combustible gas, is sometimes used instead of hydrogen in such a lamp. The gas H is first turned on; it enters the tube b, and is lighted at c. 1. How can it burn before the oxygen is turned on? 2. Oxygen passes through the tube a and out at c. Why is the flame hotter after oxygen is turned on?

furnish it pure to patients to breathe in some cases of extreme weakness, thus prolonging life a short time.

159. Hydrogen. — There are two other gaseous elements, hydrogen and nitrogen, that are common enough to be of great interest. They are not very well known because under ordinary conditions they are, like oxygen, invisible. Hydrogen, the lightest substance known, is only about one fourteenth as heavy as air. It is not often found in nature

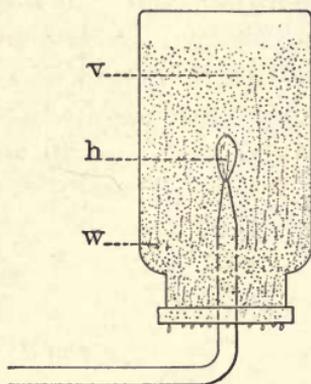


FIG. 76.—BURNING HYDROGEN

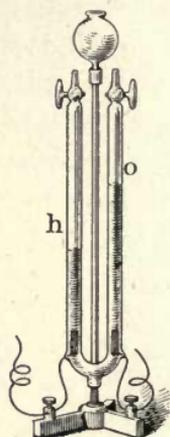


FIG. 77.—ELECTROLYSIS OF WATER

FIG. 76.—1. What is the product of hydrogen burning openly in air? 2. Could the substance be seen? 3. What would be the effect of placing a cool jar over the flame? Explain.

FIG. 77.—The two arms of the U-shaped tube were full of water when the current began to pass between the pieces of platinum near the bend. 1. Compare the condition of the two arms now. 2. What is the meaning of *electrolysis*?

in the gaseous form, as oxygen is, uncombined with other elements; but it makes one ninth of the weight of water and is found in many other compounds. Hydrogen is combustible, that is, it will burn. When burned in pure oxygen, it makes one of the hottest flames known — the oxyhydrogen flame, which is used to melt metals and minerals that do not melt in ordinary fires. It is also used to heat white-hot the block of lime which gives the intense light used in many

stereopticons. The lightness of hydrogen makes it useful in filling balloons.

160. The Composition of Water. — Whenever hydrogen is burned in oxygen or in air, it unites with the oxygen and forms a vapor, which on cooling condenses to a liquid. This liquid is pure water. On the other hand, by an electric current (Fig. 77) water may be decomposed into two gases, which, on being tested, prove to be oxygen and hydrogen. When the *volumes* of these two gases are measured, it is found that there is twice as much hydrogen as oxygen. *Weighing* the gases shows that the oxygen weighs eight times as much as the hydrogen. Thus it is shown that water is composed of two volumes of hydrogen to one of oxygen, or one unit of weight of hydrogen to eight of oxygen. From these measurements it is seen that when *equal volumes* of these gases are considered, oxygen weighs sixteen times as much as hydrogen.

161. Nitrogen. — The gas nitrogen can best be described by negatives. It does not burn as hydrogen does, nor aid in burning as does oxygen, and it does not *readily* unite with other substances to form compounds. But there are many compounds of nitrogen which are far from negative in character. Combined with hydrogen, it forms the pungent gas ammonia. With hydrogen and oxygen, it makes nitric acid, which dissolves metals. The explosives — dynamite, nitroglycerine, and gunpowder — contain compounds of nitrogen.

Compounds of nitrogen are necessary in the food of animals; these compounds are obtained from plant food or from the bodies of animals that have eaten plant food. Plants obtain a large amount of their nitrogen from compounds of nitrogen in the soil.

Air is a *mixture* of nitrogen and oxygen in the proportion of about four volumes of nitrogen to one of oxygen, together with a very small proportion of carbon dioxide, water vapor, and some other gases.

162. Chlorine. — Chlorine is of interest principally because of the importance of some of its compounds. The element is a greenish-yellow gas of disagreeable odor; when breathed, it is irritating and suffocating. It does not exist free in nature, but in combination with other elements it is found in many minerals. The most abundant compound of chlorine is common salt, which is found both in the ocean and as a solid mineral in the earth. Chlorine can be prepared from common salt for use in bleaching or in disinfecting. A powder called chloride of lime is commonly used for these purposes, as it gives off its chlorine very readily.

163. Carbon. — Most of the solid elements are metals, but there are three common solid elements — carbon, sulphur, and phosphorus — which are not metals.

Carbon is black, except in the case of the diamond, which is usually colorless. There are several other varieties of the element carbon: graphite (called black lead), lampblack or soot, coke, and charcoal. Mineral coal is an impure form of carbon.

All forms of carbon are combustible, but they must have a comparatively high temperature in order to burn. The kindling point of charcoal is lowest, and that of graphite is highest. When charcoal and diamond are burned in pure oxygen, they both form the same product, carbon dioxide. This proves that, unlike as they are in appearance and properties, charcoal and diamond are the same element.

164. Coal and Charcoal. — Many, many thousands of years ago areas of land overgrown with great forests slowly sank and were covered with water. The fallen trees were buried under layers of sand and mud which settled in the water. The plant material, shut away from the air, oxidized very slowly. In the process of slow combustion, gases were formed and passed away, leaving beds of solid matter, mostly carbon, which is called coal. Coal is the residue of incomplete combustion of wood and other vegetable matter.

Some of the beds beneath the coal contained remains of marine life. Decay caused gases rich in carbon to be forced into the crevices of the rocks, where some of these gases were condensed into liquid petroleum. When borings are made through the rocks near certain coal regions, petroleum or a gas comes from the openings, sometimes for years without cessation. The products from distillation of petroleum are very numerous. Among those most widely used are kerosene, gasolene, vaseline, and paraffin. Natural gas is used for fuel as well as for light in many parts of the United States.

Charcoal is prepared by heating wood in a kiln or oven, where air cannot enter. Gases and steam are driven off, and carbon in a solid, nearly pure form is left. The process is similar to the method by which coal was made under the rocks during many centuries, but is very much more rapid.

Carbon occurs in many compounds in the bodies of plants and animals. It is the union of this carbon with oxygen (slow combustion) which furnishes the energy needed to keep the body alive. All kinds of grains and fats furnish carbon compounds in large quantities and nitrogen compounds in small quantities. (LABORATORY MANUAL, Exercise XVII.)

165. Phosphorus and Sulphur. — The two solids, phosphorus and sulphur, are often associated in the minds of people because both are readily combustible and have low kindling points, and because they have been used together for a long time in making the tips of matches. Phosphorus occurs naturally only in compounds. The element is prepared artificially from the hard part of bones, which is calcium phosphate. Phosphorus is a wax-like, slightly yellow substance which has the property of being self-luminous, — that is, it gives off a faint light. On account of its rapid union with oxygen if exposed to air, it is kept under water in laboratories and factories.

Sulphur, under ordinary conditions, is a lemon-yellow crystalline solid. It has been obtained for centuries from fissures in the rocks of volcanic regions. Sicily has exported great quantities to the United States and to other countries. Extensive subterranean beds of pure sulphur have recently been discovered in Louisiana, and the United States is now exporting more sulphur than it imports.

Sulphur is burned in rooms which are infected by certain contagious diseases, because the sulphur oxide formed by its combustion destroys disease germs. This oxide is irritating if breathed in small quantities, and when breathed in large quantities, it is fatal.

166. Properties of Metals. — There are certain physical properties which belong especially to metals:

Luster, shining surface.

Malleability, capability of being hammered or rolled into thin sheets without breaking.

Ductility, capability of being drawn into wire.

Conductivity, ability to transmit heat and electricity.

Fusibility, capability of being melted.

No two metals possess all these properties in the same degree; and the characteristic properties of each metal vary greatly, because of the effect of temperature and other conditions. Each of the metals has its own peculiar combination of properties by means of which it can be identified. Each metal has its own specific gravity, its own peculiar color, its own degree of tenacity and of elasticity, and other special properties.

167. Iron. — At the present day, iron in its various forms is the most important of the metals. Its properties make it the best metal for car rails, steamships, locomotives, frames of buildings, and machines, all of which are necessary to the life of our times.

Wrought iron is the most nearly pure of the commercial forms of iron. *Steel* contains a small per cent of carbon;

cast iron contains a larger per cent of carbon and some other impurities. In these three forms, iron has certain properties in very different degrees; wrought iron is most malleable, steel most tenacious and elastic, cast iron most brittle. Chains are made of wrought iron; car rails and knife blades are made of steel; heavy pieces of machinery are made of cast iron. Iron rusts if exposed to outdoor air; to prevent rusting it is often covered with paint, zinc, or graphite in the form of "blacking."

168. Copper and Gold. — Copper and gold are the only well-known metals that occur in abundance free from other elements. They are said to occur free or **native**. Copper and gold have characteristic colors, copper being dull red, and gold, yellow; most of the other metals have a grayish color. Both copper and gold are rather soft, have a high melting point, and are malleable and ductile in a very high degree. They have both been used since early times. This was because they were found free and required no difficult process of separation from the ore, and because they could be hammered into shape with simple tools.

Gold is less affected by the chemical action of air and water than almost any other metal, and it is not acted upon readily by any common substance. Hence it is used the world over for coins and jewelry. As gold is too soft to be used pure for such purposes, a little copper or silver is melted with it to give it greater hardness. Such a mixture of metals is called an **alloy**. Gold that is described as "24 carat" is 100 per cent pure gold. The best grades of jewelry are 18 carat gold, while the 14 carat is used for articles which are likely to have hard wear. United States gold coins are 90 per cent gold and 10 per cent copper; they contain an amount of gold equal in value to the value of the coin.

Because of its great malleability, gold can be hammered so thin that 250,000 sheets of gold leaf are required to make a pile one inch thick. It is much thicker than that, how-

ever, when used to cover large surfaces like the domes of buildings.

Copper is of great use because it is a good conductor of electricity; many tons of new copper wire are brought into use daily. Copper is abundant enough to be reasonably cheap. It is made into coins of low denomination the world over. In pure form, it is rolled into sheets for covering surfaces exposed to air or water. A great amount of copper is used on large buildings, to cover the valleys and gutters in the roof surface. Copper is alloyed with tin to make bronze, and with zinc to make brass.

169. Silver. — Silver has properties similar to those of copper and gold, but in different degree. Silver is not affected by pure air or water. In the air of houses, however, it tarnishes somewhat, because such air often contains impurities from furnace or illuminating gas.

Both as solid and as plated ware, silver is useful for table articles. It is not affected by many kinds of food, though eggs and mustard discolor it because they contain compounds of sulphur, which make a dark coating on silver. "Solid silver" is alloyed with 10 or more per cent of copper to give it greater durability. United States silver coins contain 10 per cent of copper.

170. Aluminum. — The lightest metal in common use is aluminum, or aluminium. Its lightness and the fact that it does not tarnish in air or water make it useful for kitchen utensils, aeroplane frames, and parts of automobiles. It is a good conductor of electricity.

171. Mercury. — Mercury is the only metal which is liquid at ordinary temperatures. It is used in thermometers and barometers and in many other scientific instruments. As it will dissolve gold, it is used in stamp mills to separate fine particles of gold from sand or from rock dust. The gold is finally separated from the mercury by distillation.

Mercury is used with other metals — as gold, silver, or tin

— to form soft alloys called **amalgams**. An amalgam of silver and mercury is used by dentists in filling cavities in teeth.

172. Uses of other Metals.—Nickel is used as a plating material and in coins. Zinc, tin, and lead, in thin sheets, are used to cover wood and to line tanks. Iron coated with zinc is called *galvanized iron*; covered with tin, it is called *tin plate*. Ordinary *tinware* is thin sheet iron coated with tin; the coating makes the ware brighter and prevents rusting. The flexibility of lead makes it useful in pipes which must be bent to turn corners. Ordinary water pipes and gas pipes are made of iron, plain or galvanized. Coil pipes are frequently made of copper.

Platinum is one of the rarest and most expensive metals. Its principal use is in scientific apparatus and in the setting of precious stones. Magnesium burns with a brilliant light of great chemical energy and is therefore used in photographic flashlight work.

173. The Specific Gravity of Metals.—Most of the metals have a greater specific gravity than the common rocks. The specific gravity of common rocks varies from about 2.5 to 3.5. Below are given the specific gravities of some of the metals in the pure state:

Platinum	21.5	Silver	10.5	Tin	7.3
Gold	19.3	Copper	8.9	Zinc	7.1
Mercury	13.6	Nickel	8.9	Aluminum	2.6
Lead	11.4	Iron	8.0	Magnesium	1.8

174. Chemical Symbols.—In scientific work, abbreviations are used to represent the elements. As many of the elements have Latin names, the abbreviations or symbols may be unlike their English names; for instance, *Au* stands for *gold*, from the Latin word for gold, *aurum*. In every language the symbols used in scientific work are the same.

A *single* symbol, whether alone or combined with others, stands for one **atom**, which is the name chemists have given to the smallest portion of matter which enters into combination. For example, *Na* stands for one atom of sodium. *NaCl* means that there is one atom of sodium united with one atom of chlorine.

Two or more atoms make a molecule. If the atoms are all of the same kind, they form the molecule of an *element*. If unlike, they make a molecule of a *compound*. H_2 (read "H two") represents a molecule of the element hydrogen; H_2O (read "H two O"), a molecule of the compound water.

Below are the names and symbols of some of the well-known elements:

aluminum .. Al	gold	Au	mercury ... Hg	silicon .. Si
bromine ... Br	hydrogen	H	nickel	Ni
calcium ... Ca	iodine	I	nitrogen ... N	sodium .. Na
carbon C	iron	Fe	oxygen O	sulphur .. S
chlorine ... Cl	lead	Pb	phosphorus.. P	tin
copper ... Cu	magnesium ..	Mg	platinum ... Pt	zinc ... Zn

EXERCISES

1. Why does one end of a match "light" and the other not, with the same treatment?
2. Why is iron in its various forms the most important metal at the present day?
3. Why is iron often covered with paint, zinc, or graphite?
4. What weight of gold is there in an 18 karat gold ring weighing 25 g.?
5. What properties of gold make it useful in dentistry?
6. Compare the weights of one cubic centimeter of gold and of one cubic centimeter of a 12 karat gold-and-copper alloy.
7. In ancient times, a goldsmith used an alloy in making an article that was supposed to be made of pure gold. A philosopher detected the cheating by weighing the article in air and then in water. Explain his method.
8. 1,000 cu. cm. of hydrogen gas weigh about $\frac{1}{11}$ of a gram. What is the weight of an equal volume of air?

9. A toy balloon has a capacity of 10,000 cu. cm. What weight of air will it displace?
10. Could the hydrogen balloon be weighed in the ordinary way with platform scales or a spring balance? Why?
11. Select and write the symbols of all the elements that you know to be gases.
12. Write the symbols of all the elements that you know to be metals.

CHAPTER XIII

SOME COMPOUNDS OF COMMON ELEMENTS

175. Chemical Formulas. — A chemical formula is a collection of symbols representing the kinds and the relative amounts of the elements in a given compound. For example, CO_2 is the formula for carbon dioxide and indicates that a molecule of this compound is made up of one atom of carbon and two of oxygen chemically united. NaCl is the formula for common salt.

176. Chemical Analysis. — It is often necessary to find out what substances are present in food, medicine, explosives, and construction materials. The process by which this is done is called **chemical analysis**. A complete analysis discovers what elements and compounds are present and in what amounts. Laboratories are established by the government, by scientific schools, and by private enterprises for the purpose of learning the composition of different forms of matter. Manufactories maintain their own laboratories to examine raw materials purchased for their use.

A **test** is an examination of a substance to find out if a certain element or compound is present. A test is not analysis but may be used to show whether the conclusions drawn from the work of analysis are correct.

To apply a test, one must know how the given element or compound behaves under given conditions and then apply those conditions to the substance under examination. For example, if any compound of copper is present in a solution, the addition of ammonia gives a deep blue color. Knowing this fact, we may test a given solution to see if it contains

copper. We add ammonia; if the solution then becomes deep blue, we know that copper is present.

177. Classes of Compounds. — A *class* of compounds includes several substances which resemble one another either in their constituents or in their chemical properties, or both. For example, all substances which consist of oxygen and only

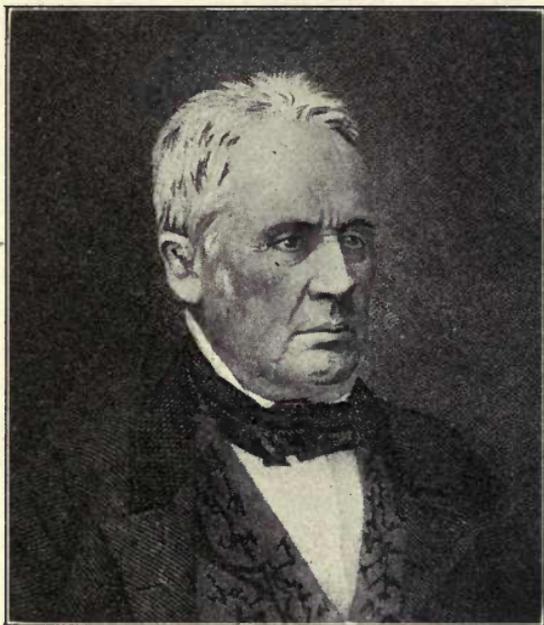


FIG. 78. — BENJAMIN SILLIMAN: CHEMIST. 1779–1864

By his lectures delivered in every part of the country, he contributed, in a large degree, to the promotion of a love of science and to the foundation of scientific institutions. — DANIEL COIT GILMAN in *Leading American Men of Science*.

one other element are oxides. Besides the oxides, there are three other important classes of common compounds: acids, bases, and salts.

178. The Two Most Important Oxides. — Water, which is a hydrogen oxide, and carbon dioxide are compounds which are absolutely necessary to living things. Naturally, both are provided as a part of the earth itself. Besides being

necessary to life, water is useful to man in a greater number of ways than any other liquid.

The amount of carbon dioxide in the air is practically constant. Respiration of plants and animals, the decay of plant and animal substances, and combustion are constantly *giving* carbon dioxide to the air. Green plants are constantly *removing* carbon dioxide from the air.

As the plant grows, it uses, in preparation of its food materials, the carbon which it gets from the carbon dioxide, and sets free the oxygen. As the oxygen which the

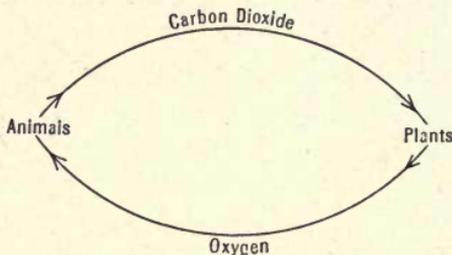


FIG. 79. — RELATION OF CARBON DIOXIDE TO LIVING THINGS

1. Arrow points indicate the direction of reading. Begin with *animals* and write fully what this diagram tells. 2. Begin with *oxygen* and write the short story.

plant releases is the only source of renewed supply, it is plain that if it were not for the work of plants on carbon dioxide, the quantity of oxygen in the air would be exhausted.

179. Acids. — Acids are compounds which in water solutions have a sour taste. They always contain hydrogen, and when they act chemically on metals, the hydrogen is usually given off. The dissolving of a metal by an acid is not a mere physical change, as when water dissolves sugar, but is a chemical change. The metal takes the place of the hydrogen in the acid-molecule, forming a new compound called a salt.

A simple test for an acid is that it turns blue litmus paper

red. Litmus paper is paper colored by a dye from a certain plant. This dye changes from blue color to red when in contact with even the vapor or fumes of an acid.

The most common acids used in the industries are hydrochloric acid (also called muriatic), sulphuric (called oil of vitriol), and nitric acid. In full strength these acids are injurious to the flesh and the clothing. They may be diluted with water and in *very* dilute form are harmless. Sulphuric acid is used in making most of the other acids.

Other acids, such as oxalic, tartaric, and citric, are found in dilute forms in the juices of fruits and leaves of plants. Acetic acid is formed when cider "works" or ferments, and it is the acid which gives vinegar its sour taste.

180. Bases. — In general, bases are opposite to acids in their properties. Their solutions turn red litmus paper blue. Ammonium hydroxide (called ammonia water), sodium hydroxide (called caustic soda), and calcium hydroxide (called slaked lime) are bases.

Most burns and stings of insects are painful because of an acid formed by the burn or injected in the stinging. The application of certain basic materials, such as soap, cooking soda, or lime water, counteracts the acid and thus affords relief.

181. Salts. — If an acid and a base are put together in the right proportions, the characteristic properties of both disappear. Since the product is neither an acid nor a base, it is said to be **neutral**. If the water is evaporated from the resulting solution, there remains a crystalline or powdered solid called a **salt**, which is not like either the acid or the base.

Nearly all minerals are salts. Most of these salts found in the rocks are only slightly soluble. The more soluble salts are dissolved by the water which is continually washing over and through the earth's crust, and are carried finally into the ocean. Since this has been going on through all the ages,

most of the soluble salts are by this time in the springs, lakes, and oceans.

The most abundant salt, which is the chief one in the ocean, is our common table salt. Its chemical name is sodium chloride, because it contains sodium and chlorine. It is a good example of salts, and the terms which describe it would, with slight variation, describe many salts. Color, degree of solubility, and the form of the crystal are important physical properties of salts. (LABORATORY MANUAL, Exercise XVIII.)

182. Some Uses of Salts. — Besides the familiar table salt, there are many other salts which are used in manufacturing.

Copper sulphate is a blue salt, commonly called blue vitriol. With water, it makes a blue solution which is used in electric batteries and in copper plating.

Silver chloride and silver bromide are used in photography, because light acts upon them chemically. The film or plate in the camera has a coating of one of these salts. The light which comes through the camera lens during the exposure acts upon the silver compound. Since the light falling on the film is stronger in some places than in others, the salt is affected in different degrees in different places, exactly corresponding with the degree of light from the objects outside. To make this effect visible, the film or plate is developed by treating it with solutions of various other salts. Developing completes the chemical action begun by light. Then another solution, the fixing bath, is used to remove all the silver compounds which have not been acted upon by light, and the negative is complete. It is on account of this chemical effect of light on silver compounds that photography is possible.

Solutions of salts containing gold, silver, and nickel are used in electroplating table utensils, jewelry, and parts of machines.

183. Carbonates. — Carbonates are salts containing various metals combined with carbon and oxygen. Sodium carbonate is the common washing soda, and calcium carbonate is the compound of which limestone and marble are composed. Sodium and potassium carbonates are much used in the preparation of soaps and washing powders, because they change fats and grease to soluble substances.

Carbonates are valued because by simple treatment carbon dioxide gas can be procured from them. Any car-

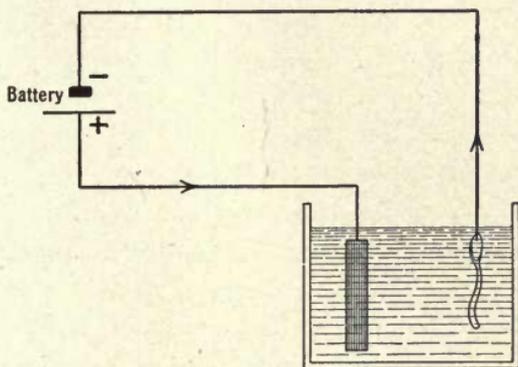


FIG. 80. — A SILVER PLATING BATH

The tank contains a solution of some compound of silver. One wire from the battery connects with a bar of silver, and the other wire with a spoon which is to be plated. 1. Starting with the positive electrode of the battery, name all the parts of the circuit. 2. When a current is passing, molecules of silver leave the solution and cling to the spoon. Their places in the solution are taken by molecules from the bar of silver. Which way, then, does the current go in the plating solution?

bonate decomposes on the addition of even a weak acid, giving off carbon dioxide.

Sodium bicarbonate is used in the preparation of some foods. Baking powder consists of a dry carbonate mixed with a weak acid in powder form. As long as both substances are dry, they do not affect each other; but as soon as they are dissolved in water or milk, they act on each

other chemically and carbon dioxide is set free. While this gas is rising through the dough, cooking stiffens the material and it remains porous, making biscuit, cake, and pastry "light."

184. Fertilizers. — Plants, during their growth, are continually removing from the soil certain salts which are needed for their food. In forests and uncultivated lands, the plants die and decay in the ground, and thus all the salts are returned to the soil. But on farms the plants are removed when they are grown, and are used as food for animals or men. Moreover, rain dissolves some of the salts of the soil and carries them away to sea. In these ways, the salts needed for plant growth are continually removed from the soil and are not returned to it.

It is easy to see that if this loss continued, the fertility of the soil would soon be exhausted, and it would be impossible to grow crops. The loss may be made good, however, by the use of **fertilizers**. These are combinations of salts to replace the material taken from the soil.

Fertilizers may be mineral or organic. A mineral fertilizer is one which is obtained directly from rocks or earthy deposits. An organic fertilizer is decaying vegetable or animal matter. Calcium phosphate, from the great beds of fossil bones near the coast in North and South Carolina, has long been a source of phosphates for fertilizers. Guano (the excrement of various kinds of marine birds) is found in extensive beds on islands off the coast of Peru and Chili. Guano contains phosphates and nitrogen compounds, both of which are used as foods for plants.

185. The Science of Agriculture. — The composition of soils is learned by analysis made in the laboratories and fields of agricultural colleges and of the United States Department of Agriculture. By analysis it is possible to determine also what compounds are needed in the soil for certain crops. Grass, corn, and potatoes each has its own needs, and the

same fertilizer will not prepare the soil equally well for all of them. The preparation of artificial fertilizers is a great industry.

The study of the needs of the soil and of crops has been of great benefit to mankind. It is not the farmers alone who are benefited, for the whole world depends on the success of crops for its daily food.



FIG. 81. — EFFECT OF FERTILIZERS UPON CROPS

This is a picture of potato harvesting in the state of Maine, which in some parts has a natural soil adapted to the needs of the potato. The average yield for the whole United States is 92 bushels per acre. A good yield in "the potato county" (Aroostook, Maine) is 275 bushels per acre. By the use of fertilizers well adapted to the soil and the crop, a yield of 462 bushels per acre was obtained from this field in the same "potato county."

186. Poisons. — A **poison** is a substance which produces serious illness if taken into the body. An **antidote** is a substance given to remove the poison or overcome its effect. The value of an emetic lies in its power to remove the poison quickly from the stomach. In most cases of poisoning, good antidotes are milk and raw eggs, especially the raw white of

eggs. In all cases a physician should be called at once and the more powerful antidotes should be given only under his direction.

Many antiseptics and disinfectants which are used to kill disease germs, will kill people also if taken internally. *Corrosive sublimate, carbolic acid, formaldehyde*, and other poisonous compounds are commonly used as disinfectants. They should be plainly marked POISON and kept where they cannot be used accidentally.

EXERCISES

1. (a) State five physical properties of water. (b) Which of these do you think would be very important in chemical work? Why?
2. Name four uses of water besides those of the home and the farm.
3. Name four uses of carbon dioxide. State one which depends upon a chemical property.
4. Is there carbon dioxide in baked bread? Why?
5. Is there carbon dioxide in cider? Why?
6. What relation is there between acids, bases, and salts?
7. What is meant by the expression, "One substance neutralizes the effect of another"?
8. What substance might neutralize the chemical effect of ammonia solution?
9. What substance might remove a spot made upon blue cloth by lemon juice?
10. Why is sulphuric acid the most important of all acids?

CHAPTER XIV

MINERALS AND ORES; THEIR VALUE AND SOURCE

187. The Crust of the Earth. — The solid outside part of the earth is composed of rock. This is covered in most places by a layer of **mantle rock**, a fine material consisting of

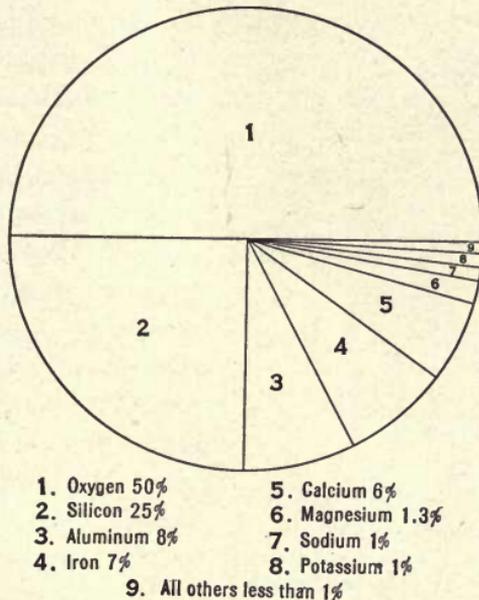


FIG. 82. — PERCENTAGE OF ELEMENTS IN ROCKS

1. What element abundant in living matter is not included in this diagram? 2. About how many elements are known? 3. How many elements must then be included in the "less than 1%"?

soil together with sand, gravel, or clay, which has generally been made from the rocks which it now covers.

188. Minerals. — Rocks consist of minerals. A **mineral** is sometimes an element, but more often it is a definite com-

pound of two or more elements. The five most abundant elements in minerals are oxygen, silicon, aluminum, iron, and calcium. Many others exist in small quantity.

Minerals differ in color, hardness, solubility, and fusibility, and in the form of their crystals. A **crystal** is a body of definite form, having a number of flat, lustrous surfaces. Crystals are formed from the cooling of a melted substance or the evaporation of a solution. Every mineral has its own form of crystal.

189. Ores. — An **ore** is a mineral which is valued for the metal that can be obtained from it. Iron ore is a compound of iron and other elements, one of which is often oxygen. Many ores, as those of silver, lead, and zinc, are compounds of sulphur and the metal. Most minerals contain a small amount of metal, but minerals are not classed as ores unless it is *profitable* to separate the metal from the other elements with which it is combined.

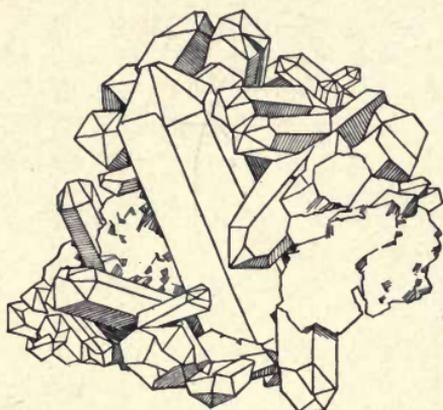


FIG. 83. — QUARTZ CRYSTALS

When solutions of minerals evaporate slowly, or when melted substances cool slowly, crystals of various sizes form. Whatever the size, the faces are planes. In crystals of a given mineral, corresponding faces always make the same angle with each other.

with which the compounds are mixed. The compound is said to be reduced, and the material which produces the separation of the metal is called the **reducing agent**.

If chemical solvents are to be used to remove the metal, the ore is first crushed under huge weights or hammers, called stamps. It is then submitted to the action of chemicals

190. Reduction of Ores. — By **reduction** of an ore is meant the separation of the metal from its compounds and from the rock

which, by solution, remove the metal from the ore. If heat is to be the chief reducing agent, the ore may be used in larger lumps. These lumps are put into a tall, cylindrical blast furnace. A blast furnace is made in such a way that a powerful blast of air can be forced through it to secure *rapid* combustion and therefore a very high temperature.

The reduction of iron is accomplished as follows: Layers of coal or coke, ore, and limestone are built up within the furnace to about two thirds its height, and the fuel is ignited. Since the fuel and ore are arranged in layers, the fire is not confined to the bottom of the furnace, but extends all through the mass. On the top, as the mass settles down, new material is added from time to time. The rock material of the ore and the limestone, which is called a **flux**, melt and unite to form a glass-like substance, known as **slag**.

When the rock has been separated from the ore, what remains is chiefly the oxide of iron. The heating is continued, and the hot carbon of the fuel unites with the oxygen of the iron oxide, forming

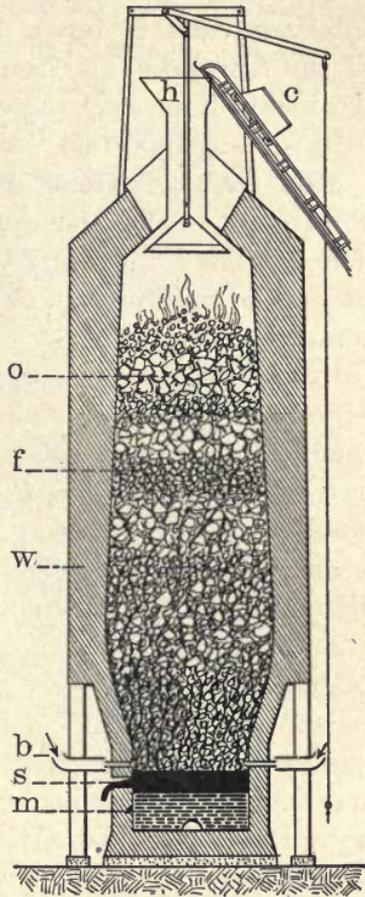


FIG. 84. — A BLAST FURNACE

w = wall lined with fire clay; *f* and *o* = fuel, flux, and ore; *c* = car for bringing the charge to the hopper; *h* = hood receiving waste gases which are used to heat the air blast *b*, which enters near the base; *s* = slag; *m* = melted iron.

The slag and melted iron collect in the lower part of the furnace, whence they are drawn out.

oxides of carbon and leaving the iron nearly pure. The melted metal sinks to the bottom of the furnace and the slag, being lighter than the metal, floats upon it. At intervals each is drawn off through openings in the side of the furnace. The iron runs into trenches in sand, where it cools in bars, and these bars are then broken into convenient lengths called "pigs."

191. Gems. — Gems are minerals valued for their beauty. This quality of beauty depends on color, hardness, and brilliance. The color is often due to a slight trace of some metal present as an impurity, like a stain, which is not a part of the compound.

"Precious stones," or jewels, are cut from gem stones, which are usually crystals. A jewel is generally very much smaller than the crystal from which it is cut, because only a part of the crystal has the clear, uniform color desired and much has to be cut away. The chips are used for jewels in watches and for ornamental settings of other stones. As the diamond is the hardest gem, diamond chips are often bedded in a metal tool for cutting other gems or glass.

192. Quartz. — The most abundant minerals are quartz, feldspar, mica, and calcite. Quartz, also called silica, is composed of the two elements, silicon and oxygen. It occurs in different forms and colors, and so has many names. Rock crystal is a kind of quartz that is colorless and transparent; amethyst is a crystal of purple color; agate is of various colors, sometimes in bands; and flint is dark and horny looking. Rock crystal and amethyst are in the crystalline form; the others are not. All have the same degree of hardness, insolubility in water and acids, and infusibility in fire. Quartz is therefore a very durable mineral. Quartz melts if mixed with soda or potash and heated to a high temperature, and the product is common glass. Finer grades of glass and colored glass are made by adding other mineral compounds.

193. Feldspar. — Feldspar contains the same elements as quartz and, in addition, the elements of lime or soda and of alumina (a very hard mineral, sometimes known as corundum or *emery*). Feldspar is not so hard as quartz, is fusible, and on being exposed to the air crumbles to **clay**. Clay is found in many soils, where it furnishes some elements required by

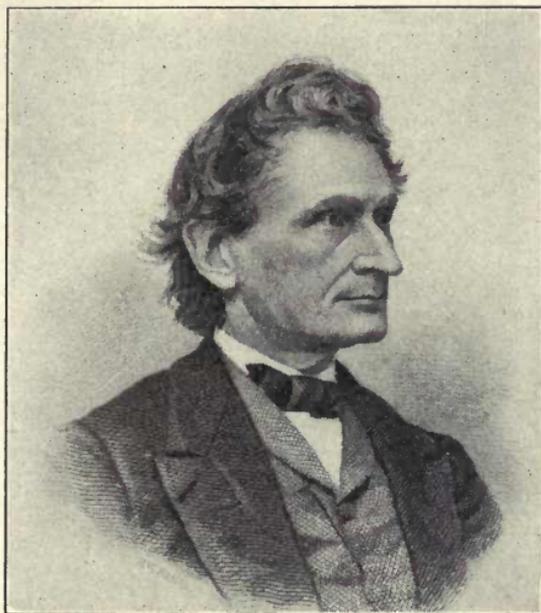


FIG. 85. — JAMES DWIGHT DANA: GEOLOGIST. 1813-1895

The characteristic that most impressed all who came to know him, whether through the reading of his works or through personal intercourse, was his profound sense of the sacredness of truth. . . . Even to extreme old age he remained hospitable to new truth and ready to change opinions. Disloyalty to truth was infidelity to God. In his scientific investigations he always felt, like Kepler, that he was thinking God's thoughts after him. — WILLIAM NORTH RICE in *Leading American Men of Science*.

plants. Because of its fusibility, feldspar is common in volcanic rocks; these rocks on decaying make fertile soil.

Common crockery is made from white clay, pressed into shape and baked. Powdered feldspar is used to make the glazing for the surface. There are feldspar quarries in

Connecticut from which the crushed mineral is shipped to various potteries in New York and New Jersey.

194. Mica. — Mica has a composition similar to feldspar, but it has different properties. It is usually gray or very dark in color, and breaks into thin sheets, which are almost transparent and are very tough. It does not decompose as readily as feldspar. The shining scales found in sand and sandstone are mica. Sheets of mica, commonly called *isinglass*, are used in the doors of stoves, because mica is not affected by the heat and the fire can be seen through it.

195. Hornblende. — Hornblende is another mineral similar to feldspar in composition. Very small pieces of hornblende often look like mica. Unlike mica, however, it is brittle and does not split into thin layers. It has various colors and forms. One kind, called *asbestos*, is fibrous; its threads are made into a kind of paper or cloth. Asbestos is used to protect surfaces from heat, because it is non-combustible and infusible and is also a non-conductor of heat. It is often used for a covering to furnace and steam pipes, to prevent the radiation of heat from the pipes.

Quartz, feldspar, and either mica or hornblende are the minerals which compose the great class of rocks known as granite.

196. Calcite. — Calcite, or carbonate of lime, is the name of a mineral composed of calcium, carbon, and oxygen. It is sometimes found in the form of clear, transparent crystals, but more often it occurs in an opaque, non-crystalline form called **limestone**. Limestone is white or gray, and is much softer than quartz. On being heated, it gives off carbon dioxide and leaves lime.

Limestone is soluble in water in which carbon dioxide has been dissolved. Rain water that has passed through the soil contains dissolved carbon dioxide obtained from the air and the decay of plants. As this water flows over and

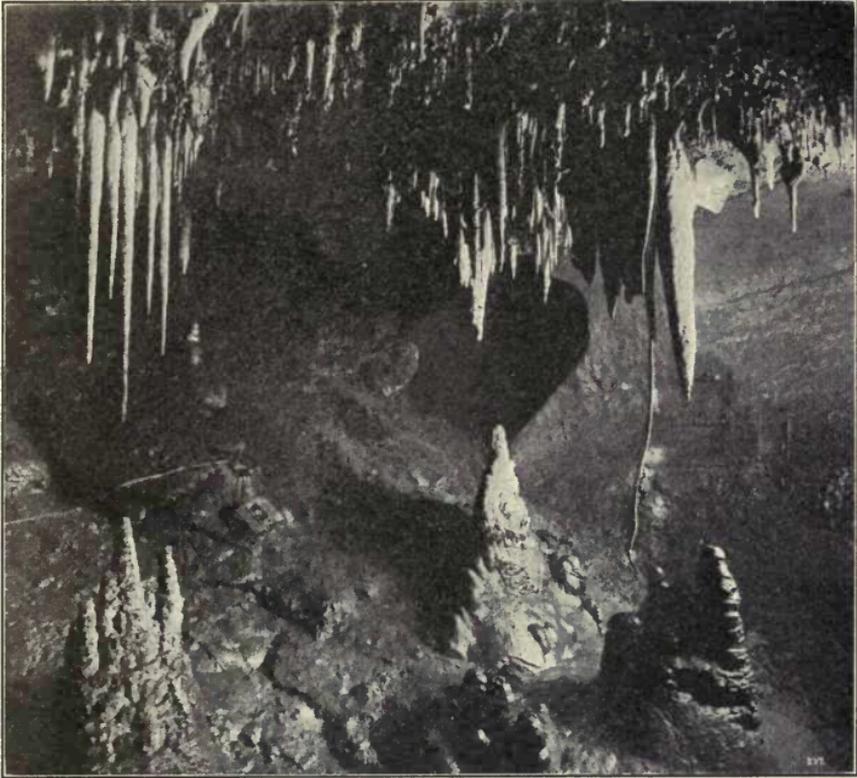


FIG. 86. — IN THE CAVE OF THE WINDS, MANITOU, COLORADO

This cave has been made in limestone rock by water which has trickled through and dissolved the calcium carbonate. 1. What name is given to the hanging masses? 2. How are the masses on the floor formed? 3. In what respect, beside form, do they differ from the roof and sides of the cave?

through limestone, it dissolves some of the rock, leaving crevices and sometimes large caverns. Later, as the water trickles through the roofs of such caverns, some of the water evaporates and leaves limestone pendants of *crystallized* calcite, hanging like icicles from the roof. The falling drops leave on the floor a deposit of limestone which gradually accumulates and makes a little mound. The pendants are **stalactites**, and the mounds are **stalagmites**. They extend toward each other, until they meet and gradually form a

column, which increases in size as the trickling water deposits more and more material. The Mammoth Cave in Kentucky, the Luray Caverns in Virginia, and the caves of the cliff dwellings in Colorado are the result of the dissolving and removing of limestone rock by underground waters.

197. Marble. — Calcite which has been changed from the ordinary form of limestone to a crystalline condition is called marble. A broken piece of marble has a glistening look, because every face of the tiny crystals of which it is composed is smooth and shining. The Washington Monument and many public buildings at the national capital are built of coarse-grained marble. Statuary is made of a finer grained marble, free from stains. The marble quarried at Carrara, Italy, is highly prized for this purpose. Most of the marble used for building in the United States is from Vermont; quarries in Tennessee furnish much of our marble for interior use.

198. Gypsum. — Gypsum is a sulphate of lime. It is a white mineral which is found dissolved in sea water and is deposited after the water evaporates. It is sometimes found in large masses of rock. When fine and translucent, it is called *alabaster*, and is used for ornaments. A coarser kind of gypsum, on being heated, crumbles to a powder, which is called **plaster of Paris**. This is used extensively as a wall finish. If water is added to the plaster, it soon hardens into a solid mass. In this way, it is used by artists to make plaster casts, and by surgeons to form a rigid support for a broken limb.

199. Petrifications. — When plants and animals decay under the ground and in the presence of water containing dissolved mineral matter (such as silica or calcite), the mineral sometimes takes the place of the decaying material. Although the old form and frequently the old color remain, a stone body results. This is called a **petrification** or a petrified body.

In some places, as in parts of Arizona and the Yellowstone Park, there are great areas covered with fragments of petrified wood that was buried for long ages. Hundreds of thousands of years ago a forest was there. In the course of time, the trees became submerged, and while under water the wood decayed and its molecules were replaced by molecules of the mineral silica. The trees were petrified. Later the region was elevated; the surface was removed by rain,

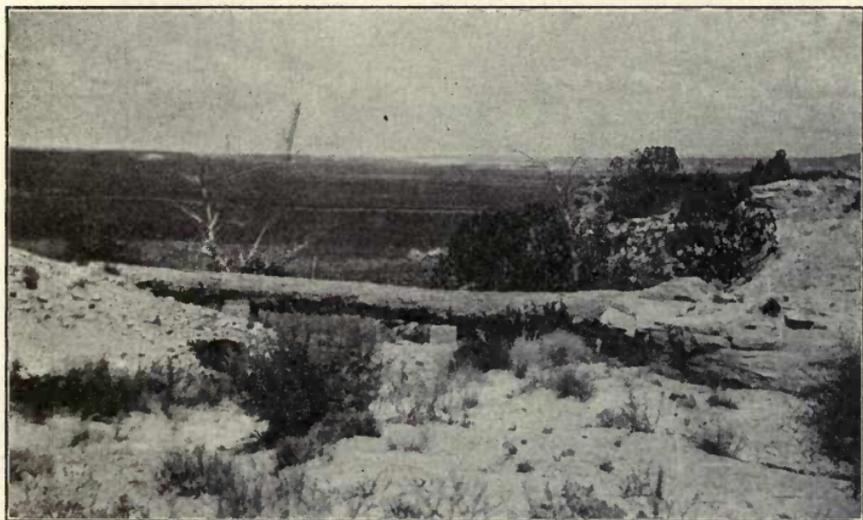


FIG. 87. — NATURAL BRIDGE

This is a large petrified tree trunk in the petrified forest at Adamana, Arizona. This tree must have fallen, been covered with water containing silica, and petrified while submerged. In the erosion which has since occurred, earth has been taken from underneath, leaving it across a gully or arroyo.

wind, and running water; and now stone trunks of trees and broken fragments lie on the surface of the sandy plain.

200. Importance of the Study of Minerals. — A description of minerals, some of which we have never seen, is rather uninteresting. It seems of no use to know whether calcite is soluble, whether feldspar crumbles, whether quartz is hard or soft. When we associate these facts with others, however,

we find that they help to explain some very important and interesting things about our home, the earth. How the rocks were made; where the material came from; why some rocks are under water and some above; why some hills are higher than others; why some are rounded and some sharp; why some plateaus are deeply cut and others plain — these are a few of the questions that depend, for their answers, on a knowledge of minerals.

An old proverb says that "A chain is not stronger than its weakest link." We might borrow the form and say that a rock is not more lasting than its softest mineral. The hills are not everlasting, although they remain apparently unchanged for many generations of human life. The durability of the rocks of which they are made depends largely upon the hardness and solubility of the minerals which compose the rocks.

EXERCISES

1. Which is more valuable, a gem cut from rock crystal or one made from amethyst? Why?
2. Asbestos may be woven like thread or made into sheets like paper, but it has a property entirely different from either thread or paper. What is this property?
3. For what purposes is asbestos cloth or asbestos paper used?
4. What mineral is a large constituent of volcanic rocks? Why?
5. The soil on the old slopes of Vesuvius is very fertile. Give a reason, remembering that soil is partly made of decomposed rock.
6. Why are underground caves never made in granite rock?
7. Why does it not always prove profitable to take the gold from a vein?
8. Why cannot quartz, as well as feldspar, be made into pottery?
9. Give directions for preparing some crystals of salt, or copper sulphate, or alum.
10. Explain why stalactites show a crystalline structure.
11. Arrange the following in groups, as *rocks* or *minerals*: marble, agate, iron ore, sandstone, calcite, granite, feldspar, limestone, gypsum, quartz, asbestos, amethyst, mica.

CHAPTER XV

THE CRUST OF THE EARTH, MAN'S STOREHOUSE

201. The Formation of the Earth's Crust. — We do not know what was the beginning of the earth, how it came to have a cold surface and a hot interior, or where the atmosphere and the oceans came from. But we do know that millions of years ago melted rock was squeezed out from the interior of the earth and became solid at the surface. The rocks within reach of the water at once began to wear away, as the waves beat upon them.

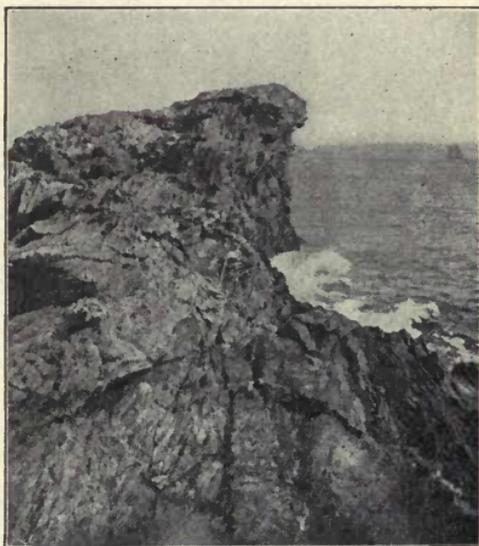


FIG. 88. — WATER-WORN ROCKS

Some of the soluble minerals composing the rocks were dissolved, and the insoluble minerals formed fragments and grains of different sizes, more or less water-worn.

Finally these fragments were distributed in beds or layers by the action of the waves and currents. The spaces between the fragments became filled with a cementing substance obtained from the dissolved minerals, and thus the whole mass was consolidated or bound together into new rock.

In the course of time, many of the rocks were changed into crystalline rocks. From that far-away age of the world even up to the present time, rocks have been, and still are, in the process of formation.

Rocks are divided, according to the way they were made, into three classes: igneous, sedimentary, and metamorphic.



FIG. 89. — A GRANITE QUARRY

Observe the irregular surfaces of the rock exposed, unlike those of Figs. 90 and 91. When this igneous rock contracted as it solidified, cracks called joint planes were made. 1. What is their general direction with regard to the earth's surface? 2. Are they a help or a hindrance to quarrying?

202. Granite and other Igneous Rock. — Igneous rocks are those which originally rose in a melted condition from within the earth, and afterwards cooled either near the surface or often very far below it. The microscope shows these rocks to be made of crystalline grains of different sizes, neatly fitted together.

Granite is the most common igneous rock. It is of coarse structure and is made up of small crystals of quartz, feldspar, and mica, which can be plainly seen and distinguished. Granite may be gray, red, or pink, varying according to the color of the feldspar. It is one of the hardest and most durable of rocks. It forms a part of most mountain chains; in the wearing down of old mountains, it is often left exposed, sometimes standing in peaks, like the White Mountains and the Sierra Nevadas. The rocks of the New England coast show that granite underlies much of that region.

Granite is used for the foundations and walls of buildings, and for bridges, paving blocks, and monuments. Maine has long been supplying granite to the country, in many varieties of color. All the New England states have large quarries.

Lava is a fine-grained igneous rock which varies greatly in color. Vesuvian lava is very dark; the lavas on the west slope of the Rocky Mountains are light, of reddish-gray color. In the eastern states the lava, which is called trap rock, is a dark bluish-gray and contains a compound of iron. Mount Holyoke in the Connecticut Valley in Massachusetts and the Palisades of the Hudson opposite New York City are ridges of hard trap rock.

203. Sedimentary Rocks. — Sedimentary or fragmental rocks are formed from fragments broken and worn off from older rocks by the action of frost, waves, and wind. These fragments are carried by streams and ocean currents until finally, in quiet water, the sediment falls to the bottom, forming horizontal layers. The finer fragments, being lighter, are carried farther from shore and thus the fragments are assorted according to size. These fragments, in the course of time, are cemented together in great beds or sheets. These are called *strata*, which is the plural of the Latin word *stratum*, meaning "a bed."

The principal sedimentary rocks are conglomerates, sandstones, shales, and limestones.

Conglomerates, or "pudding-stones," are rocks made from beds of sand mixed with pebbles and stones.

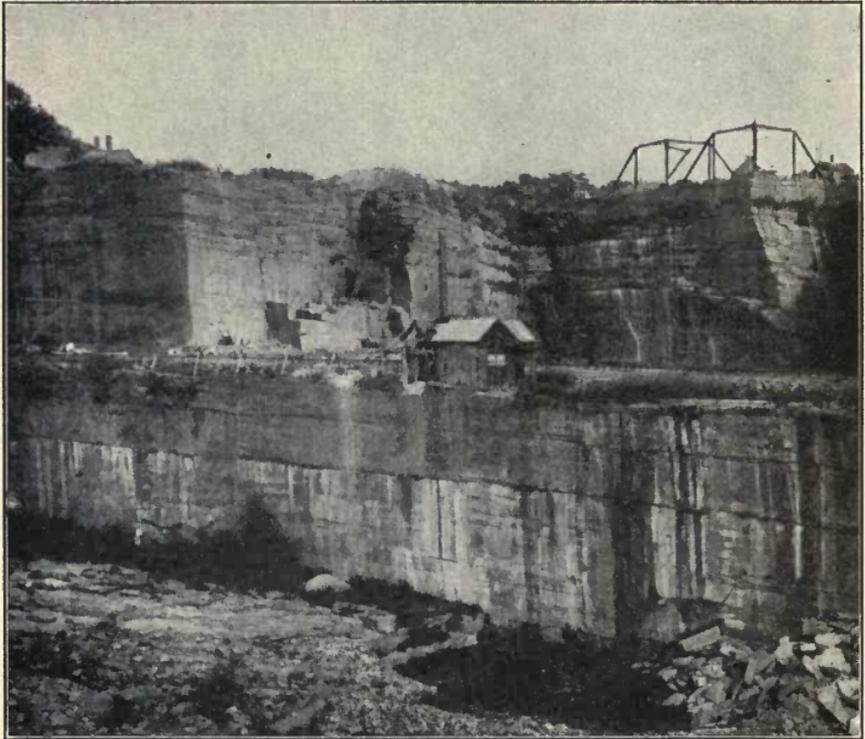


FIG. 90. — A SANDSTONE QUARRY

Find in this picture evidence: 1. That layers of sediment are not all of the same thickness. 2. That these strata have not been much disturbed by uplifts.

Sandstones are made from sand beds, the grains of which are mainly quartz. They are the most common rocks. A well-cemented conglomerate or sandstone makes a very durable rock. The so-called brownstone, widely used both as building and as trimming stone, is a sandstone in which the cement is an oxide of iron that gives the stone a reddish-

brown color. Other sandstones are light colored, the cement being silica or bicarbonate of lime.

Shales are consolidated clay beds or mud beds. They often contain mica flakes. As their chief mineral is feldspar, shales decompose readily and make good soil.

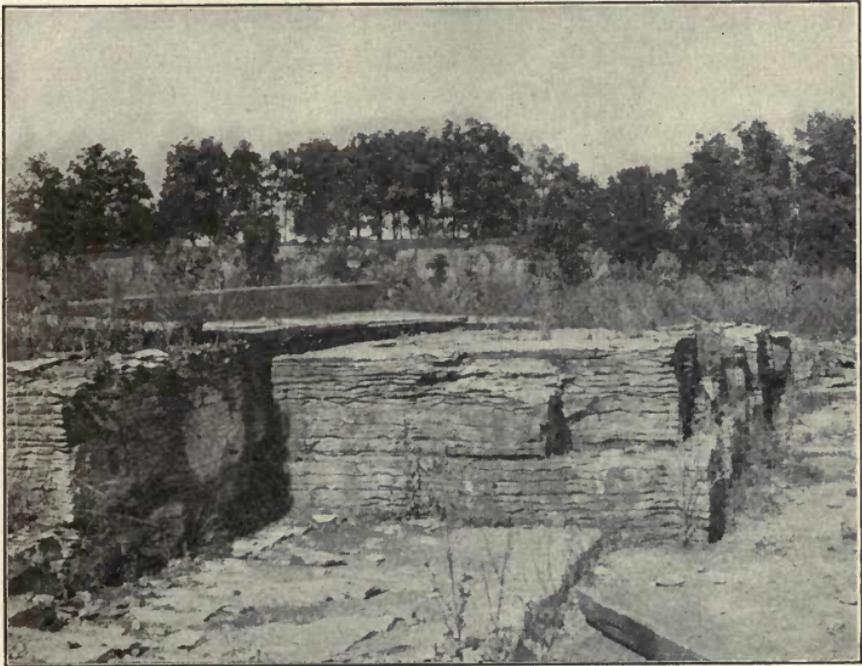


FIG. 91. — LIMESTONE QUARRY NEAR COLUMBUS, OHIO

1. Tell what you can learn by observation about the formation of this rock and any changes that have occurred in it since it was formed.
2. What shows this to be a disused quarry?

Limestone rock is made from animal skeletons, such as shells and coral. The animals get carbonate of lime — of which the skeleton is composed — from the waters of the ocean where it is dissolved. When the animals die, their skeletons are ground up by the action of the waves. The white sand and mud so formed are very fine-grained, and when consolidated make limestone. Sometimes the lime-

stone is colored gray or streaked with black from the carbon in decayed seaweed and animal bodies. The chalk cliffs of Dover, England, are a kind of limestone made from shells so minute that they need no grinding to form a fine-grained rock. Limestone is much used as a building-stone, especially in the central and middle western states.

204. Metamorphic Rocks.—Crystalline rocks which were made from sedimentary or igneous rocks are named metamorphic rocks. These rocks were made by great pressure or heat in the presence of moisture. The heat, not sufficient for melting, was caused by friction between layers of rock when they were bent or pushed up in mountain making.

Metamorphic means "changed in structure." Fragmental limestone changes to crystalline marble, soft shale becomes slate, and sandstone becomes schist.

Two important classes of metamorphic rocks are gneisses and schists: gneisses oftenest produced by metamorphism of granite, and schists by metamorphism of sandstone and shale. Gneisses and schists contain the same minerals as granite, but in different proportions. Gneisses, containing a large proportion of feldspar, split into thick layers; schists, containing more mica, split into thinner layers. Mica schist often contains crystals of the mineral garnet, which is used as a gem.

Some of the flagstones used in the eastern states are of local schists, but the better flagstones are of a clayey sandstone from New York. Curbstones in many cities are cut from gneiss. Much so-called "granite" is really gneiss.

205. Folded Rocks.—Metamorphic rocks in hills and mountains are often composed of layers; in this respect they resemble the sedimentary rocks from which they were evidently made. They are not in the original position of such rocks, but are tilted at various angles. This change in position of the rocks came about in the following way. As the heated interior of the earth cooled, it shrank; and

the colder crust, not being able to fit the shrinking interior, wrinkled and formed what we call mountains. The once horizontal rocks were folded up, while igneous material of the interior was squeezed up into these folds.

206. Dikes and Veins. — Sometimes, in this process of folding, the rocks break, forming deep cracks or **fissures** through which comes *melted* rock. This melted rock *cools* and solidifies, completely filling the fissure with material



FIG. 92. — DIKES; SPANISH PEAKS, COLORADO

The wall-like elevations are of hard lava which once filled fissures in a less hard rock. The latter has been eroded and the lava has been left in ridges from 50 to 100 ft. high. What shows that the ridges have been somewhat eroded?

different from the rock on either side of it. Such a formation is called a **dike**. Its width may be a few inches or hundreds of feet. Its resemblance to an artificial dike is shown when it is harder than the rock near it, for it remains as a ridge after the softer rock has been worn away. If the dike is softer or full of cracks, it will be worn away faster

than the rock around it, but the formation is still called a dike. Many chasms seen in the rocks at the seashore are formed by the wearing out of a dike.

If fissures are filled with minerals left by evaporation from *solution*, the material filling the fissure is called a **vein**. Many valuable ores are veins. Gold is oftenest found in quartz veins.

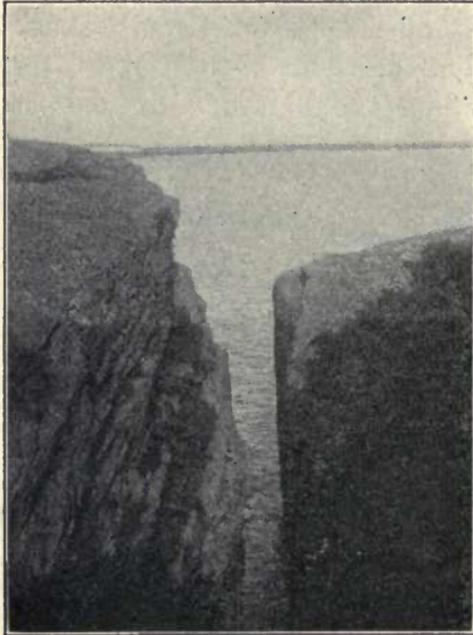


FIG. 93. — A CHASM IN A SEASHORE CLIFF

The opening between the rocks was once filled with igneous rock. There were many cracks in the dike caused by contraction in cooling. 1. How did their presence lead to the removal of the dike? 2. Will the chasm widen as time goes by? Why?

207. The Value of Rocks and Minerals.

— The crust of the earth is a veritable storehouse of materials from which man has drawn for thousands of years. Buildings still standing in ancient cities, as Athens and Rome, show that more than two thousand years ago men knew how to quarry and cut stone. The pyramids of Egypt and the buried temples and palaces of Babylon are even older.

The modern cities of Europe and America require immense quantities of stone, which is shipped from regions where it is accessible, to the place where it is to be used.

The requirements of a good building-stone are firmness of structure, fine grain, and resistance to water and changes of temperature. Sedimentary rocks and rocks which were slowly metamorphosed best fulfill these conditions.

The broad valley between the two great mountain systems of the United States furnishes sedimentary rocks but no metamorphic rock. In this region there are beds of limestone, hundreds of feet thick. In many places the covering of mantle rock is thin and quarries are easily opened. These furnish an inexhaustible supply of material for buildings and for making lime. Lime is necessary for all masonry and concrete work, and is prepared by heating limestone.

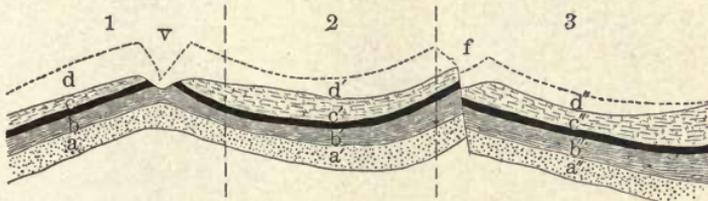


FIG. 94. — FOLDED COAL-BEARING ROCKS

Dotted line = surface when strata were folded. *a*, *b* = fragmental rock. *c* = seam of coal. *d* = present surface. *f* = faulted fracture. *v* = an eroded valley. 1. In which vertical section would the discovery of coal be most likely to occur? Why? 2. In which least likely? Why? 3. How do you account for the thicker covering at *c'*?

The oldest mountains are in the eastern states and California. These furnish the finest metamorphic rocks, granite and gneiss, both of which are called granite commercially. The granite of the Rocky Mountains is a coarse granite. The lavas of the Rocky Mountains are used for trimming stones, but are too porous for other use in regions where the atmosphere is humid.

A source of great industrial prosperity in this country is the coal-supply. Beds of coal lie between beds of shale and sandstone in large areas from Nova Scotia to Iowa and south to Texas, and farther west on the slopes of the Rocky Mountains through Mexico and Central America. Where the strata have been lifted up in mountain making, the coal is fairly accessible. If the strata have been very much com-

pressed, the coal is hard coal, **anthracite**. Through the middle and western states the coal is soft; this is called **bituminous** coal.

Ores of iron, silver, gold, and lead are reckoned of inestimable value to a country; but they would be of little use without coal, which is used as a fuel in separating the metal from the ore.

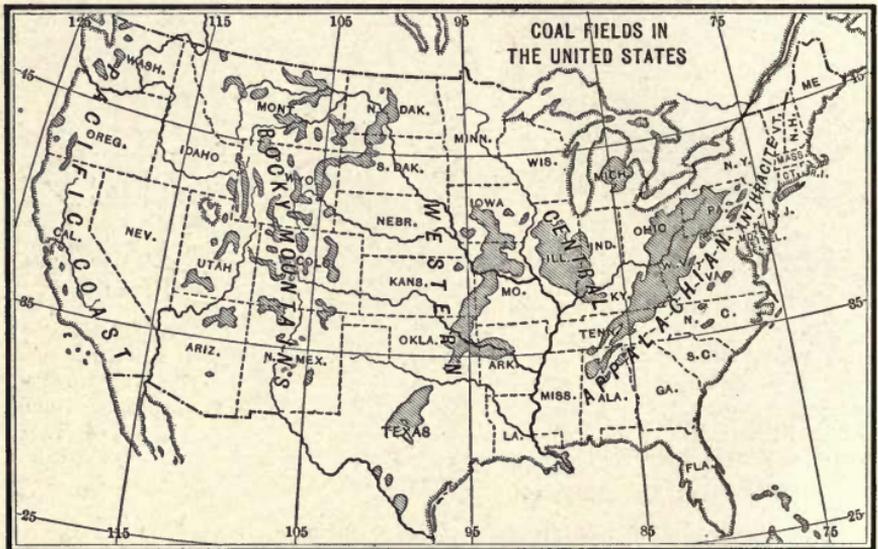


FIG. 95. — COAL FIELDS IN THE UNITED STATES

1. The coal fields of the United States occupy about one sixth of the area of the country (not including Alaska). 1. In which half of the country is the greater supply? 2. In how many states is coal found? 3. What is the importance of its wide distribution?

Petroleum is found in many regions where coal is inaccessible. It is used to some extent as fuel in locomotive engines and steamships.

208. Rock Making at Present. — When it rains, the water flows down the mountain slopes, making rills which combine into torrents; these join and make larger streams which finally reach the ocean. This running water is at work wearing away the earth's crust and making valleys.

It takes away soluble minerals in solution, and carries insoluble fragments with its current to the sea. There the fragments are assorted by the ocean currents and finally are made into sedimentary rock. (LABORATORY MANUAL, Exercise XIX.)

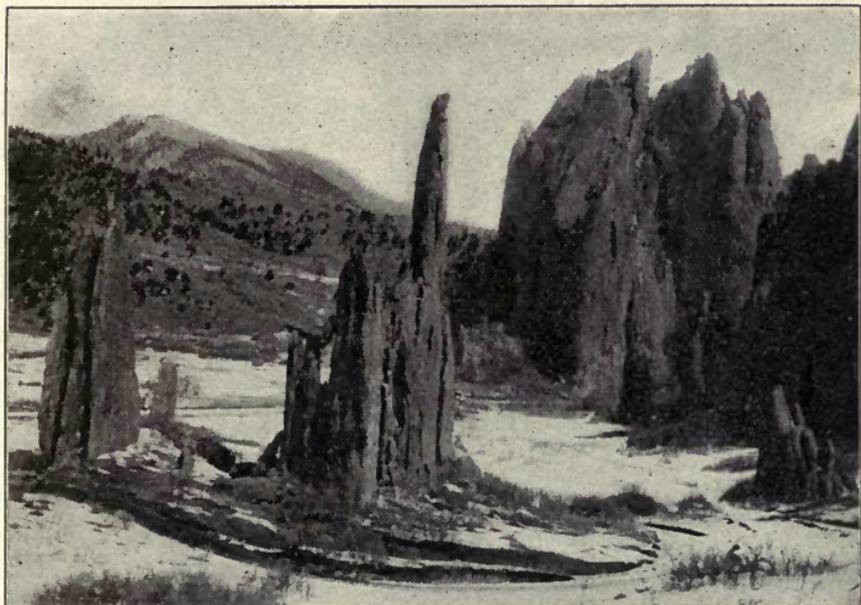


FIG. 96. — CATHEDRAL SPIRES IN THE GARDEN OF THE GODS, MANITOU, COLORADO

These rocks are of soft red sandstone. The highest is more than 200 ft. high. 1. In what position are the layers shown here? 2. What was their position originally? 3. What connection is there between their present position and the rate of erosion?

209. The Age of the Earth. — Just how long a time has been required to bring the earth to its present condition cannot be known exactly. One method of estimating the length of time is by calculation of the average rate of deposit in river deltas whose extent, a few hundred years ago, is known. The time required for the folding into mountains and the wearing down which have followed in some particular



FIG. 97. — FOSSIL FORE LIMB OF AN ANCIENT REPTILE

A "fossil hunter" has been putting plaster of Paris around the bones and in the cracks of this valuable specimen so that it can be safely shipped to some museum. 1. Compare the size of the man's hand and the foot. 2. Compare the length of his arm from wrist to shoulder with the fossil bones between the foot and the upper end.

region must be ascertained by knowledge of the rock material and the agencies at work. The Appalachian Mountain system, about one hundred miles wide, was formed by the folding of strata of fragmental rock many thousands of feet thick. The accumulation of this material under the water is *estimated* to have taken at least thirty-six millions of years. Since that was done, it is thought that one third as much time has elapsed. Scientists conclude, from this estimate alone, that the earth must be many millions of years old.

Another method of judging the age of the earth is by the study of fossils. A **fossil** is the remains or impression of a plant or animal that was buried in mud or sand. The mud or sand afterward became rock and thus preserved the hard parts of the body.

The soft parts decomposed and passed off as gases or liq-

uids, but they left imprints from which the character of the organism can be determined. Fossil leaves are often found on layers of slate in beds of coal.

Only fossils of the *simplest* animals and plants are found in the lower, *older* rocks, while fossils of more complex animals and plants appear in the later rocks. The study of life has shown some of the changes that have occurred since few and simple forms of plants and animals began to live. Long ages must have elapsed during the period when the later, more complex forms of life were developing from the simple forms.

EXERCISES

1. What kinds of matter form the sediment of a river? Where does it come from?
2. Why are layers of shale and sandstone found with coal beds?
3. What does conglomerate rock tell of its origin? Why?
4. Why does the folding of layers of rock produce great heat?
5. What changes in rock does the heat of folding cause?
6. (a) Name the metamorphic rocks made from sandstone and shale.
(b) From limestone.
7. Give a reason why more coal is mined in Pennsylvania than in Indiana.
8. Iron ore from the vicinity of Lake Superior is sent to Pennsylvania for reduction. Give a reason why it is sent so far for reduction.
9. Name three crystalline rocks consisting of the same minerals.

CHAPTER XVI

CONTINENTS; OCEANS

210. The Relation of Land and Water.—If we could view the earth from a great distance, we should see vast stretches of level water broken by smaller areas of uneven land. The water is all one body, though separated into somewhat distinct parts called by different names. The land masses, or continents, are gathered into two groups which almost meet around the north pole. Two thirds of all the land is in the northern half of the globe. The continents are like the tops of great elevated blocks of the earth's crust. Some islands are parts of the same block as the neighboring continent, but many are the summits of ocean mountains and volcanoes.

To the east of the United States, the continental block extends far into the Atlantic Ocean. For a great many miles from the coast the water is shallow; that is, it is six hundred feet deep or less. It then suddenly becomes several thousand feet deep. The place where the water deepens is the eastern edge of the continental block. The portion of this block covered with shallow water is the continental shelf. Newfoundland, Cape Breton Island, Martha's Vineyard, and Nantucket are elevations in the continental shelf.

Sand and mud brought from the land are all the time being deposited upon the continental shelf. As the sediment collects, it adds little by little to the extent of the land, just as the rock waste brought by a river sometimes forms a great delta at the mouth. A slight elevation of the continental shelf may bring above the surface of the water many acres of low barren plain and thus extend the

border of the continent. The now fertile Coastal Plain of the middle and south Atlantic states was added to the continent by elevation of the continental shelf.

211. The Story of the Continents Told by the Rocks. — We have seen how limestone rock was formed at the bottom of the ocean. When beds of limestone are found to-day in the interior of a continent, as they are in Indiana, Kentucky, and neighboring states, it shows that there was once a shallow sea in that region. If the limestone is bordered on some sides by beds of sandstone and shale, it is evident

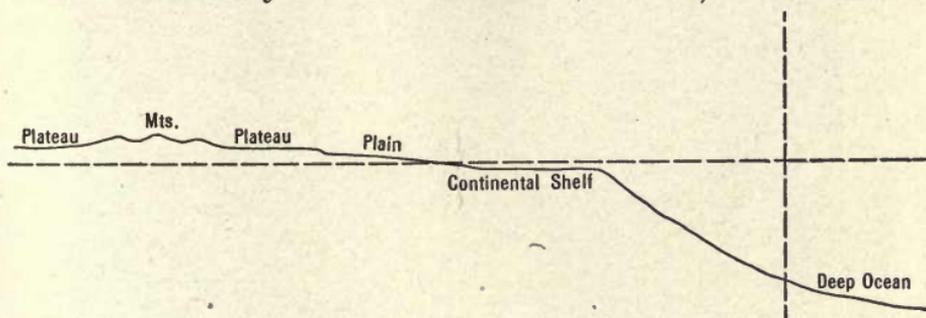


FIG. 98. — THE CONTINENTAL BLOCK

The dotted horizontal line represents the level of the sea; the dotted vertical line represents the eastern limit of a continental block. 1. To what point does the continent extend? 2. What change of elevation would increase its area?

that the limestone was formed in a shallow sea which became unfit for corals and such water animals because of the wash of mud from the land. Corals live only in clear, warm, and shallow waters.

Layers of limestone are sometimes succeeded by layers of sandstone and shale. This shows that corals and shell animals were once abundant there; but as conditions changed, cooler water or muddy water destroyed the life and covered the remains with deposits of sand or mud.

Ripple marks in the rock show where the water was very shallow so that sand and mud were disturbed by wavelets. Imprints made by falling raindrops prove that mud was

out of water (perhaps at low tide) and partly dry when the drops fell. The mud must later have been slowly covered and more mud must have been deposited to fill the imprints of the drops. Such relics are usually found in very thin layers of shale.

By such observations, some of the past history of a continent is learned. It has not always been dry land. Where-



FIG. 99. — LOW TIDE ON A CORAL REEF

The coral polyps whose skeletons have made these stone-like masses, cannot live many hours out of water. The living polyp is always on the surface of a mass representing many generations of ancestors. 1. Which varieties of coral would resist the action of heavy waves longer, the branching skeletons (stag-horn coral) or massive coral like this? 2. Is this scene, then, probably on the shore of an ocean or an interior sea?

ever there is sedimentary rock, at some past time there has been water to deposit sediment. Fossils tell us whether it was salt or fresh water.

212. Changes in the Size of Continents. — Study has shown also that the continents have not maintained a steady growth in size by increase around the borders. In

some period a region which had been dry land was submerged; then later it was again elevated. Some continents have lost by slight subsidences along their borders. After hundreds of years such changes have brought the shore line farther inland than it was at a former time in history.

A curious example of successive falling and rising of the borders of a continent is found at Pozzuoli, Italy. A temple built near the sea long before the Christian era was afterward partly submerged as the land sank. There is no written history of this event and none is needed, for the story is told on the stone pillars of the temple. Upon the stone many feet above the level of the sea, which is now quite distant from the temple, are marks made by sea shells that had grown upon the pillars. They were as securely fastened there as barnacles are on rocks of the shore to-day. These shells were below water when they were parts of living animals; therefore their present position shows the re-elevation of the coast.

An evidence of continued wearing away by waves is seen in the diminishing size of the island of Helgoland in the North Sea. In the year 800 it had a circumference of one

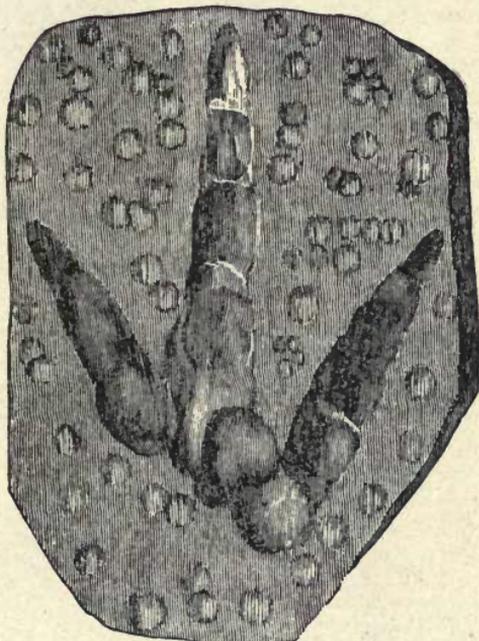


FIG. 100.—FOSSIL RAINDROP IMPRESSIONS

This piece of shale is an old weather report. It tells of a short shower of heavy raindrops on half dried mud. It also tells that an animal with a foot resembling a bird's walked over the mud.



FIG. 101. — RUINS AT POZZUOLI, ITALY

Study of these ruins has shown that: 1. The deposit of several feet of sediment upon the floor caused the building to be abandoned. 2. Later a second floor was laid upon the sediment, indicating that the building was used again. 3. Several feet of deposit were removed 200 years ago, revealing the remains of shells grown upon the pillars. What change of level is indicated (a) by the covering of the first floor? (b) by the laying of the second? (c) by the presence of shells?

hundred and twenty miles. In 1600 it was only eight miles in circumference. It is now much smaller, being a little over a mile long.

213. The Location of Continents in Relation to History. Why the lands of the earth are mainly north of the equator, and why there are land projections to the southward with broad expanses of ocean between, may never be known. If the unoccupied northern lands were in the temperate latitudes of the Pacific Ocean, their climate, the history of the peoples of the earth and their occupations, would have been vastly different. The joining of two continents which are now separated, or the separation of two now joined, would have resulted in great differences in the history of mankind. The spread of peoples, the conquest of races, and the development of industries would all have been different.

214. The First Oceans.— That the first oceans were not pure water is known from the great variety of salts dissolved in the ocean. These salts were probably formed by the chemical action of acid waters on the metals of the rocks.

215. The Composition of Sea Water.— After continents were formed, rivers carried material, both dissolved and in solid form, into the oceans. To-day every soluble mineral substance known in the solid part of the earth is to be found in the sea water. One of the largest constituents of sea water is common salt, which forms $2\frac{1}{2}$ per cent of the weight of the sea water; that is, from 1,000 grams of sea water 25 grams of salt can be obtained. The sea water also contains much dissolved air, which is necessary for the sea animals that breathe by gills. Spray tossed from the waves catches air and carries it back to the sea.

216. The Depth of the Ocean.— The average depth of the ocean is two and one half miles. The greatest depth is about twice as much, while along the shores of the continents a child may sometimes wade safely many rods from

the land. The ocean bed does not slope uniformly from the edge of the continent to the deepest water. There are ridges, plateaus, and even mountain peaks rising from the general plain of the ocean bed.

217. Ocean Temperatures. — Except at the shores, where the water is somewhat warmed by contact with rocks and sand, the ocean is warmed by absorbing heat from the sun. The heat penetrates, however, only a few feet below the

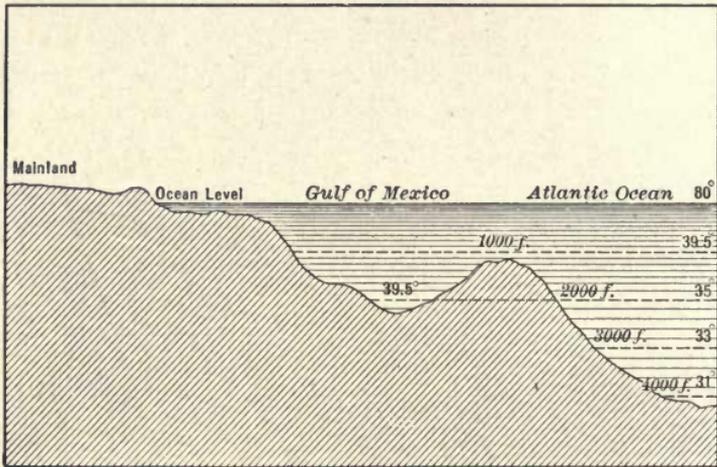


FIG. 102. — TEMPERATURE IN AN ENCLOSED SEA BASIN

Water enters the Gulf of Mexico from the ocean at the strait of Yucatan, where the water is about 1,000 fathoms deep. 1. What is the ocean temperature at that depth? 2. What is the greatest depth of the gulf? 3. What is the temperature of the coldest water that enters the gulf? 4. What is the temperature at the bottom of the gulf? Why is it not so cold as that at the bottom of the ocean?

surface. The temperature of the *surface* water is highest (ranging from 80° to 85° F.) in the tropics, where the sun is directly overhead somewhere every day in the year. At the bottom, the temperature of the ocean the world over is at about freezing point.

If a strait connecting a partly inclosed body of water with the ocean is shallower than the ocean, only the warm sur-

face water passes through the strait into the smaller body. As a consequence, the deepest water of these arms of the ocean is much warmer than that of the ocean depths outside. The Mediterranean Sea and the Gulf of Mexico are both much warmer than the ocean.

218. Currents. — Winds blowing constantly in one direction set in motion currents of water, and so in the ocean there are streams of water flowing through the quieter waters on either side, like a river between its banks. If these currents are warm waters from the tropics, they carry and distribute heat to cooler parts of the world. The Japan Current crosses the wide Pacific Ocean toward southern Alaska, where it is bent southward, and after moderating the climate of the states on the Pacific coast, it swings again westward. Logs from Oregon forests have been carried by this return current and have drifted ashore on the Hawaiian Islands.

Cold currents from the arctic regions make a low average temperature from Labrador to Massachusetts. The warm Gulf Stream, flowing from the Gulf of Mexico northeasterly, carries heat far from the tropics to the northern countries of Europe. From these two causes, there is a great difference between the average temperature of the northeastern part of the United States and that of the same latitudes in Europe.

Steamers sailing from New York to Europe reach the Gulf Stream about the third day out and passengers then find quite superfluous the heavy clothing which they needed at first. The air over the warm water is very humid, and when icebergs drift into or near the Gulf Stream, dense fogs result from the condensation of the vapor carried by the warm air. When the warm current reaches Great Britain, the westerly winds distribute the heat and moisture to Ireland and Scotland and in some degree to England. These lands have not the parched, brown look of much

of the United States in late summer, and the climate is much warmer than that of northern Canada, which is in the same latitude. Even as far north as 60° in Norway, cherries, strawberries, and some vegetables ripen, while in northern Labrador nothing but the hardiest plants grow. There is as little trouble from floating ice in the harbor of the most



FIG. 103. — ST. MARTIN'S HEAD, QUACO, BAY OF FUNDY

1. Give two reasons for thinking this "head" is not a boulder resting against a cliff. 2. This is a low tide scene; high tide at this point may be 30 ft. higher. Using the height of the man as a measure, indicate on the "head" the place which high tide would reach? How do you know that the water at high tide does not cover the rock?

northern Norwegian port as in New York harbor, which is over two thousand miles farther south.

219. Tides. — Besides the ceaseless swinging of the surface water in waves and the onward motion of the currents, there is a regular rise and fall of the water along all shores.

This regular movement of the ocean surface is known as the **tide**. If the shore is steep and precipitous like a wall, the water literally rises and falls vertically, sometimes several feet. Where the shore is gently sloping, with the rising of the tide the water moves farther inland, covering a wide beach, which is again uncovered as the tide falls. The water mark upon a stake driven vertically into the sand at the low-tide line will show to what *vertical* height the water rises at high tide. There is an interval of a little more than six hours between low tide and high tide.

It is known that this piling up of the water is due to the attraction which the sun and the moon have for the part of the earth directly beneath them. The moon, because of its nearness, has a stronger attraction than the sun. The water, which is the movable part of the earth, is actually lifted toward the moon, making a huge wave which follows on across the ocean after the moon.

Currents, waves, and tide have all had a share in making the borders, and in some cases the interior, of continents what they are now.

220. The Life of the Ocean. — The ocean has always been of immense value to man as a source of food supply, and its value is constantly increasing. Nor is its value confined to the population living close to its shores. Thousands of tons of salmon, sardines, and lobsters are annually canned and distributed to places far from the ocean. Cod, herring, and other fish are smoked or preserved by salt. Newfoundland and Norway send supplies to warm countries where fish cannot be so well cured on account of the heat. The use of ice and rapid transit make possible the distribution of fresh ocean foods, and now more than ever we depend upon the ocean for food.

The living things of the ocean have by their shells and other hard parts contributed greatly to making layers of rock, sometimes thousands of feet thick. These rocks are now

parts of mountains, high plains, or the shores of a continent. Sea shells have been found imbedded in rocks in the high Alps of Europe hundreds of miles away from the sea. The upper Mississippi basin of North America is underlaid with layers of coral-limestone rock. Ocean water furnished mineral matter for the food of sea animals, and the skeletons of these animals helped to make the land. The ocean, then, not only furnishes food for man, but has been the origin of large areas of land.

221. The Dependence of Lands upon the Ocean. — If there were no oceans, the earth would be nearly useless to man, for the lands would be deserts. Water from the surface of the ocean is constantly evaporating and passing into the air. Vapor-laden winds from the ocean pass over the continents, the vapor condenses, and rain or snow falls. As soon as rain water touches the earth, its journey back to the ocean begins; and as it creeps slowly through the ground, it brings dissolved minerals to plants, and fills springs and lakes to provide man and beast with drink. During the last stage of its return journey the water, now become a river, furnishes power by which work is done by machines, or by which electric currents are furnished for light and power.

222. Ocean Travel. — Even before the days of the Vikings, men ventured far from land over the seas in search of food, wealth, and new countries. In the last four hundred years, as a result of these ventures, North and South America and Australia have been peopled by Europeans, and great nations have become established. We may now travel comfortably for business, pleasure, or study, completely around the world, over oceans which once confined people to the continents on which they were born. Where continents obstructed an ocean journey, canals have been made, as at Suez and Panama, so that goods may now be carried without change from Boston to Japan by the western as

well as by the eastern route. The long and often dangerous voyage around either the Cape of Good Hope or Cape Horn is a thing of the past.

EXERCISES

1. What is the width in degrees of longitude of all lands lying between the tropics?

2. What is the width of ocean lying between the tropics?

3. How does the extent of ocean compare with that of land in the south temperate zone?

In answering Nos. 4-7, suppose that all the continents were 20° farther south than they are.

4. What countries would the equator then cross?

5. Would any continent extend into the antarctic zone?

6. Would the area of tropical land be increased or diminished?

7. How would conditions in Alaska be changed?

8. What countries of South America does the meridian of Boston cross?

9. In what direction from New York is the main part of South America?

10. What is the only isolated continent?

11. Why is the Red Sea warmer than the Indian Ocean?

12. What changes of level are shown by the ruins of Pozzuoli? Show how these changes are known.

13. To what level can sediment be deposited in ocean water?

CHAPTER XVII

MOUNTAINS; MINING; FORESTRY

223. Changes in Elevation of Lands.—Two kinds of changes in the surface of the earth occur from time to time: elevation or rising, and subsidence or falling. These changes of level are usually due to the contraction and consequent wrinkling of the earth's crust. As a result of the elevation, new land may be lifted above the ocean level, or a portion of a continent may be raised a few feet or thousands of feet, or a great mountain system may be made. The subsidence may reduce the area by bringing portions of a continent below sea level, or it may make valleys between elevations.

Another change of level called **degradation**, or lowering, is going on all the time wherever high land is exposed to the physical and chemical changes caused by air and water. The general name of this work is **erosion**, which means "wearing away." The chief agents of erosion are gravity, running water, moving ice, and wind. In the formation of mountains, erosion plays almost as important a part as elevation.

224. Mountain Making.—Mountains are formed in three ways: by the erosion of high lands; by the breaking and lifting of portions of rock strata as a result of unequal pressures from below; and by the folding of strata over large areas.

225. Mountains of Erosion.—Some elevated lands are composed of horizontal strata which have been lifted so gently from their position beneath the water that the strata have scarcely been disturbed. Slight inequalities of level

have directed the flow of surface waters, which by erosion have made great changes. Cracks in the rocks give entrance to air and water, and thus erosion begins before uplifting ceases. Some minerals in the rocks are more soluble than others and some are softer; thus the rocks wear unequally. The result is a group of peaks or ridges of resistant rock with ravines and valleys of different depths between. The Catskills and the mountains within the great canyon of the Colorado in Arizona are illustrations of mountain formation by erosion.

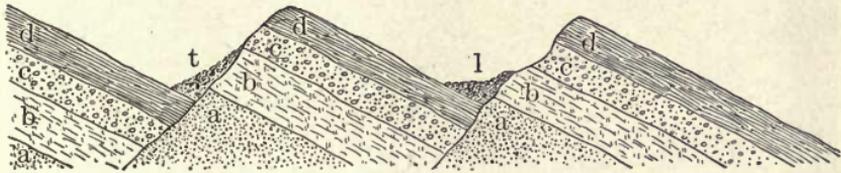


FIG. 104. — FORMATION OF BLOCK MOUNTAINS

a, b, c, d = four rock strata. *t* = fragments of rock called talus.

1. Name at least three changes which have occurred in these strata since they were made at the bottom of the sea. 2. Account for the presence of the talus. 3. Under what conditions might a lake be formed at *l*?

226. Block Mountains. — Another form of elevation was caused by a series of breaks in the strata; one side of the break was pushed up or the other fell. The result is a succession of ridges having a steep slope on one side and a gentle slope on the other. These are called **block mountains**, because at the time of the uplift the strata were broken into blocks. The mountains of the Great Basin in Utah are of this origin.

227. Folded Mountains. — A third form of mountain was made by a series of folds. As fragments of rock worn from the land were brought to the ocean and deposited along the continental shelf, they were consolidated by great pressure, and cemented by heated waters which contained dissolved

quartz or limestone. After a great thickness of sediment had been deposited, its weight weakened the rock beneath. Then contraction and the pressure of the ocean block against the continental block wrinkled the crust and thus a fold was made along the weakened rock. The result was a slowly



FIG. 105. — FOLDED ROCK EXPOSED IN A RAILROAD CUT,
BERTON, VIRGINIA

This is not a part of a mountain now, but it illustrates the first form of some mountains. 1. Is this igneous or sedimentary rock? How do you judge? 2. The camera case upon the rock is about 10 in. long. Estimate the height of the fold.

uprising fold, or sometimes two or even many parallel folds, as in the Appalachian Mountain system. In this way most of the great mountain systems of the world were formed. When they were uplifted, they were near the borders of an ocean or a great interior sea. They have since been worn down so much that all appearance of folding is gone.

Fissures extending to great depth were made when the rigid rock beds were folded, and erosion has made sharp peaks and narrow clefts. Such mountains are called young mountains, as if there had not been *time* enough for the work of the atmosphere to smooth the rough places, round the sharp points, and carry rock fragments down the sides into valleys where they might be borne away by the streams. Sometimes young mountains are older in *years* than others which appear older, because hardness of the rock or an arid climate has delayed the work of change, and their features are still rugged.

228. Degradation.— The process of lowering the land has been occurring ever since there was any land above the level of the sea. The work of the atmosphere tends to separate and loosen particles at the surface of the rock; wind and rain carry them away. The result of this work is **denudation** or uncovering. A new surface is then exposed, and the work continues, all the time lowering the average level of the land. But while degradation is taking place, the land is also being raised slowly by the wrinkling of the solid crust of the earth, so that the land has not yet been brought down to the level of the ocean. The Appalachian Mountains have been degraded from an original height equal to that of the Rocky Mountains. The Adirondacks and White Mountains are much degraded and southern New England is worn down almost to a plain.

229. Veins.— The folding of the rocks of the earth, the breaking which accompanies folding, and the erosion which follows, have been the means of bringing valuable minerals near the surface on mountain sides. Here they can be more easily mined than if they lay far below a level surface. In the process of formation, the fissures in the rocks were filled with minerals in solution or in a state of vapor. Crystals were deposited from these solutions on the sides of the fissures, sometimes completely filling them. Such

formations are called veins. They may contain grains of copper, gold, and silver, with quartz and other minerals. Sometimes the material filling the vein is a compound of a metal, and by reduction the pure metal can be obtained.

230. Mining.—Metal-bearing veins occur oftenest in regions of disturbed and broken rocks which are found in the mountain folds. If the upper rock is fractured or is soft, it becomes worn away and thus a vein may be ex-

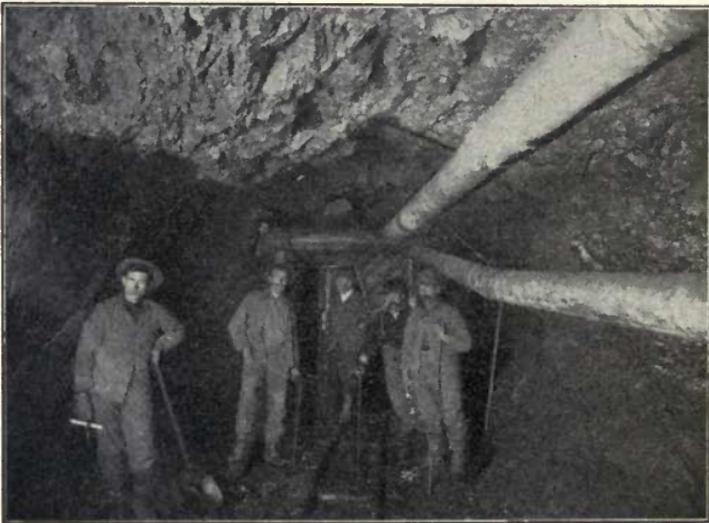


FIG. 106. — INTERIOR OF A MINE

This tunnel enters the mountain horizontally. The large pipes furnish compressed air for running machinery for drilling. The track is for transportation of materials used in or procured from the mine. 1. Mention material of both kinds. 2. Is it better to have a level or an inclined track? Why?

posed for a short distance. In other instances, particles of the metal, or its ore, may be found on the mountain slope, but the end of the vein itself may be as completely covered with fallen rock waste as the rest of the mountain side. Mines are frequently opened on the slopes of a mountain, where by tunneling horizontally many veins may be crossed. The most promising vein is then followed as far as possible.

The material removed in tunneling is usually taken to the mouth of the tunnel, and there dumped on the mountain side. For one mine in operation, there are many heaps of "dump" which show where unsuccessful openings have been made.



FIG. 107. — MARSHALL PASS ON THE DENVER AND RIO GRANDE RAILROAD, COLORADO

This is one of the highest mountain passes (nearly 11,000 ft.) in the Rocky Mountains. 1. How many distinct levels of track are seen on this side of the pass? 2. The road rises about 3,000 ft. in 25 miles. What is the average rise per mile?

231. The Influence of Mountains.—The location of mountain ranges has had a great influence upon human history. In olden times mountain chains were such obstructions to travel that people living on one side knew nothing of those on the other. The Pyrenees, the Caucasus Mountains, the Andes, and the Himalayas are examples of barriers between

countries. In the settlement of North America it took two hundred years for the population to spread beyond even the low ridges of the Appalachians. With the advance in the science of engineering, however, and the application of steam power in locomotives, railroads have been built over and through very high mountains.

The railroad often makes long detours to take advantage of a valley cutting through a ridge, or winds back and forth on a long slope, rising at each turn a few feet above the last stretch of road. In climbing a mountain a few thousand feet in elevation, the train may travel many times the distance across the range, and when near the highest part, passengers may look down upon several parallel stretches of road over which they have passed.

On some of the railroads crossing the Rocky Mountains in the United States tunnels have been built through the highest parts of the mountains. This is done to save the time that would be required to haul the train over the top, and also to avoid the obstruction of the track by snow avalanches. The greatest tunnel in the world is over twelve miles long, through the Simplon Mountain between Switzerland and Italy.

Mountains are famed as health resorts on account of the purity and dryness of the air, and for summer homes because of their coolness in comparison with lower regions. The average decrease in temperature is about 15° F. for every 5,000 feet of ascent.

Mountains act as barriers to the spread of plants and animals from one part of the country to another. Because of cold and thin soil, trees do not grow above certain elevations, called the timber line. If the summit rises beyond the timber line, trees cannot spread from one side of a range to the other. Above the timber line the ground is covered with short grass and other plants which do not require long seasons. As a rule, the flowers of mountain plants are short

stemmed and of brilliant color, so that where there is any soil, the ground is covered with a variegated carpet. But these plants are, like trees, adapted to their surroundings and are not found beyond certain elevations. The summits of high mountains, even when not snow-covered, are often destitute of life.

High mountains furnish an obstacle to wind and thus affect the climate. Winds blowing from the ocean are moist



FIG. 108. — TIMBER LINE, PIKE'S PEAK

How do you account for the fact that pine trees are found higher up the mountains than other kinds of trees?

winds. As they meet a mountain range, the air rises; it is then cooled and the vapor condenses. Rain or snow falls on the slope toward the ocean, and a dry wind passes over. The western slopes of the Sierra Nevadas are well watered; the plains to the east are deserts.

232. Forests and Forestry.—With the exception of a few forest-covered plains in the northern states, the moun-

tains bear the forests of our country. When the pioneers entered a new region, their first need was ground suited for agriculture. Low plains along the rivers were ready for plowing and planting; but in the East, which was settled earliest, the plains were very soon occupied, and then began the felling of "the forest primeval."

People are now beginning to realize that the methods



FIG. 109. — SCENE FROM A WESTERN FOREST

1. Observe the standing timber and tell what it promises as a beginning for a new forest.
2. What do the owners gain by this method of lumbering?
3. What forest "enemy" have they introduced?

properly employed by the pioneers in clearing fields for agriculture should not be used in securing wood for building, furniture, or fuel. Much waste has occurred from ignorance of right methods and from selfish desire for the present profit only. Young trees too small to be of value have been cut and burned to clear the way for removing larger trunks. The branches cut from the trees have been left

to decay slowly, or to become fuel for accidental forest fires. In the first case, new growth is prevented; in the second, much young timber is destroyed.

Forestry is now recognized as a most valuable study. Its object is to discover and use the best methods of managing forests.



FIG. 110. — CONSERVATIVE LUMBERING

“Like the plant of a successful manufacturer, a forest should increase in productiveness and value year by year.”—*Practical Forestry*, U. S. Department of Agriculture. 1. In this picture, what shows that the owner agrees with the Chief Forester’s opinion as stated above? 2. What is the evidence that he desires to get the greatest net money return from the forest?

233. The Division of Forestry.—The United States has reserved many large tracts of forest land, mainly in the Appalachian, Rocky, and Sierra Nevada mountains. The care for the growth, protection, and cutting of trees in these reservations is in the hands of the Forest Service. This

is an organized body of trained men working in the Forestry Division of the Department of Agriculture. Several states also and many individuals have reserved forest land for the purpose of scientific management. A forest can be made to yield a steady income by right methods of cutting trees of a proper size without injury to smaller ones, by careful removal of material which would be fuel for accidental fires, and by replanting areas which have been cleared.

State agricultural schools and some universities have established Schools of Forestry to fit men for the position of foresters. To be qualified for the position, a man must know, among other things, the requirements of different kinds of trees as to soil, temperature, light, and water; the methods by which each kind of tree distributes its seed; the conditions which favor the growth of trees from the seed; and the kinds of trees which grow best together.

234. Forest Enemies. — The enemies of the forest, which the forester must recognize, are fire, reckless lumbering, sheep grazing, wind, insects, squirrels, and mice. Each enemy must be fought by the best means available, and these the forester must be able to discover and use. The methods used by the official foresters can be employed with profit by every owner of a wood lot.

235. Forests and Rainfall. — Much has been said about the effects of forests upon rainfall, climate, and floods. It has not yet been proved that the presence of forests increases rainfall or changes climate, but there is no doubt that the *removal* of forests from large areas helps to cause floods in times of great rainfall. The soil of a living forest is deep and spongy, and prevents the rain water from flowing immediately into streams; and the surface of the leaves upon the trees and undergrowth holds part of the fallen rain. Thus the streams are not so suddenly filled to flood heights. With the protecting forest removed, the ground becomes hard; and when the soil can hold no water, the

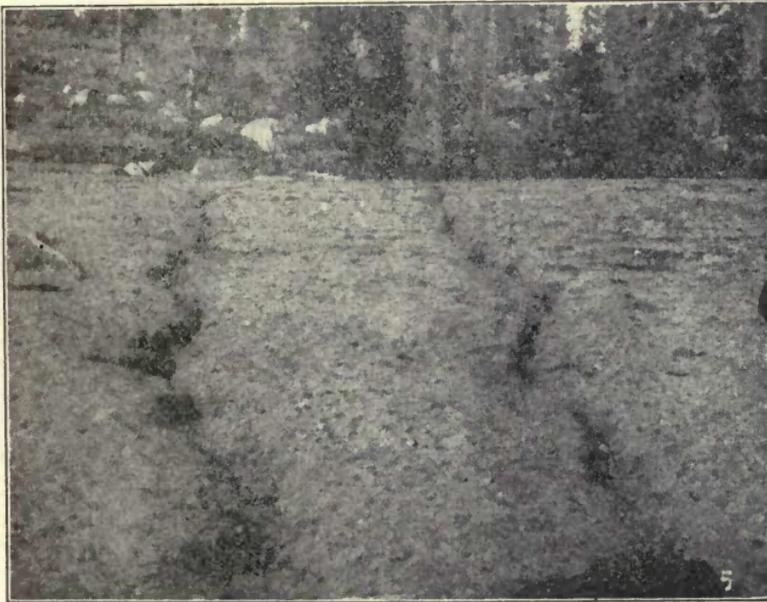


FIG. 111. — A FOREST ENEMY; RESULTS OF GRAZING

Relate the story told by these pictures of a forest region in the Pacific states and tell of its probable future.

fallen rain must run off. Excessive rainfall *may* produce floods even in forested regions; it will *surely* do so in deforested regions.

China suffers greatly from floods. Its forests long ago disappeared, as every inch of land was needed to produce food for the dense population. In southern California floods from the deforested San Bernardino Mountains have covered fertile lands with sand and gravel. Later, in the dry season, when water is needed for irrigation, there is none in the beds of the streams, because the water was not held back by the trees nor absorbed by the spongy forest floor.

236. The National Importance of Forests.— Young forests are sometimes destroyed by fire or by grazing. Denu- dation follows, and the soil, from which a new forest might have grown, is carried away to the sea. Correction of damage done by floods has already cost France thirty-five million dollars and the task is still unfinished. These floods resulted from the destruction of forests by the grazing of sheep.

The prosperity of a nation depends upon its ability to provide food, water, and fuel for its people. Soil, rivers, and forests are necessary to this provision. There is no more important duty of the government than to guard with care and to develop the sources of its prosperity.

EXERCISES

1. How early in the history of a mountain or a continent does degradation begin?
2. Explain what is meant by the statement that "gravity assists in degradation."
3. Why is the work of frost more rapid in mountains than in plains?
4. What is the appearance of young mountains? Why?
5. Why is the air purer on mountains than on lowlands?
6. Tell why there are desert regions north of the Himalayas.
7. How long must the track of a railroad be, in order to reach an elevation of $1\frac{1}{2}$ miles at a uniform 4% grade (a rise of 4 ft. in 100 ft. of track)?

8. In what sort of places are most of the gold and silver mines located?

9. Explain the fact that the gold earliest found in California was in the sands of old river beds.

10. Why is there a short season for growth of plants on high mountains?

11. Name some kind of injury that can be done by each of the forest enemies named in § 234.

CHAPTER XVIII

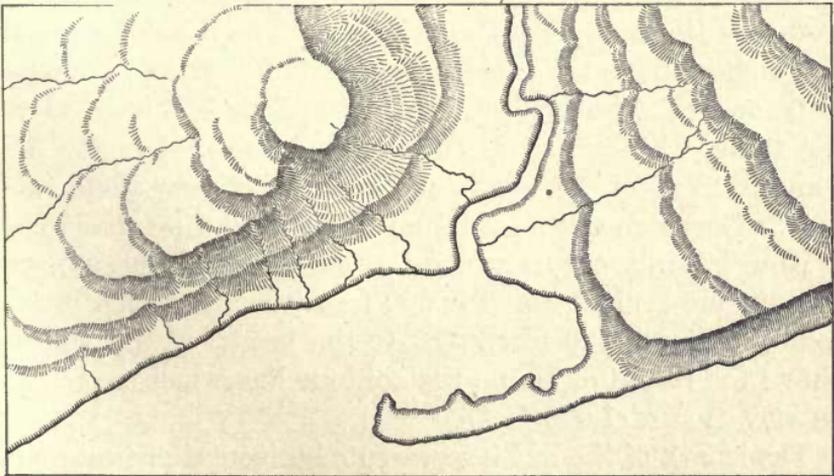
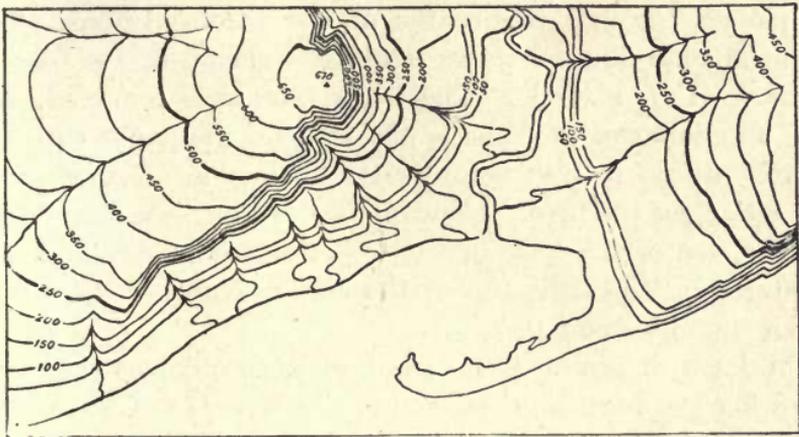
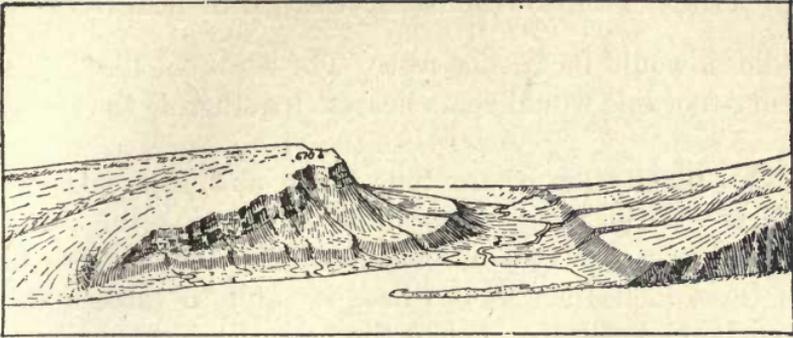
TOPOGRAPHIC MAPS

237. Map Making.—By the **topography** of a continent or region is meant the description of its physical features — mountains, plains, rivers. There are several ways of representing differences of elevation of a tract of country. One is the method of **relief maps** by which the region is pictured as if carved from a solid block. Another is the method of **hachures** or shadings, by which the steeper slopes are represented by heavier shadings.

A third method is that of **contour lines**. This method is now used in all topographic maps published by the United States government. It is superior to the other methods because it shows not only the location of all physical features, but also the exact elevation of any point on the map.

238. Contour Lines and Intervals.—A contour line is a line on which every point represents the same level. Suppose we stand at the shore of the ocean; we are at sea level. Other people at various places on the shore are at the same level. A line representing the shore is the contour line of zero feet above sea level. One person might climb a cliff a few feet away from the water and at the top stand twenty feet above the sea level, while another might walk twenty rods from the shore before he rises to the same level as the top of the cliff. The same contour line would pass through the points where these two people stand, but it would not be parallel to the shore line.

The space between the two contour lines would represent the *horizontal* distance from the shore to the twenty-foot elevation. The **contour interval**, or *vertical* distance between



FIGS. 112, 113, 114. CONTOUR, RELIEF, AND HACHURE MAPS

1. What kind of region is represented by these maps? 2. Which best shows the topography? 3. Which gives the most exact information about the elevations? 4. Which would be easiest to make from observation?

the lines, would be twenty feet. The zero-foot line and the twenty-foot line would come nearest together at the steepest place.

239. Illustration of Contour Lines and Intervals.— To illustrate the use of contour lines in showing the form of the land, suppose that a cone measuring three inches high and three inches across the base is cut into three sections of equal thickness, parallel to the base. A long pin or wire is passed through the center of the three sections. The cone is placed upon paper and the outline of its base is drawn. It is a circle. The lower section is removed, and the remainder of the cone is placed upon the paper with the center where it was before. Its outline is another circle smaller than the first. Continuing the work, we get a circle of the size of the base of the upper section. A dot at the center represents the top of the cone. Number the circles from the outer one, 0, 1, 2.

Make a diagram of the front view (profile) of the cone, showing the horizontal sections. On the side of the profile number the base 0, the first line 1, and the second line 2. Compare the cone with the diagram. The base of the cone is 0 inches above the table. The circle 0 is the contour line of 0 inches. The first section of the cone is 1 inch above the table; the circle 1 is the contour line of 1 inch. The contour interval, the vertical distance between them, is 1 inch. Compare other points on the cone and on the circles.

Now let this cone represent a cone-shaped volcano, the contour interval of which is 500 feet (that is, 1 inch on the cone represents 500 feet). State the height of the volcano above the level 0. Name the contour line which represents an elevation of 1,000 feet.

The length of the line 0 represents horizontal distance, and the diameters of all the circles represent horizontal distances. The base of the cone extends three inches from east to west, three inches from north to south. The point 1

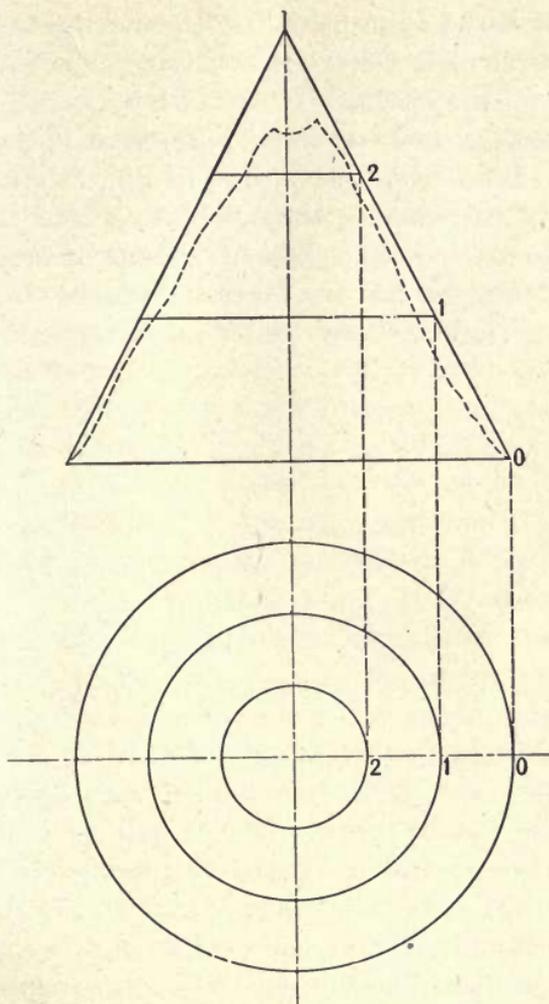


FIG. 115. A CONE REPRESENTED BY CONTOUR LINES

The upper figure is a profile of a cone cut into 3 horizontal sections, as described in § 239. The lower figure represents by its outer circle the base of the cone; the second circle (1) represents the base of the portion of the cone above 1, the lower section being removed. 1. What circle would represent the journey of an insect around the base of the cone? 2. Around the cone at the point 2? 3. If the insect crawled to the summit, where would it be in respect to the circular figure?

is farther west than the point 0. It cuts the line 0 just as far to the west of 0 as the point 1 on the circle is west of the point 0 on the circle.

Land forms are not perfectly symmetrical, as a cone or a globe is. Let the dotted outline in Fig. 115 represent the real profile of an eroded volcano. The contour lines of this volcano are not circles. The horizontal distance between them is not uniform, but the vertical distance between them is uniform. (LABORATORY MANUAL, Exercise XX.)

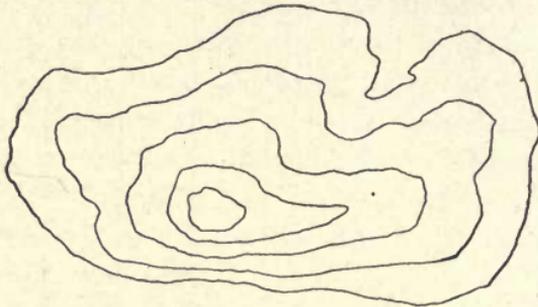


FIG. 116. — CONTOUR OF AN ISLAND

240. Reading a Contour Map. — Fig. 116 is a contour map of an island. The difference of elevation represented by successive lines is 50 feet. The island is 5 miles long. Determine the elevation of the highest part. Name by direction the line of steepest slope; that of the most gentle decline. Compute the average descent on the longest slope, giving the number of feet of descent to the mile.

A line at the base of a mountain range may be 500 feet above sea level. Calculating from that, we can estimate the altitude of the summit above the surrounding country and above sea level by counting the number of lines above the base and multiplying by the number of feet in the contour interval. (See Fig. 113.)

241. Valley Contours. — In following streams on a topographic map, it is seen that the contour line nearest one bank of a stream is of the same elevation as the line nearest

the other bank. If the two lines are followed upstream, it is found that they are both really parts of a single line, which crosses the stream somewhere. Farther up the stream the land is higher than this first line, and at a longer or shorter interval, according to the slope, another line is found crossing the stream. The contour lines consequently bend upstream. Where there is no stream, a similar upward bend of contours shows the presence of a valley, as is indicated in Fig. 116.

242. Reservoirs.— If at any place a wall is built across a valley with its top at the elevation of the contour nearest to the stream, the water flowing down the valley will be stopped by the wall. When the water has reached the top of the wall, it will have overflowed the banks of the river to the first contour level. A narrow reservoir will be formed, with the water setting back upstream to the place where the contour line crosses the stream. If the dam should be built between the second contour lines from the river, the reservoir would be deeper (as much deeper as the number of feet in the contour interval), and the water would set back to the crossing of the second contour.

243. Topographic Maps of the United States.— The United States Geological Survey has undertaken the work of making topographic maps of the whole country. Each state shares the expense of printing the maps after the government survey has been made. The scale of the maps is about one mile to the inch. If all the maps were put together to make a map of the United States, they would measure about 250 feet from east to west. Each sheet of the government maps represents a piece of country thirteen miles wide (east to west) and seventeen miles long (north to south). Contour lines are in brown ink; lines representing man's work, such as boundary lines, roads, and railroads, are in black; water is in blue. Houses on a country road are shown by black dots; city and town streets are solid black lines. (LABORATORY MANUAL, Exercise XXI.)

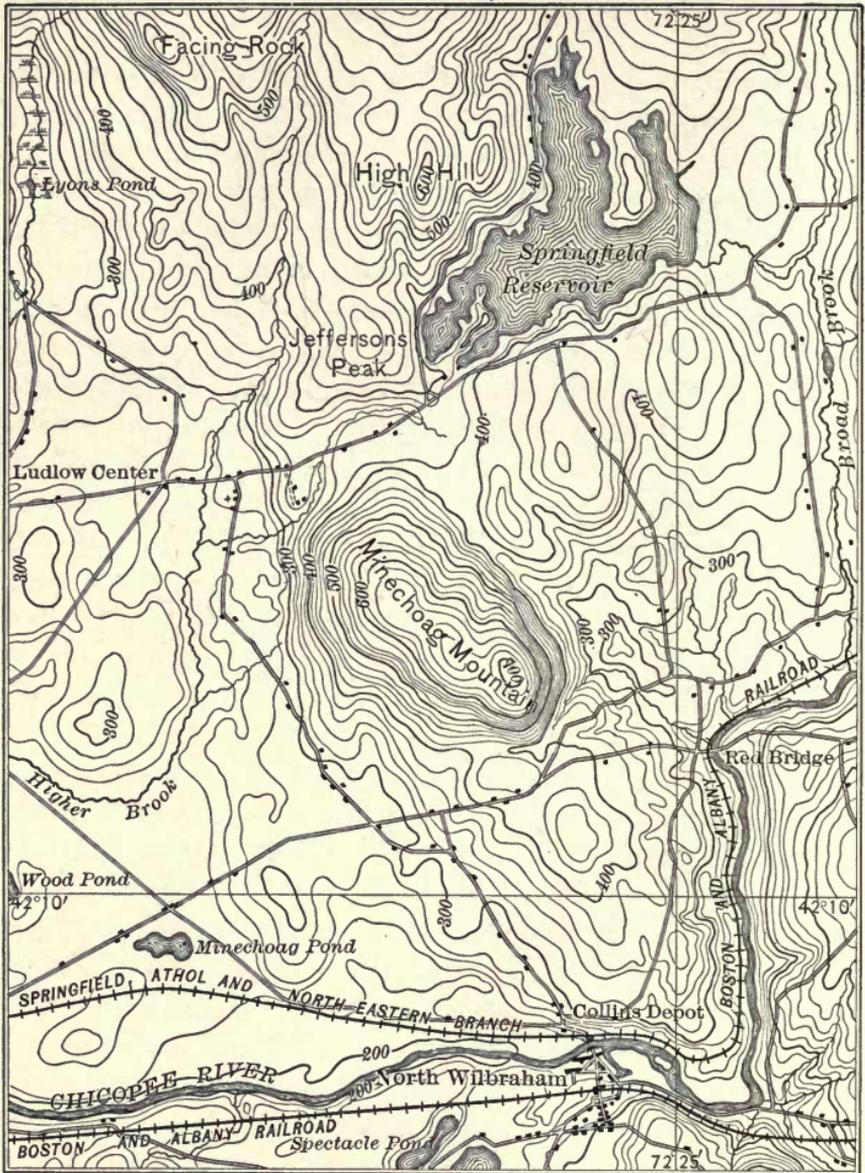


FIG. 117. PART OF A TOPOGRAPHIC MAP

Horizontal scale 1 in. = 1 mile. Contour interval = 20 ft. 1. What lines on this map tell you how to locate the region in the United States? 2. What and where is the lowest land in this region? 3. The highest? 4. How do you account for the locations of the railroad lines? 5. Does the more southern line ascend or descend after leaving the Chicopee River valley? 6. Describe as to habitation, value for agriculture, or any other occupation, the area bounded by four roads, near the center of the map.

244. Uses of Topographic Maps.—Topographic maps are much used by tourists traveling for pleasure, by carriage or automobile. The most direct roads between towns, as well as the more circuitous routes, are easily traced. Contour lines show the ascent or descent of the grade. If the lines crossing the road are far apart, the grade is gentle; if near together, a steep grade is indicated. By consulting a map, the traveler can choose at a fork of a road whether he will take a short, steep road or a longer one with a more gradual rise; whether he will drive along a river course or away from it.

It is by careful study of elevations as shown by contour lines that sites are selected for reservoirs for irrigation, water power, or city water supply. The first condition is, of course, a permanent and sufficient supply of water. This is generally determined from the number of square miles included in the basin of which the stream is the outlet, and the average rainfall for the region.

People planning for a summer camp can select the site from a topographic map nearly as well as from the place itself. The positions of brooks and ponds, hills and waterfalls are accurately shown. Distances from town centers and roads are correctly indicated.

In planning for new trolley routes, the company interested not only ascertains the best grades between large towns, but sees which roads would go through regions likely to give patronage, and where the line could leave a highway to make a short cut through the woods or across open country with the least loss of business. All these things can be learned from a study of the maps.

Maps of any locality whose survey is completed can be obtained at Washington for a small sum. The survey of many of the eastern states is already finished; but in the great plain and prairie regions, only the populous areas or those most important geologically are completed.

EXERCISE ON A SIMPLE CONTOUR MAP



FIG. 118. CONTOUR MAP

Contour interval: 100 feet

Horizontal scale: 1 inch = 1 mile

1. Fig. 118 is a contour map of a mountain ridge with a stream on one side. What is the height of the summit above sea level?
2. Trace a copy of this map upon exercise paper. Rule a line from a point representing the top of the mountain to the base in the direction of the steepest slope. Label the line.
3. Rule a line indicating the direction of the gentlest slope.
4. In general, how do you distinguish a gentle slope from a steep slope?
5. In particular, how do you select the gentlest slope? The steepest slope?
6. What is the length of the river shown on the map?
7. What is its average fall per mile?
8. Calculate the actual length of the shortest path from the summit to the base of the mountain. (Put down your calculations.)

CHAPTER XIX

EARTHQUAKES; VOLCANOES

245. Causes of Earthquakes. — In the process of mountain making, the thick, rigid layers of rock bend and break here and there, and when a fracture occurs, there is a mighty jarring of rocks, sometimes perceptible for many miles. The earthquake motion on the surface of the earth is really a side to side movement, as is shown by the swinging of chandeliers and of pictures upon walls, and even by the swaying of chimneys. The sensation which people experience is one of giddiness, such as is produced by unexpected swaying of the body. It is the surface motion that is called an earthquake.

The fracture below may cause the broken rock to separate and the separation may extend upward to the surface, or

the fracture may make the broken edges slip up or down. In the latter case, the displacement is called a **fault**.



FIG. 119. — ONE RESULT OF THE SAN FRANCISCO EARTHQUAKE

1. If this crack had been made under a building, what would probably have been the effect? 2. Measure the widest part of the crack and compare it with the length of a block. 3. An ordinary paving block of this form is about 10 in. long; what is the width of the crack?

Young and growing mountains are likely to be the centers of earthquake disturbance. By means of delicate instruments for detecting and recording the direction of the movement, scientists can locate the region where the rocks parted, sometimes several miles below the surface.

During volcanic eruptions, earthquakes are caused by the sudden pressure of expanding steam, which has the effect of a blow upon the rocks. When the steam finds an outlet, the shaking ceases.

246. Effects of Earthquakes.—The vibrations of a severe shock are felt in every direction for long distances from the center of disturbance. But earthquakes make very little change in the surface of the earth. They may cause a landslide, or a lifting up of a piece of ground, or an opening like a ditch varying from a few inches to some feet in width; otherwise they make little change except in man's handiwork. It is the *suddenness* of the shock which damages buildings and thus causes loss of life.

247. Famous Earthquakes.—In "The One Hoss Shay," Oliver Wendell Holmes refers to a disaster in Portugal in 1755:

" That was the year when old Lisbon town
Saw the earth open and gulp her down.
.
.
.
.
.
.
.
It was on that terrible earthquake day
That the Deacon finished the One Hoss Shay."

In 1812 a great depression of the surface occurred in Missouri, and the most violent earthquake known to the United States resulted. About seventy-five years later there was an earthquake which was most severe near Charleston, South Carolina. In one minute many houses were entirely wrecked and thousands of chimneys were thrown down. Outside the city, a rent some rods in length was made in the ground. The shaking was felt, in a less degree, from Boston to Cuba. These are the only serious earthquakes

which have been felt in the eastern half of the United States since its occupation by Europeans.

In 1906 a severe earthquake occurred in California, in and about San Francisco. It was caused by the faulting of rocks along the line of a break which had been made years before. Many lives were lost and much property was destroyed. Fire followed the earthquake, and as the water-mains had been broken and the fire department was without



FIG. 120. — EFFECTS OF AN EARTHQUAKE AT MESSINA

1. Which would have more elasticity, a wooden building or a stone building?
2. Which would be least injured by a swaying motion, a one-story building or a higher one?
3. A building with a broad or a narrow base?
4. Give directions for the erection of an earthquake-proof structure.
5. Have you read of a country where such buildings are erected?

water to fight the fire, \$500,000,000 worth of property was destroyed before the fire was conquered.

Regions in which earthquakes are of most frequent occurrence, for example the Pacific coast region from California to Chili, are near young mountain chains. Japan and Italy have suffered from numerous earthquakes, some of which are known to have been of volcanic origin. But the two

most severe ones of modern times were undoubtedly due to faulting, as no marked volcanic disturbance occurred at the same time.

In 1908 two large cities on opposite sides of the Strait of Messina were almost totally destroyed by violent earthquake shocks. Seventy-five thousand people were killed and as many more were injured or rendered homeless. Practically every building of any considerable height was wrecked. The center of the disturbance was under the sea in the Strait of Messina. An earthquake second only to that of Messina occurred early in 1915 in the Italian province of Abruzzi in the Apennine Mountains. There are no large cities in this region, but many towns and villages were completely destroyed, and all communication by wire and rail was cut off. The loss of life was between twenty and thirty thousand. The tremors were felt to a distance of three hundred miles and some of the monuments and ancient buildings in Rome were damaged.

248. Volcanoes.—Scattered over the earth, sometimes in groups but often singly, there are cone-shaped elevations called volcanoes, or volcanic mountains. If a volcano is **active**, steam is seen rising above its summit; fine rock dust, called ash, is blown in clouds from the opening at the top; and melted rock, or lava, pours down the slope. At the summit of many volcanoes there is a bowl-shaped depression called the crater, which is sometimes partly filled with lava even when none flows over the edges.

A volcano is said to be **dormant** when for a long time there has been no sign of activity. If sufficient time has elapsed for the crater to become filled with rock waste or water, and the sides to be covered with soil and forested or cultivated, the volcano is considered **extinct**. Mount Shasta, an extinct or dormant volcano of California, has been quiet so long that glaciers have formed upon its sides. Mount Lassen, another California volcano, began to send out

clouds of steam and ash in the spring of 1914. It had never before been seen in eruption, but now it can no longer be considered even dormant.

249. Famous Eruptions.— Vesuvius, near Naples in Italy, had been so long dormant that when a great eruption occurred in 79 A. D., the people living near by were utterly



FIG. 121. — VESUVIUS AS SEEN FROM ACROSS THE BAY OF NAPLES

From this position, it looks as if there were two peaks to Vesuvius. There is, in fact, only one peak. The elevation to the left is a part of the rim of an old crater which was blown away at the eruption in A. D. 79. A column of steam is rising almost all the time from Vesuvius. 1. Why should it often look red at night? 2. Account for the red streaks sometimes seen at night on the slope of the mountain.

incredulous that harm could come to them. Even though black clouds of ash were falling upon them and shocks of earthquake were repeatedly felt, they could not believe that there was real danger. Two cities, Herculaneum and Pompeii, were completely buried by this eruption. The

ash and condensed steam, falling as rain, made a mud covering which after some time hardened into stone. The location of the ancient Pompeii was discovered in 1748. Excavations which have been made since that time show that the mud crept into all places, even into ovens and chests in the houses. Articles and bodies buried by it have been preserved in form by the mud which hardened around them. The hardening mud formed a mould having exactly the form of the object within, and after a time the object crumbled to dust. The remains have been removed and plaster casts have been made in the moulds. Jewel boxes, loaves of bread, and a watch dog chained beside a door are some of the objects which have been reproduced in this way.

In 1906 there was a violent eruption of Vesuvius which destroyed many small villages on the slope. Streams of lava overflowed and also burst through the sides of the crater, burying houses and fertile fields.

Sometimes poisonous and very hot gases pour down the slopes of a volcano, causing death to plant and animal life. Such was the case in the eruption of Mount Pelée in the West Indies in 1902. More lives were lost there than at Pompeii, but they were destroyed by superheated steam and other hot gases. The ruins of the city of St. Pierre, near Mount Pelée, were not buried as Pompeii was. There were no survivors to rebuild the city, as San Francisco was rebuilt, and it is still a desolate waste.

250. The Cause of Volcanic Eruptions.—There are a few volcanoes which have been made since history began, and descriptions by eye-witnesses are recorded. From an opening in the ground, or sometimes from under the sea, rose clouds of steam, and columns of ash and rock, or lava. The solid matter fell around the opening and built up a cone, and the hardening lava added to its extent. Many of the cone-shaped volcanoes undoubtedly began in this way.

Others began where there were fissures in rocks that were rising or were already uplifted. In one case a single eruption began and ended the life of a volcano two hundred feet high, south of Sicily. The cone has since been swept away by the sea and nothing but a ledge of rock remains.

An eruption is probably caused, in most cases, by the great pressure of the steam formed in regions where water has percolated to heated rock far below the surface. Since unconfined steam occupies about 1,700 times as much space as the water from which it is made, its pressure when confined is tremendous. As it pushes its way out, it often forces out solid rock above it, as well as the liquid rock which is near it. Some of the lava rises into the air in a fine spray, as water does from a hose, but it solidifies in the air and falls as a fine dust, called **volcanic ash**.

Before an eruption, the earth is often violently jarred and shaken by the expanding steam, and the resulting earthquake is thus a warning of an eruption. The whole side of the volcano is sometimes blown away by an especially explosive eruption, as in Krakatoa, in the Straits of Sunda, near Java, in 1883.

Volcanoes, like earthquakes, are more numerous in young mountain regions than in old ones, because while the folding of the rocks is going on, the fractures provide openings for the release of the melted rock, which is always under pressure below.

251. Lava Sheets and Dikes.— Volcanic action does not always produce a typical, cone-shaped volcano. Sheets of lava may flow over a great extent of country, through a fracture one hundred or more miles in length. Such old lava flows are found in states west of the Rocky Mountains, where they cover an area of 150,000 square miles in Idaho, Washington, and Oregon.

When the liquid rock cools in the fissures, it closes the

opening. If the rock on either side of the fracture is softer and becomes worn down, the harder rock stands like a ridge or dike.

EXERCISES

1. What changes in the surface of the earth are sometimes caused by earthquakes?
2. Why is there loss of life by earthquakes when there is no permanent effect on the earth's surface?
3. Use the terms *cause* and *effect* correctly in describing a connection between volcanoes and earthquakes.
4. What are the earthquake regions of North America? Of Europe?
5. What is the volcanic region of North America? Of Europe?
6. Explain any relation between the answers to Ex. 4 and Ex. 5.
7. How does one judge whether a volcano is extinct or dormant?
8. What changes take place in the form of an extinct volcano?
9. How long have we had any history of California and Oregon, which contain our only volcanoes?
10. How is volcanic ash made?
11. Why are volcanoes found in the regions of growing mountains?
12. Describe a volcanic dike.

CHAPTER XX

RIVERS AND THEIR WORK

252. Temporary Streams.— In places where the surface is bare rock, every rainfall sends sheets of water flowing over the slopes and streams rushing in the ravines. The flow ceases when the rainfall does. Such temporary streams are found on rocky slopes of deforested hillsides and in gullies in semi-arid regions. Travelers crossing barren country are sometimes caught by a flood while camping in a seemingly desert hollow. It is important in the study of rivers to know how the loose covering of the earth was made, because that covering holds the rain water for a time and makes possible the beginning of permanent streams.

253. Weathering.— The earliest lands were of rock with no covering of plants and with no animal inhabitants. Animals cannot live without plants, and few plants grow upon bare rock. But the rock began to decay almost as soon as it was formed, and decayed rock is the beginning of soil.

Many natural forces act together to wear away the surface of rocks. The oxygen and carbon dioxide of the air, in combination with water, act chemically upon some minerals to change their composition and cause crumbling and decay. Water enters crevices in a rock; freezing there, it expands about one tenth of its volume and forces the rock apart. The sun's heat also expands the surface layer and loosens it from the under rock, and rain and wind remove the grains which afterward accumulate in hollows. The wearing away of rock in these ways is called **weathering**.

In the course of time the earth became covered with an accumulation of rock fragments; this covering is called **mantle rock**. By the process of decay, a thin covering capable of supporting plant life was formed.



FIG. 122. — WEATHERED ROCK

1. What evidence do you see of the work of air, water, and changes of temperature on this rock? 2. How do you account for the fine material around the base?

254. Soil.—Decayed rock material containing animal or vegetable matter is called **soil**. Some forms of plants can secure all the material they need to make food from air, water, and rock waste, especially if the rock waste is of volcanic origin. Such plants would be the first to flourish on new land; their remains would contribute to soil and their roots would assist in the process of weathering. Earthworms and burrowing animals also are agents of weathering and assist in making soil. Even now, after millions of years,

much of the earth's surface has only a few inches of soil, although in some old valleys the soil is many feet thick.

255. The Formation of Rivers.— The soil filled with roots of living plants and the broken rock beneath it retain for



FIG. 123. — ERODED SOIL

This is a place where a road is being made. Streams caused by a heavy rain have cut deeply into soft earth. 1. What becomes of material taken out by rain water? 2. Why does not this happen on *all* slopes every time it rains? 3. What reason can you give for the fact that hillsides are not often planted for crops that require cultivation?

a short time some of the water which falls upon the ground. Gravity makes the water sink slowly through cracks and porous rock until it reaches some less porous stratum. If this stratum slants downward, the water follows the rock until it comes to the surface lower down the mountain. There is then a constant discharge of water which, running as a little brook in a valley, may be the beginning of a river. Other brooks join it; springs from the valley slopes feed it here and there; rivers from side valleys bring water

from other hills; and a mighty river carries it all to the sea.

256. The Load of Rivers.— There is much besides water that is being carried to the sea by the rivers. The **load** of a river consists of dissolved mineral matter and rock waste in the form of mud and sand. All this has been gathered from every part of the land whence water has flowed into

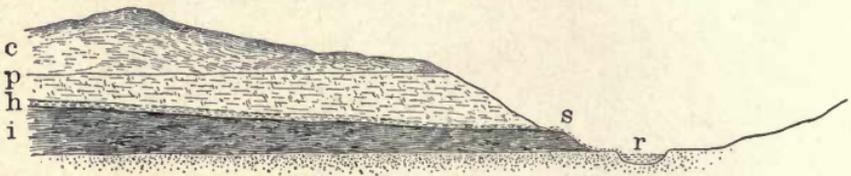


FIG. 124. — SURFACE SPRING

i represents impervious rock; *p*, *h*, porous rock; *c*, loose earth; *s*, a hillside spring; *r*, a river bed. 1. What is the source of water flowing out at *s*? 2. Does it come out with great pressure? Why? 3. If a wall were built around the spring, how deep could the water be in the basin, as judged by this diagram? 4. Describe the stream that would flow from *s* to *r*.

the river. The Mississippi River, which carries a greater load than any other river in the United States, gathers it from the mountains of Montana, the forests of Minnesota, the farms of Kentucky, and other lands along its course.

It is hard to realize how much solid material a river carries. It deposits its load on the banks, in the bed of the stream, and at the mouth. A swift current carries much material, coarse and fine, and deposits none. A slower current drops coarse material and carries only the finer. When a river enters a lake or the sea and its current is checked, it usually drops the last of its load. Whether the material settles here or is carried farther and distributed by currents and waves of the sea, depends upon the form of the coast and the direction of currents and prevailing winds. The current of the Amazon pushes out to sea and carries some of its load three hundred miles from land, as is indicated by the muddy color of the ocean.

257. **Erosion.**— From the time rain falls upon the earth until it reaches the sea, the water is doing the work of erosion. Mantle rock and soft rock are carried away grain by grain, leaving sometimes deep gullies, sometimes pyra-



FIG. 125. — THE COLORADO RIVER IN THE GRAND CANYON

The river is flowing here in a gorge worn in granite which is as old as any known. The highest elevations shown are not so high as the plain in which the work of erosion began. 1. Describe the rock resting upon the granite. 2. Give a reason why the valley is wider at the upper levels. 3. What may have become of the material removed from this valley?

mids or irregular columns of material slightly harder than the rest. Erosion continues to take place after the stream is formed. The grains of sand carried by the current wear upon the bed or banks of the river and scour them, as sandpaper rubs off wood or soft stone.

The Colorado River shows remarkable results of erosion

in its hundreds of miles of water-worn canyons, thousands of feet deep. Its velocity is so great that it carries coarse sand and even large pebbles. The St. Lawrence River is in direct contrast to both the Mississippi and the Colorado. It neither deposits sediment in its bed nor erodes by means of what it carries. Its waters have flowed through lakes whose quiet depths have received the transported material, leaving clear water to flow on to the sea.



FIG. 126. — A FLOOD SCENE

A railroad bridge and its abutments have been carried away. The position of the tracks is evidence of the force of the current. What shows the direction of the current?

258. Deposit.—By depositing the material that it carries, a river may build up its bed and its banks; at the mouth it may form a delta and sand bars. At flood times, when torrential rains or melting snows in the spring have caused the river to overflow its banks, the receding water leaves a thin layer of mud on the land. Wherever the velocity of the current is decreased, some material is deposited in the river bed, and thus sand bars are formed.

These bars may become permanently joined to the shore or may remain as islands.

The Mississippi River, flowing very slowly in its lower course, has been filling up its channel. As the bed of the stream has thus been raised, the water would in many places overflow the banks every year if artificial banks (called



FIG. 127. — EROSION OF ELEVATED SURFACES, MONUMENT PARK, COLORADO

This is a stratum of coarse sandstone which had a layer of harder rock over it. In its elevation, vertical cracks were made, and erosion resulted in the making of columns. How was this assisted by freezing water?

levees) had not been built. The levees must be high enough to restrain the water at flood times. The higher the river, the greater pressure there is against the side of the levee. Constant watch is maintained when the river is full, in order to prevent disastrous breaks, and millions of dollars are spent annually to prevent and repair damage.

The Ohio, the Arkansas, the Amazon, and the Yellow rivers have great floods. In thickly populated China, the loss of life is often great and the destruction of rice fields results in famine. On the other hand, the flood of the

Nile in Egypt, which formerly occurred annually, has been a real benefit to the land. It has deposited the fertile soil upon which depends the support of millions of people. The great dam at Assouan now holds back the water, so that it may be distributed by irrigating canals.

259. Changes in the Continents.—It is said that the sediment deposited in one year by the Mississippi would make a pyramid half a mile square and seven hundred feet high — a small mountain, in fact. This material must have been removed from the land through which the river and its tributaries flowed. What the Mississippi is doing, other rivers are doing to a lesser degree. That means that the mountains have been lowered and the hillsides have lost some of the slowly made soil — perhaps only the fraction of an inch; but the final result must be the lowering and leveling of the continents. By the work of rivers, mountains become rounded and low, valleys are filled, and the borders of continents are extended. (LABORATORY MANUAL, Exercise XXII.)

260. The Usefulness of Rivers.—Rivers are invaluable to pioneers in opening up a new country. They furnish an easy means of traveling and of carrying supplies, and often penetrate forests otherwise impassable. After settlement is completed, they continue to furnish the cheapest means of carrying freight.

The shorter, swift-flowing rivers, which are not navigable because of falls and rapids, are useful for the power they furnish to run machinery. The great rivers often have rapids in their upper courses, where they are known as young rivers, because of their velocity, great erosive power, and uneven bed. The mature streams, characterized by gentle flow, greater volume, and absence of rapids, transport fine rock waste which the younger part of the stream has brought in. They carry upon their surface millions of dollars of freight from the interior to the seaports.

Knowing the character of the towns and cities upon a river, one can tell which is the youthful and which the mature part. Manufacturing places on the borders of the young working river are followed lower down by centers of commerce and trade on the mature navigable stretch.

261. The Absence of Rivers.— A land without rivers is usually a desert. The principal reason for the absence of

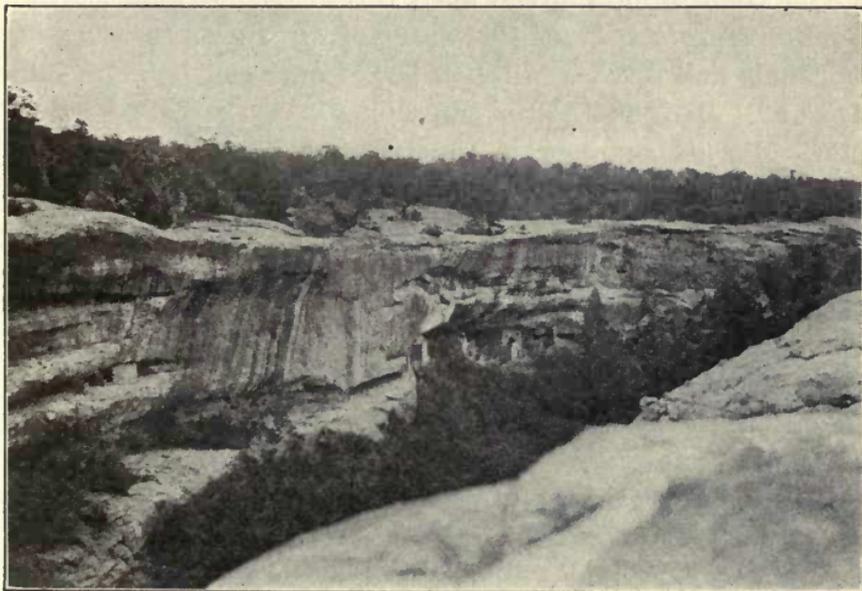


FIG. 128. — SPRUCE TREE CANYON, MESA VERDE, COLORADO

1. What are the signs of surface drainage into the valley? 2. How has weathering changed the side of the valley? 3. What is the cause of the horizontal caverns? One of them contains ruins of a village deserted long before the Spaniards discovered them 400 years ago.

rivers is that the winds blowing from the great source of vapor, the ocean, lose their moisture before reaching the interior of the continent. If the warm vapor-laden winds encounter a range of mountains, the air cools as it rises, and the vapor condenses. Rain falls on the slopes of the mountain nearest the ocean. Here there are forests, mountain streams, and peaks whose melting snow keeps the supply

of water constant on that side. On the other side is the desert.

262. Irrigation.— There are thousands of square miles of land in the United States, as well as elsewhere, which have long been considered worthless and have been both impassable and uncultivated because of desert conditions. It has always been known that the land bordering a stream is more fertile than similar areas at a distance from the stream. By diverting a part of the water of streams into a system of canals and ditches, a much larger area can be artificially watered. This method of supplying water is called **irrigation**. By its practice, in the last fifty years much of the desert in this country has been reclaimed for cultivation.

The United States Reclamation Service and some private enterprises are conducting extensive systems of irrigation in the region between the Rocky Mountains and the Sierra Nevadas. They have secured possession of, or the right to take water from, streams whose headwaters are at a considerable elevation above the lands to be irrigated. In some places reservoirs are built to accumulate water during the spring, the time of freshets and melting snows. The water passes by gravity from the reservoirs, or streams, through canals and ditches and sometimes by tunnels through mountains, to the arid region. At intervals, gates are provided by which water can be let out into a canal on a lower level. From this canal, water flows through parallel trenches all over a great farm.

Many sections of eastern Colorado, Utah, New Mexico, Arizona, and southern California are now producing melons, peaches, oranges, and lemons, as well as sugar beets and all kinds of garden produce. A few years ago these regions bore only sage brush and cactus and were the homes of the prairie dog, the scorpion, and the coyote.

EXERCISES

1. How does the presence of soil and mantle rock help in the formation of rivers?
2. (a) What is the load of a river? (b) Where does it come from? (c) What becomes of it?
3. Make a comparison between any two rivers you know: (a) in regard to their load; (b) in regard to the work they do.
4. If the sediment at the bottom of a slow stream were consolidated, what kind of rock would be made?
5. Why are pebbles in the bed or on the banks of some streams rounded and smooth?
6. Why are there more pebbles of quartz than of other minerals?
7. When a river meets an obstruction, why does it flow around instead of over the obstruction?
8. Describe a method by which you could find out very nearly how fast a stream flowed.
9. Why are swift streams straighter than slow ones?

CHAPTER XXI

GLACIERS AND LAKES

263. The Snow Line.—Whenever the temperature of the air is below the freezing point, if much water vapor is present, crystals of ice form and fall singly or in groups, called snowflakes. These sometimes melt in passing through warm air near the earth and then fall as rain, but in cold climates they reach the earth as snow. At very high altitudes, even in the tropics, the mountains and plateaus may be perpetually covered with snow. The summer limit of the snow is called the **snow line**. In winter, of course, the snow line is lower down the mountain than at other seasons. In summer numerous waterfalls on the mountains testify to the melting of the snow back to a higher line.

264. The Beginning of a Glacier.—Above the summer snow line, the snow by its own weight becomes more and more densely packed. As the air between the flakes is pressed out, the snow loses its white look and becomes almost like ice. Where this takes place on a slope, the ice begins to move slowly downward in a broad or narrow sheet, according to the form of the land beneath. Such moving ice is a **glacier**. It may extend many miles down the valley, as is the case with several glaciers in Alaska, Norway, and Switzerland.

A high plateau may be covered with an ice sheet which moves very slowly in all directions from its highest part. A large part of a continent may be covered with moving ice, as happened in the northern part of North America many thousand years ago and as is the case in Greenland to-day.

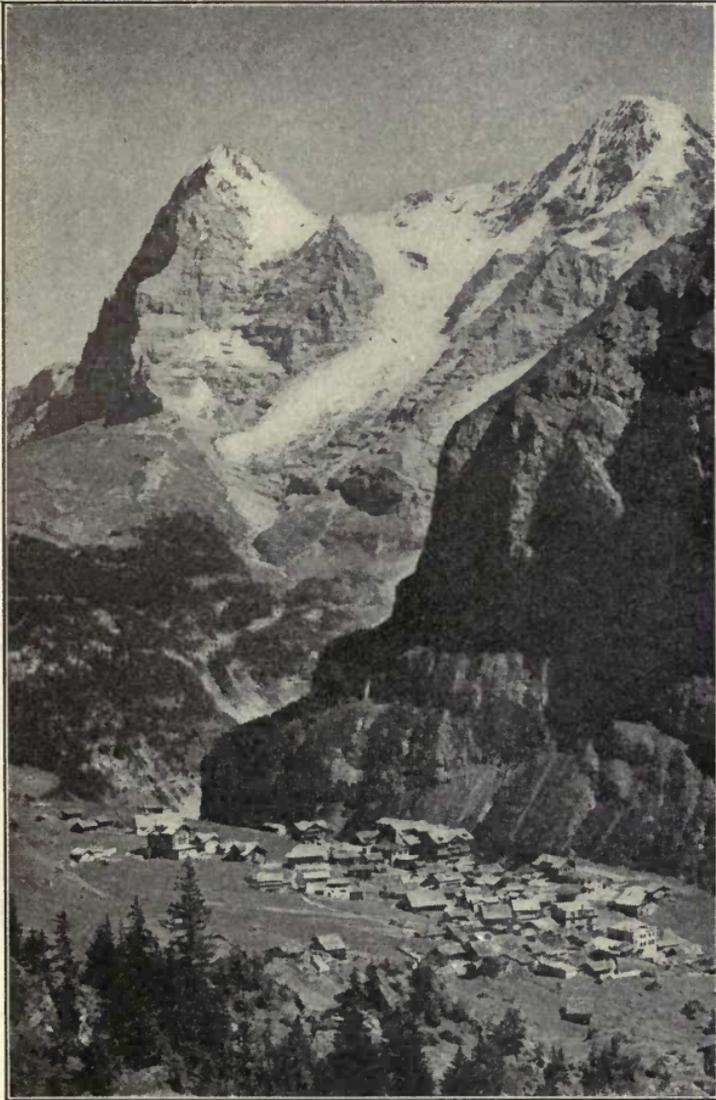


FIG. 129. — GLACIERS IN A VALLEY IN SWITZERLAND

This is a summer view of peaks perpetually covered with snow. 1. A glacier fills a steep valley between the peaks. What seems to be its lower limit in winter? 2. Why are there so many waterfalls among the Alps?

265. The Work of Moving Ice.—Rock waste beneath the glacier becomes frozen into the ice and is like a

tool held in a firm grasp, scraping and chiseling the rock beneath. Erosion takes place in the bed of the glacier and along the sides of the valley. Rocks and earth, brought by avalanches to the surface of the glacier, are carried along by the moving ice. As the lower end of the glacier is always melting in the warm season, the rubbish lying on

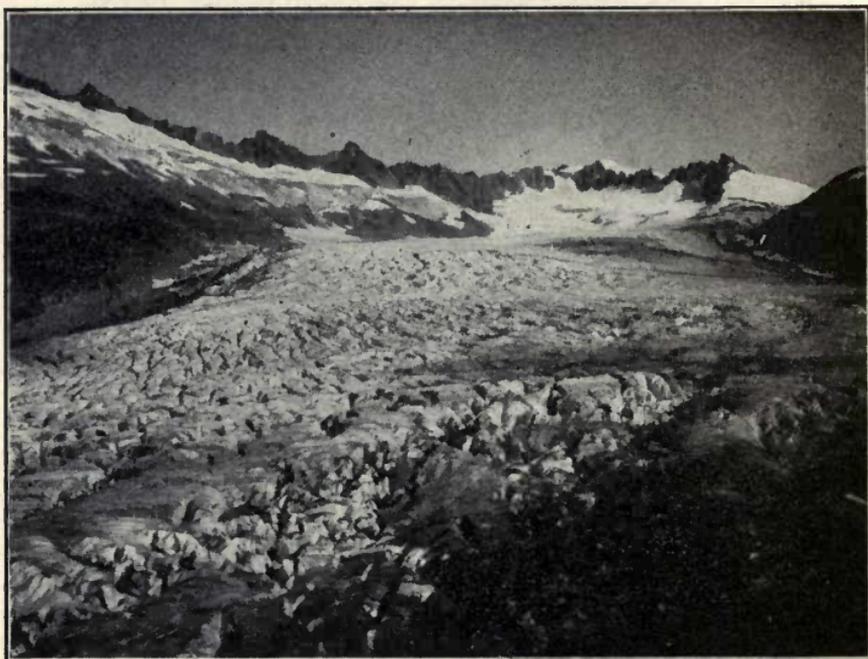


FIG. 130. — SNOW FIELD AND GLACIER

This glacier comes from the high Alps. The mountains are so steep that snow cannot rest upon their peaks. 1. How are the snow fields formed? 2. How do you account for the roughness of the surface of the glacier?

the surface and embedded in the ice falls at the end of the glacier. The material deposited in a ridge at the end is known as the **terminal moraine**.

266. The Retreat of a Glacier.— Where a distinct ridge of mixed coarse and fine rock, sand, and clay is found across an old valley or stretching over a continent, it indicates the

end of an old glacier. The glacier long ago retreated from a former position and left moraine material where the ice had been melting. This does not mean that the glacier moved backward, but that the end melted faster than the glacier advanced and thus each season the glacier receded farther up the valley, nearer its source than the last season. Such will be the history of a glacier if, because of change in climate or



FIG. 131. — GLACIATED ROCK

This is hard trap rock exposed on the top of a hill. 1. Two sets of lines are shown on the rock. Which were made by the glacier? How do you judge? 2. If the thin layer of soil covering parts of the rock were removed, do you think glacial marks would be found upon it? Why?

elevation, there is a decrease in the supply of snow, whose weight causes the glacier to move. Many glaciers in the United States are known to have retreated to the summits of the Rocky and Sierra Nevada mountains. There, melting during the summer, they now furnish a permanent source

of water, which is stored and used for city water supply, for irrigation, or for hydraulic mining.

267. Drift.—The rock fragments, sand, and clay which a moving ice sheet carries, are all left on the land beneath when the ice melts. This deposit is called **drift**. It covers the northern United States as far west as the Rocky Mountains and as far south as the Ohio and Missouri rivers. The British Isles, Scandinavia, and parts of Germany are covered with a similar deposit. In river valleys, the drift has been covered by deposits of flood material, but it may still be seen on hillsides and even on high ridges where are scattered loose stones, more or less rounded in shape, varying in size from a pebble to a small house. The large stones are called **boulders**. They are often totally unlike any other rock within many miles, but are similar to rocks found farther north. The location of such boulders and the direction of scratches upon rocks over which the glacier passed, have helped to determine the direction in which the ancient North American ice sheet moved—in general, toward the south.

268. Glacial Lakes.—If you examine a map of any of the New England or other northern states, you find many small lakes scattered over the country, while in the southern and middle states there are very few. Some of the lakes lie among hills; some are in the plains. The making of lake basins is an important work of a glacier.

In its progress, the ice with its rock tools scooped out hollows in the softer rocks, and after the ice withdrew, the basin was a receptacle for water from the hillsides around. Such lakes are found in the Highlands of Scotland, in the Swiss and Italian Alps, in Canada, and in some of the northern states.

The terminal moraine sometimes makes a dam across a valley and thus forms a basin to receive drainage. Lakes made in this way are usually long and narrow. All of the Great Lakes, except Lake Superior, were probably the re-

sult of glacial obstruction. Most of the lakes in the northern states result from irregularities in the surface of the drift deposited by the ice sheets. Minnesota and Wisconsin are dotted with lakes of this type.

There is still another kind of lake which is glacier-formed. When the ice of a glacier is thickly covered with earth and stone — as are parts of the Malaspina glacier in Alaska,



FIG. 132. — LAKE LOUISE, A GLACIAL LAKE

There are no lakes more beautiful than glacier lakes. 1. Name two ways in which their basins have been prepared by glacial action. 2. What is the source of their water? 3. Why is the water that enters them often muddy? 4. Why is the outflow clear?

upon which forests are growing,— the covering prevents melting in that portion of the glacier. During the melting of the rest of the glacier, deposits are made around the unmelted area. After a long time, it too is melted and

the water sinks into the ground, leaving a hollow where the ice was. This may fill and form a pond or small lake. Such hollows, if they are not filled with water, are known as "kettle holes," because of their rounded form.

269. Other Causes of Lakes.—Some lakes — like Lake Superior, lakes in Central Asia, and lakes in Africa — were formed in basins left when elevations were made in the earth's crust. Others, like Crater Lake in Oregon, fill the craters of extinct volcanoes. Still others were formed by the damming of a river by a landslide or a lava flow.

270. Lakes as Sources of Rivers.—When the basins, formed as described, have filled with water up to the lowest part of their walls, the water of course flows out at that point and the lake then becomes the source of a stream. If a lake "has no outlet," as is sometimes said, the water will eventually become salt. Many lakes which apparently have no outlet, discharge their water through passages from the bottom or sides of the lake into underground streams, and thus remain fresh water lakes.

271. Uses of Lakes.—Many lakes furnish abundant supplies of fish for food. They also add greatly to man's pleasure by their beauty and by their facilities for boating and bathing. The large lakes modify the extremes of heat and cold in surrounding land, as do the oceans. If a lake is situated in an elevated region, its water may be carried long distances in pipes, to be used for power or for supplying domestic needs in cities.

272. Reservoirs.—The commercial use of lakes has led to the making of artificial lakes or reservoirs by building dams across the outlets of a basin and thus holding back the water that enters it. There may be many millions of gallons of water flowing daily into the reservoir from constant springs and streams draining many square miles of territory.

Reservoirs may be constructed many miles away from the city, and the water may be carried in open canals or in closed pipes. The pipes may pass through a mountain or

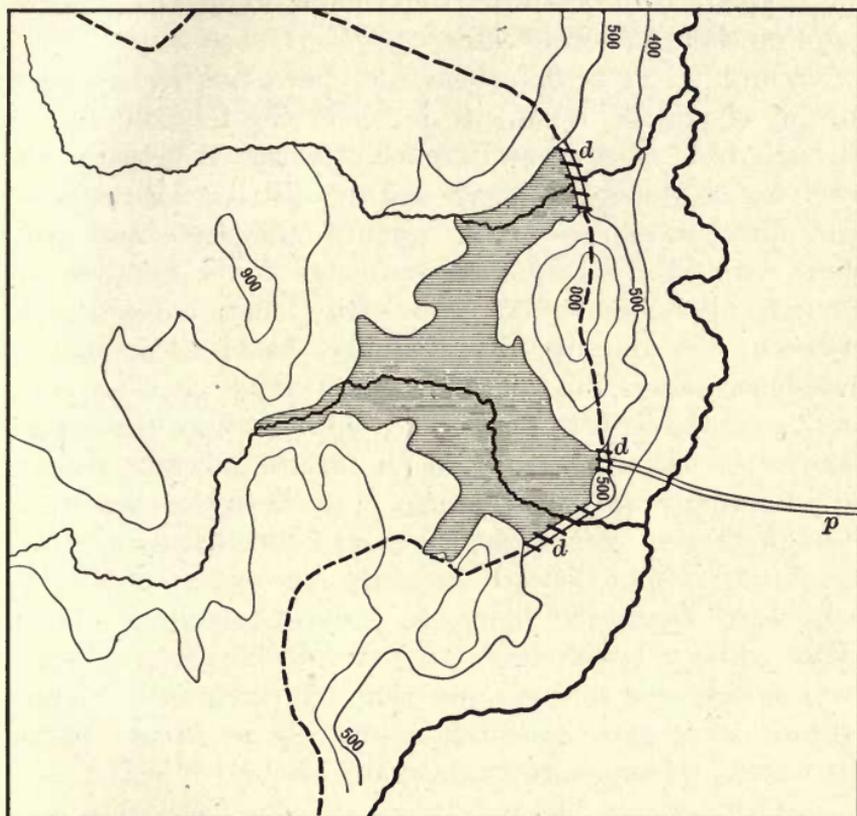


FIG. 133. — SUPPLYING A CITY WITH WATER

The dotted line is part of the boundary of the region which supplies most of the water to the two streams flowing east. The shaded portion is the area of a possible reservoir having natural hillside boundaries. If dams or embankments are built at three places, *d*, the waters of the two streams will be held back. 1. What is the elevation of the contour line bounding the reservoir? 2. What must be the level of the top of the dams? 3. The southern stream flows now at *d*, at an elevation of about 400 ft. If a dam is built there, how high must it be?

under a river, even up and down hill, always provided that no part of the pipe is as high as the source of the water it

carries. In 1873 the city of Vienna was supplied with water from the Alps, seventy miles away. That was one of the first enterprises of the kind. Water is now carried a much greater distance from the mountains to Los Angeles, San Francisco, and other cities.

Natural water is not chemically pure, but for domestic uses it should be clean. It is made clean by filtering it through beds of sand and gravel constructed between the receiving or storage reservoir and the distributing reservoir. The filtering removes some minute organisms and sediment. As disease germs are too small to be removed by filtering, they must be prevented from entering the reservoir by keeping the drainage basin clear of all dwellings, camps, and cattle. State laws give to cities and towns the right to remove all buildings from land which has been selected for a basin to furnish a water supply. Suitable compensation, of course, is made to the owners.

In the region of the great central plain, where in many towns the people depend on wells for water supply, the same care should be taken to prevent pollution of the water. Many large cities use river or lake water which has been exposed to contamination. In such cases, chemical means are sometimes used to destroy germs and purify the water. (LABORATORY MANUAL, Exercise XXIII.)

EXERCISES

1. Describe the beginning of a glacier.
2. Where is the glacier that is nearest to your home?
3. Are there glaciers on mountains in your state? Why?
4. What change of conditions of the earth's surface or of the atmosphere might cause a glacier to form in the Allegheny Mountains?
5. How do people know that a glacier once covered North America as far south as the Ohio River?
6. Where are there now great glaciers in North America?
7. Moving at an average rate of 20 in. a day and melting 22 in., how would the end of a glacier change position from April 1 to October 1?

8. What is such a change of position (described in Ex. 7) called?
9. What rate of motion, allowing for no melting, would bring the glacier of Ex. 7 back in 6 months to the position of April 1?
10. How are long narrow lakes sometimes formed?
11. Name two other ways in which lakes are made.
12. How must a lake be situated to furnish, by gravity, a water supply for a city?
13. Why is the water salt in lakes having no outlet?

CHAPTER XXII

LIVING MATTER

273. Physiological Properties. — Plants and animals are made up of matter, and have certain physical properties, such as weight and extension, which are possessed by all matter. In addition to physical properties, both plants and animals possess certain properties which never belong to non-living matter. These are called physiological properties; they are irritability, spontaneous motion, reproduction, and nutrition. Any body possessing these properties is called an **organism**, and much of the material of which it is composed is called **organic** material.

274. Irritability. — Both plants and animals respond to influences from without. For example, leaves turn toward the source of light, and the odor of food will make a dog's mouth water. This property of responding to external conditions is called irritability.

275. Spontaneous Motion. — Both plants and animals have the power to change the position of parts of the body or the whole body. This is the property of spontaneous motion. A fish darts rapidly or moves slowly through the water at will. Plants move their leaves, stems, flowers, or other parts, but generally so slowly as to be unnoticed in brief observation.

276. Reproduction. — Both plants and animals possess the property of reproduction; that is, they can form other bodies like themselves. For example, the bean plant reproduces by means of seeds, and the fish by means of eggs.

277. The Need of Energy. — These three properties — irritability, spontaneous motion, and reproduction — con-

stitute the **functions** or work done by the animal or plant. Work, whether it is done by a machine or a living thing, requires energy or work-power for its performance. A machine may obtain energy for working from electricity, or from falling water, or from the oxidation of fuel. The oxidation in the body of a plant or animal may be compared with the process which goes on in the firebox of a steam engine. The burning of fuel causes heat, which makes steam. Steam has energy; that is, it can do work when properly employed in a machine. The energy by means of which plants and animals perform their physiological functions is always derived from the oxidation of some of the material found in the working part. If oxidation ceases, there can be no energy and life is at an end.

278. Nutrition.—Food is the name given to substances that furnish materials by which an organism makes new structures or repairs old ones in its body, and to substances that can be oxidized to give energy to the organism. Ani-

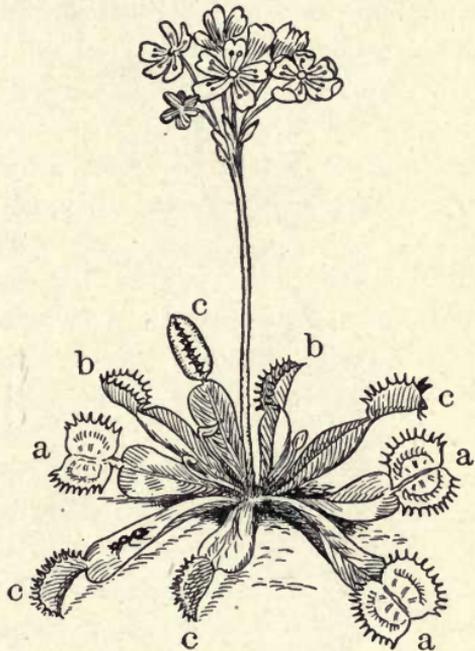


FIG. 134. — THE VENUS FLY TRAP

Under ordinary conditions, the end of the leaf is spread out flat as in position *a*. The edges of the leaf are toothed; the inside is covered with hair-like projections. If these projections are touched lightly, as with a straw, the leaf slowly folds together as in *b*, and finally as in *c*. If a small insect crawls on the leaf, he is shut within. The plant absorbs food from his decaying body; after some days the leaf opens again and the thin shell of his body is all that remains. What properties of living matter are thus illustrated?

mals and plants possess the property of taking up such substances. This property of taking food and converting it into

energy or the material of the body is nutrition.

The food of the young plant is mainly *starch*, a compound of carbon, hydrogen, and oxygen; and *proteid*, which is a compound of these elements with nitrogen and traces of others. This food material is stored in the seed and from it, together with water absorbed from the ground, is formed the material of the first root, stem, and leaves of the plant. Some plants grow many inches in height with no food but that in the seed. The newly hatched fish or chicken, turtle or bird, has grown to a considerable size from the material stored within the egg.

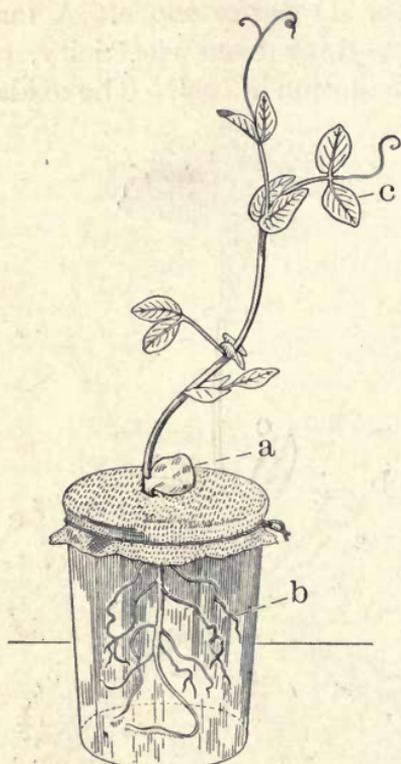


FIG. 135. — GROWTH FROM FOOD STORED IN THE SEED

A garden pea was sprouted in a damp place. It was then placed so that the sprout passed through a hole in a piece of cheese-cloth stretched over a tumbler of water. Fig. 135 represents a growth of several days. The roots, stem, and leaves have developed. What have they been made from?

provides the material to be oxidized, but oxygen also is necessary. The power to take oxygen, or **respiration**, is a part of the property of nutrition. Respiration is much more noticeable in animals than in plants.

279. The Need of Food. — Response to outside influences, motion of a part of the body or the whole body, digestion of food, and formation of other bodies like themselves, are the physiological properties of plants and animals. Each of these processes is *work*, and requires energy. Energy can be obtained by living things only from oxidation; oxidizable material (which is provided by food) and oxygen are necessary for oxidation. Therefore all living things require food and oxygen. (LABORATORY MANUAL, Exercise XXIV).

280. Amounts of Food Required. — Plants require less food than animals because they do less work in performing their functions than animals do. The temperature of a growing plant is slightly, if at all, higher than that of the surrounding air. Its temperature averages much lower than that of many animals living under the same conditions. Hence less oxygen is needed by plants in respiration and less food material is needed as fuel.

All animals do not require the same amount of food. The robin is an active, rapidly moving organism; a toad is inactive much of the time. Therefore a robin needs more energy than a toad and, consequently, more food.

281. Waste Products from Oxidation. — When the coal in a furnace is brought to the kindling temperature, its principal constituent, carbon, unites with oxygen, and heat energy is released. The gas, carbon dioxide, which is not only of no assistance to combustion, but is a positive hindrance, passes off. It is called a waste product.

A similar process takes place in the body of a plant or animal. Carbon is an element in many kinds of food and becomes a part of the body itself. This body material unites with the oxygen taken in by the plant or animal to produce energy and, just as in the furnace, carbon dioxide is formed. As this gas cannot be used and is injurious when retained in the body of the plant or animal, it is a waste product and is given off from the breathing organs of animals and from the

leaves of plants. There are other waste products which are disposed of in different ways. The removal of waste products which would hinder oxidation is a part of nutrition; the process is called **excretion**.

282. Residue Left from Food. — When coal is the fuel used in a furnace, besides the waste product in the form of gas, there is a residue which can not be oxidized to give heat. This residue of clinkers, stones, and ashes cannot be burned, and is of no use as fuel. The bodies of living things take in, with their food, substances which *never become a part of the body* and are never oxidized. This residue is expelled from animal bodies from the lower end of the intestine; in plants it collects in the leaves and is removed when the leaves fall.

283. Protoplasm. — No matter how different from one another the many forms of plant and animal life may be, they are all alike in one particular: they are largely composed of a kind of matter called **protoplasm**. Protoplasm is not life itself, but it is the only material in which life is known to occur. Protoplasm is a colorless liquid, nearly transparent, about as thick as the white of a raw egg. There are minute living bodies which consist of nothing but protoplasm. Most living things, however, consist of protoplasm and certain other substances made by it, such as sugar, fat, the wood of a plant, or the shell of an oyster.

284. The Composition and Behavior of Protoplasm. — Chemists have studied the composition of protoplasm and have found it to be very complex. It is made up of a number of compounds, which contain some of the commonest elements occurring in the air, in water, and in the earth's crust. These are carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus.

All protoplasm, whether in plants or animals, has the same appearance, the same chemical composition, and the same physiological properties. But there must also be certain

differences, not yet understood, for protoplasm does not always and everywhere behave in the same way, or perform the same kind of work.

The protoplasm in the tip of the stem of a plant causes growth toward the light; that in the root causes growth away from the light. The protoplasm in a sweat gland under the skin makes perspiration, while that on the outside of a clam or an oyster makes shell. The great number of variations of life found among plants and animals — all of them composed of the same living substance, protoplasm, — must be due to differences in the way in which protoplasm does its work and not to differences in the protoplasm itself.

285. The Necessity for Water. — Protoplasm contains a considerable amount of water. For this reason all living things require water. The water lily and the cactus show, however, that there is a difference in the quantity of water required by different plants. Water is also used by some plants and animals as a means of transferring dissolved substances from one place in the body to another. Sap is such a liquid in plants; blood, in animals.

286. The Necessity for Food. — We have seen that plants and animals alike require food to furnish materials from which new structures may be made or old ones repaired. Animals must have, for food, organic matter already formed; plants make their own food. *This difference distinguishes animals from plants.*

Some plants are green because in the protoplasm of the leaf-cells there are green chlorophyll bodies. Green plants take water from the soil through their roots, and it rises to the extremity of the highest leaf. They take in carbon dioxide through pores in their leaves. This is not breathing; it is more like collecting material to make food. The elements contained in water and carbon dioxide — namely, carbon, hydrogen, and oxygen — are made into food for the

plant by the action of the chlorophyll bodies, aided by the energy of the sun's light.

With the water from the ground, green plants take mineral matter which has been dissolved in the water. Nitrates and phosphates are mineral matter that is present in most fertile soils. Certain elements of these substances, such as nitrogen and phosphorus, are combined with the elements of sugar and starch, in green plants, to make proteid, another food. Protoplasm is made of proteid.

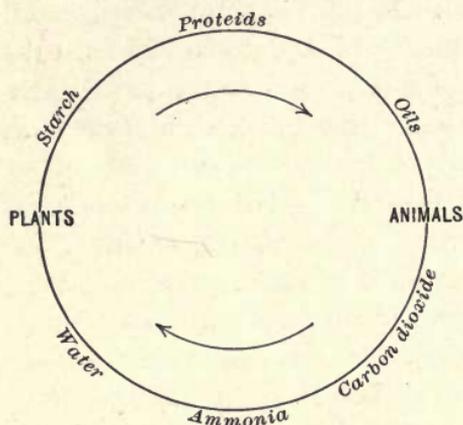


FIG. 136. — RELATION BETWEEN PLANTS AND ANIMALS

1. Which of the six substances named on the circle can be obtained from earth and air? 2. How are the others provided? 3. Read this diagram so as to express the dependence of one kind of organism upon the other.

upon plants. Animals cannot exist without green plants. On the other hand, the waste product of animals, carbon dioxide, is absolutely necessary to plants for food manufacture.

Animals that eat plants only are **herbivorous**; those that live upon other animals only are **carnivorous**; while those that eat both plant and animal food are **omnivorous**. The food of a sheep and of a lion can be traced to the same source. The food of a sheep is proteid matter and starch found in

287. **The Relation of Plants to Animals.**—Earth, air, and water contain all the elements necessary to the growth of plants and animals, but no *animal* can use these in preparation of food. The protoplasm of green plants, with the energy of sunlight, makes food which is used by animals as well as by plants. Animals feed upon plants in which food has been made, or upon other animals which have fed

leaves, stems, and seeds of plants. This is made over into muscle, fat, and other tissues which a lion or other carnivorous animal eats. The part which nourishes the lion is the proteid and fat that were made from leaves and stems of plants, but the leaves and stems themselves would not have nourished the lion.

288. Permanence of Material in Organisms.—An adult animal in normal health has about the same average weight from day to day. His weight is increased by food, but this increase is offset by the decrease resulting from the oxidation of food. If he is inactive, his weight decreases slowly. When body or mind is actively at work, oxidation

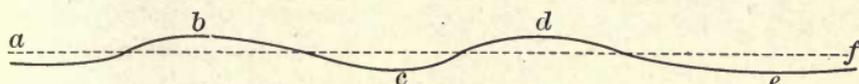


FIG. 137. — PERMANENCE OF MATERIAL IN A LIVING BODY

1. The dotted line represents the average weight of an organism for 24 hours.
2. What is the significance of the rising line *ab*?
3. What points on the line represent a condition of rest after taking food? Why?
4. What points represent the effects of severe muscular work?

is more rapid than when they are at rest. If a line were used to show the weight of an animal for twenty-four hours, it would be a line of curves rather than a horizontal line, though its ends might be connected by a horizontal line.

Not only does the weight of an animal vary but the actual material making up the body changes. . . Parts of the body are removed as waste products; and new matter is taken into the body to replace the old and to make new cells. The source of this new matter may, for instance, be a mineral. A molecule of limestone may by several steps become a part of the body of a horse. Limestone, when heated to make lime, gives off carbon dioxide into the air. The carbon dioxide is used by plants in making starch, which is found in seeds. The seeds which contain carbon (oats and corn, for example) may be the food of a horse, and thus the carbon once contained in the limestone becomes part of a muscle.

289. The Cell. — After the invention of the microscope about the year 1600, people began to make use of its magnifying power to examine all kinds of plant and animal substances. It was not until 1838, however, that the fact was established that all organisms are made up of definitely formed parts or units, somewhat in the manner in which the walls of brick buildings are made up of separate bricks.

These small units had been seen two hundred years earlier, and at that time were called cells, because it was thought that they were practically empty spaces. In 1838 it was demon-

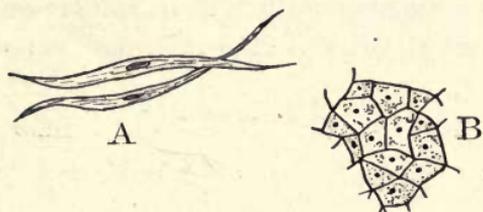


FIG. 138. — TWO KINDS OF CELLS.
(magnified about 100 times)

Figure A represents two animal cells, many of which make what we call a muscle. Figure B represents several cells from the thin covering on the surface of the body. There is one point of resemblance between these two kinds of cells. What is it?

some are globular, some flattened, some thread-like, some like a pillar.

290. Tissues. — Cells more or less alike are often grouped in a plant or animal. Such a collection of like cells is called a **tissue**. Examples of tissues are the cells of the skin covering the human body, wood cells, pith cells, and muscle cells.

291. Organs. — Different kinds of tissue are often combined to form a definite part of an organism, called an **organ**, such as a leaf, a hand, an eye, or a root. A leaf consists of a thin covering, green pulp, and veins. There are more than three kinds of tissue in the hand. An organ is a part of an organism which has a special kind of work to do.

strated that the cells were in reality separate masses of protoplasm, generally surrounded by an envelope which is called the cell wall. The size of cells varies from $\frac{1}{25000}$ of an inch in diameter to two inches, the average diameter being about $\frac{1}{3000}$ of an inch. The shape of cells also varies greatly;

292. The Importance of the Cell. — From what has been said of cells, it will be understood that the work of an organ is really the result of the combined work of all the cells which make up its tissue. The contraction of a muscle is in reality due to the contraction of every cell of which the muscle is composed. The cell may therefore be regarded as the working unit, as well as the unit of structure.

293. Division of Labor. — Some very tiny plants and animals have bodies consisting of but one cell. Since this cell must perform all the physiological functions essential to life, each function must be performed in a very simple manner. But the bodies of all the larger organisms consist of many cells, among which the work of living is divided. Certain cells are concerned with irritability alone, certain others with the taking of food alone, and each has a shape fitted for the work it has to perform in order to support life.

The single-celled animal or plant may be compared to a hermit, who must provide with his own hands his shelter, food, and clothing. A man living in a large city, on the other hand, may purchase all these necessities from different people, each of whom has done one kind of work. Meanwhile the city dweller has perhaps been making tools, or designing improved machinery for the other workers. The assignment of the necessary work of life among different individuals, whether cells or complete organisms, is called **division of labor**

294. Division of Cells. — Most cells contain a structure of denser protoplasm, known as the **nucleus**. A cell never grows beyond a certain maximum size. When this is reached, the cell may divide into two new cells through an equal division of the nucleus and the rest of the protoplasm. Then each resulting cell may grow to the maximum size of its kind, when division may take place again. Thus, from one cell many cells may result by repeated cell division. This process is the usual method of **growth** observed in the tissues of plants and animals.

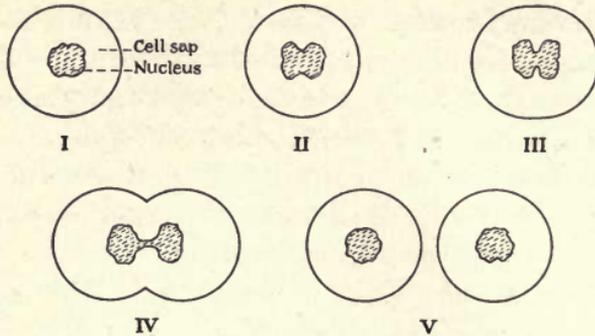


FIG. 139. — DIVISION OF CELLS

1. Cell I has attained its greatest possible size. What change has begun in II?
2. How does the size of each cell in V compare with the size of I?
3. What does this show about the method of growth of an organism?

When a new cell, instead of helping to make new plant or animal tissue, separates from the plant or animal and develops into a new organism, **reproduction** has taken place. The new cell that left the tissue of which it formed a part is called an egg cell or a sperm cell.

EXERCISES

1. (a) What are the physical properties possessed by all bodies?
- (b) What other properties are possessed by organisms only?
2. Why is food a universal necessity for all living things?
3. What are the symptoms of starvation in an animal? In a plant?
4. Why can animals live longer without food than without oxygen?
5. (a) Why is breathing necessary? (b) When is breathing the slowest? Why?
6. What property makes possible the closing of a flower at night?
7. Why does a humming bird need more food than a snail?
8. Give an illustration, drawn from this chapter, of the Law of Conservation of Matter.
9. Why cannot the leaves of most plants live separated from the plant?
10. How could cells have been mistaken, in early microscopic study, for empty spaces?
11. What is the object of reproduction?
12. What makes division of labor possible in higher forms of life?

CHAPTER XXIII

THE LIFE OF A PLANT

295. Study of a Plant. — We have learned that plants and animals alike are characterized by certain life activities or functions; namely, nutrition, reproduction, irritability, and spontaneous motion. A common plant that can be grown readily in a schoolroom will help us to understand how plants are able to carry on these life activities. A bean plant will illustrate the structure and the work of all green plants.

If we examine a mature plant, we notice first that it has several parts or organs. These are roots, stems, leaves, and sometimes flowers.

296. Roots. — If we dig up a bean plant, we note how firmly the roots anchor it to the ground and how the particles of soil cling to the young rootlets. The central root, which seems to be the downward continuation of the stem, is called the *primary root*, and its branches are called *secondary roots*.

297. Extent of Roots. — The total length of the roots of an ordinary plant is much greater than is commonly supposed, for when a plant is pulled up, a large part of the whole mass of roots is usually broken off in the ground. The roots of winter wheat extend downward seven feet, and the roots of certain trees in arid countries have been known to reach a depth of sixty feet. All the roots of a full-grown corn plant, if cut off and pieced end to end, would reach over one thousand feet, and a large squash vine has several miles of roots.

298. Functions of Roots. — Near the ends of the roots are delicate root hairs, which are really cells with very thin walls. They look like a fine fuzz and are estimated to be about $\frac{1}{800}$ of an inch in diameter. Small as they are, the

plant needs them. It is their function to take water from the ground into the roots for the plant's work of food making. If the roots are allowed to become dry, the root hairs, being small, are soon rendered unfit to take water from the soil, and the plant droops and usually dies.

Most shade trees have a long primary root. This helps to hold the tree in an upright position, even if strong winds push

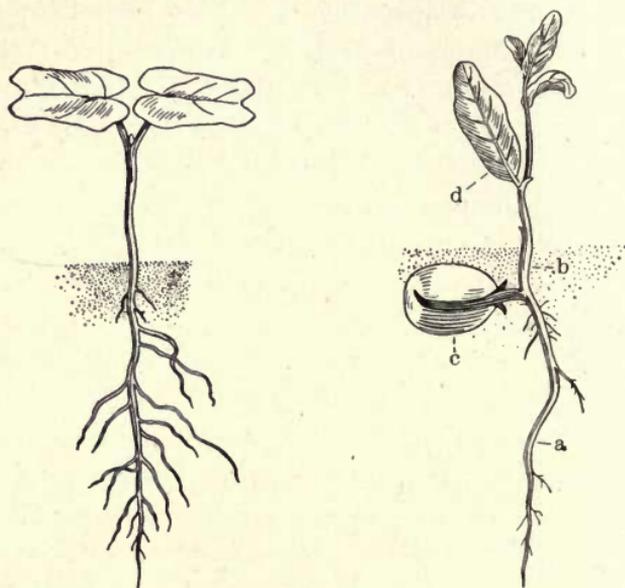


FIG. 140. — PRIMARY AND SECONDARY ROOTS

The figure at the left is a seedling morning-glory; at the right, a seedling oak. 1. Compare the roots in the two seedlings as to kind and number. 2. Which of these plants lives more than one year? 3. What relation is there between the answers to 1 and 2?

against its spreading crown. The elm tree is an exception in this respect, and as a result, it is much oftener overthrown in a gale than is the maple, the oak, or the chestnut.

Roots serve a useful purpose in holding particles of soil together. The cutting of a forest from a hillside is likely to result in the rapid washing away of the soil and in floods. Large tracts of valuable land have been ruined in this way,

by the removal of fertile soil and the formation of deep gullies. (LABORATORY MANUAL, Exercise XXV.)

299. Stems and their Functions. — Stems bear the leaves and hold them out in the most advantageous positions for receiving light and air. They also serve as pathways for

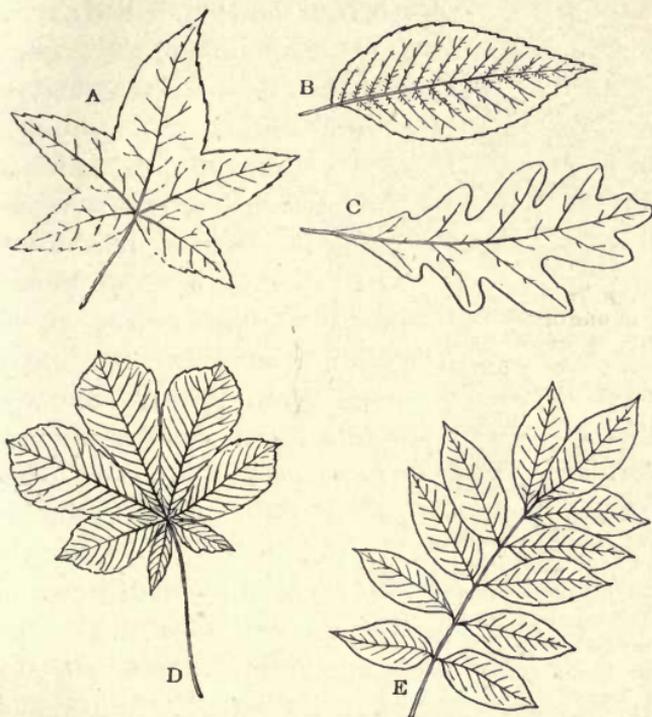


FIG. 141. — SIMPLE AND COMPOUND LEAVES

1. Which compound leaf does *A* resemble? 2. What would make the resemblance closer? 3. Compare another compound leaf with one of the simple ones. 4. State some resemblances in veining between one of the simple leaves and a compound leaf.

transmitting liquids between the roots and the leaves. In a very young plant, the stem depends largely upon water in its cells to keep it stiff. In order that stems may be able to stand upright and bear the weight of branches and leaves, they are strengthened, as they grow, by many tough fibers. We are all familiar with such fibers in the "strings" of celery.

300. Leaves and their Functions. — The examination of a bean plant will show that what we might at first take to be separate leaves of the plant are joined in groups of three.

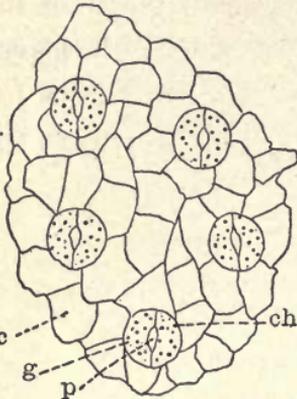


FIG. 142. — CELLS FROM THE SURFACE OF A LEAF. (magnified about 250 times)

c is one of the irregular-shaped cells of the covering of a leaf. *p* is a pore or opening into one of the cells below. *g* is a guard cell; two of these regulate the size of the opening *p*, according to conditions. *ch* is one of the few chlorophyll grains in guard cells; the cells in the interior of the leaf contain many such grains. The pores admit air and give out the water vapor and oxygen that are released by the chemical work of the leaf. 1. Why would the pores be smaller in dry air than in moist air? 2. What properties of living matter are illustrated by the opening and closing of pores?

These leaflets, as they are called, are really parts or divisions of one leaf. Such a leaf is called a *compound leaf*. The clover, the rose, and the locust have compound leaves. Most of our commonest plants bear *simple leaves*. The elm, the geranium, and the lettuce have simple leaves.

The leaves of a plant are so placed as to shade one another as little as possible. The leaves at the lower end of the twig may have longer stems than those above. In some plants leaves grow in pairs on opposite sides of the stem, the second pair at right angles to the first. If a leaf is held up to the light, many fine branching veins can be seen. The veins of a leaf are not like veins in an animal — tubes *solely* for carrying a liquid. They furnish a framework for the softer parts of the leaf. (LABORATORY MANUAL, Exercise XXVI.)

Microscopic examination of a leaf would show us a great number of minute pores which open into tiny cavities or air spaces in the interior of the leaf. These pores furnish the means of entrance for the air. They also provide an exit for those constituents of the air which are not of use to the plant, and for the waste products of

oxidation. In the apple leaf there are 24,000 pores to every square inch, and in the leaf of the black walnut there are 300,000 to the square inch.

The important work of starch making in leaves will be considered later (§ 302).

301. Presence of Water in Plants. — If seeds are placed on damp blotting paper, the root hairs of the first root will turn downward to the surface of the damp paper, even if the end of the root does not touch it. Several leaves may grow in these conditions; this shows that water passes through the root hairs into the root, and then up the root, stem, and veins of the leaf, until at last it reaches the cells in the interior of the leaf.

Capillarity and osmosis aid in this rise of liquids through the cells of the root and the stem. Capillarity makes the liquids rise along the sides of the slender tube-like cells, while osmosis causes them to pass from one cell to the next. *Root pressure* is the name given to the sum of all the agencies by which liquids are raised in opposition to gravity.

Water is constantly passing up into the leaves, where a large part of it is given off or evaporated through the leaf pores. We can test this fact by placing a sheet of rubber on the ground around a plant, and inverting a jar over the plant. On cooling the jar, we find that vapor condenses on the inside.

Experiments with sunflower plants have shown that a single plant often gives off a quart of water a day, while a single birch tree with its greater number of leaves may give off 800 quarts in the same length of time. Grass may give off as much as 13,000 quarts per acre every twenty-four hours. (LABORATORY MANUAL, Exercise XXVII.)

302. The Starch-making Process. — Plants, of course, do not elevate water simply for the sake of evaporating it from their leaves. They put water to several important

uses. They combine water chemically with carbon dioxide from the air to form starch and sugar, which are foods for the growing plant. The starch-making process is carried on by the chlorophyll grains within the interior cells of the leaf by the aid of the energy of sunlight.

The presence of starch in leaves may be proved. First extract the chlorophyll by heating the leaf in alcohol, until the leaf has lost its color. Boil the leaf in water to cook the starch, and then add a few drops of iodine. Iodine always turns anything which contains cooked starch to a dark blue color, and is usually employed as a test for the presence of starch.

303. Light and Chlorophyll Necessary in Starch Making. It can easily be shown, from leaves which have grown in the dark, that plants cannot make starch without light. Neither can leaves destitute of chlorophyll make starch. Toadstools and Indian pipe have no green color; the iodine test shows no starch in these plants.

Starch making is most rapid in direct sunlight, but it probably goes on in all degrees of brightness, even in moonlight. Light from other sources will also serve. For example, if an arc light is in use in a greenhouse for half of every night, lettuce plants grown there will be ready for market a week before others which are not so treated. The blooming of Easter lilies may in the same way be hastened from four to ten days.

304. The Proteid-making Process. — It may be asked why water is constantly carried up through the plant, and then in large part evaporated. It is because the salts dissolved in the soil water are present in such small amounts that the plant must absorb great quantities of water in order to secure enough of these compounds for making proteid.

These minerals are compounds containing several elements, chief among which are nitrogen, sulphur, potassium, and phosphorus. These elements the plant combines with the

elements of which starch and sugar are composed — carbon, oxygen, and hydrogen — to form proteid, another plant food. Starch making can occur only in *green* leaves and only in the *light*, but proteid making can take place in other parts of the plant, and in darkness as well as in light.

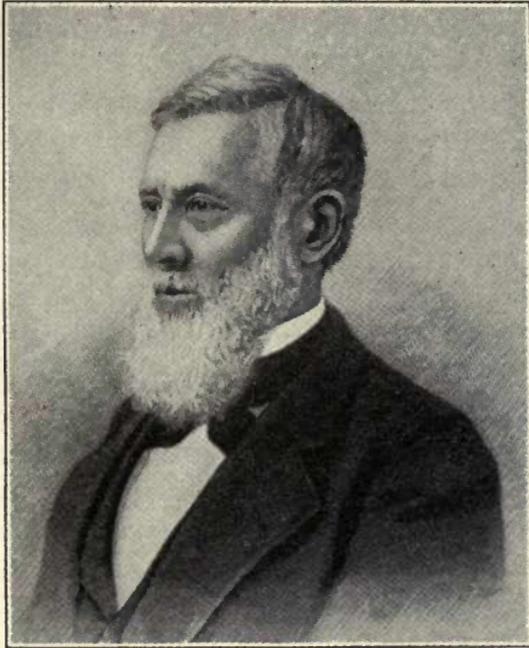


FIG. 143.—ASA GRAY: BOTANIST. 1810–1888

Very few great investigators are willing to take the trouble to prepare textbooks of their subject, much less elementary textbooks. But Gray was also a great educator and his ambition was to develop the science of botany by training the greatest possible number, from the elementary schools to the university. . . . For nearly half a century he taught not only the teachers but also the children. — JOHN M. COULTER, in *Leading American Men of Science*.

305. The Importance of the Chemical Work of Plants.—Plants themselves use these manufactured foods to build up their tissues—to grow, as we say. If there were an inexhaustible supply of carbon dioxide in the air and of minerals in the soil, plants could get along without animals. But ani-

mals (including man, of course) could not live a generation without green plants, even if there were an abundance of all the elements needed for their growth. Animals cannot make organic matter from inorganic matter.

Wild cattle, horses, sheep, and deer live mainly upon leaves. Domestic cattle require dried grass to eat in the winter. Wild hogs and bears find their food largely in nuts and roots. These are simply a few illustrations of the need of plants among the large herbivorous animals. Many worms, insects, and birds live upon plant food. The waters of the land and of the ocean are rich in plant life (some of it microscopic in size) which is food for fishes, corals, and sponges. The carnivorous animals of the land and sea feed upon the herbivorous animals.

Starch, sugar, fat, and proteid are the food of all kinds of animals. These are the products of the chemical laboratory in the plant. Plants are the food makers of the world.

306. Digestion. — Starch and proteid are foods, but both of them are insoluble in water, and hence need to be digested before they can circulate through the plant. **Digestion** consists in changing foods chemically so that they are soluble. For example, starch is changed to sugar, and then the sugar is dissolved in the water which is present in every part of a growing plant. After this, the dissolved sugar can be transported from the leaves to any living cell of the plant, to be used as a basis for making proteids, for immediate use as food, or for storage against future need.

307. Storage of Food in Plants. — Plants store food for their own use in the root, as the beet does; in the underground stem, as the white potato does; or in the base of the leaves, as the onion does. Food for the benefit of a future plant is always stored in the seed. The reason that roots of beets and carrots furnish food for man and animal is that the plant has stored here starch, proteid, and sugar for its own use the *next year*, when new stems, flowers, and

seeds will grow from the old root. The food of man consists largely of grains, which are rich in starch, stored for the nourishment of the young plant that would grow from the seed. Man makes use of materials which the plant would use if it continued to live and reproduce. (LABORATORY MANUAL, Exercise XXVIII.)

308. Respiration. — The process of respiration for plants is *exactly the same* as for animals. It consists of inhaling, or taking oxygen into the interior of the organism for the purpose of oxidation; and of exhaling, or expelling the gas resulting from oxidation. The necessity of respiration for the plant can be easily shown. Oxygen is necessary for the oxidation of foods and tissues, and for the consequent release of energy to be used in movement and growth. Since plants have a lower temperature and less movement than many animals, less oxygen is required to furnish energy, and less carbon dioxide and water vapor are returned to the air. When we recall that starch and its digested product, sugar, contain much carbon and hydrogen, we can readily see why carbon dioxide and water are the substances resulting from the oxidation of these foods, and why therefore they are exhaled.

309. Excretion and Removal of Oxygen. — The term *excretion* is commonly applied to the removal of *waste products* of oxidation, such as carbon dioxide and water, which are eliminated because they are of no further use in the cells of the plant.

In the making of protoplasm, proteid food is chiefly used. If it is oxidized, as is sometimes the case, it forms products not easily excreted, because they cannot be given off as gases, as can water and carbon dioxide. So these waste products, together with certain salts from the soil, which perhaps cannot be utilized, become stored in leaves, bark, and fruit. As these parts are in time detached, the waste products from proteid are removed from the plant.

Another very important work of plants is the giving off of oxygen from the carbon dioxide which the plant absorbs from the air. The carbon only is used in starch making, and the oxygen is passed out through pores in the leaves. As starch making occurs naturally only in sunlight, so the liberation of oxygen occurs only in the daytime. Oxygen is not a waste product but a *residue* that is useless to the plant.

310. The Processes of Plant Nutrition. — Plant nutrition includes:

The preparation of food from materials in soil, water, and air.

The digestion of these foods.

The excretion of waste products of oxidation.

The use of the foods in individual cells, either to make new protoplasm in the process of growth and repair, or to yield energy through oxidation by means of the oxygen taken from the air.

The elimination of any useless residue.

EXERCISES

1. Why do we not usually see the root hairs when a plant is dug up?

2. (a) Why does the gardener take pains to keep soil about the roots of a plant which he is transplanting? (b) What is the effect on a plant if the soil is dry? (c) Explain the change that watering produces.

3. (a) In what state is the water given off from leaves of plants? (b) Describe a simple method by which we could show that it is given off.

4. How can carbon dioxide reach the interior of a leaf?

5. What substances pass out of the pores of a leaf?

6. What would be the appearance of a leaf after the chlorophyll had been removed?

7. Name some plants having simple leaves; others (besides the bean) having compound leaves.

8. What organs of a plant are its starch factories?

9. How do the materials used there get to these organs?

10. From what materials do plants prepare food?
11. (a) What is prepared from starch by digestion? (b) For what is the product used?
12. What waste products do plants excrete?
13. What materials useless to the plant are otherwise eliminated?

CHAPTER XXIV

REPRODUCTION AND DEVELOPMENT OF PLANTS

311. The Object of Reproduction. — Up to this point only the activities necessary to the plant itself have been considered. A maple tree three feet high, or a wheat plant six inches above the ground, is a complete, independent plant. It responds to the influence of water and light; it makes its own food; that food is digested and new cells are formed from the product. Oxidation of parts of the plant gives heat and energy for necessary movements. If, however, the plant died at this stage, its death would be premature. It would have failed to provide for the continuance of its own race. The function of reproduction, without which a race of plants or animals ceases, is performed only by a mature organism.

312. The Structure of Flowers. — Many plants, of which the bean plant is a type, reproduce by means of seeds found in the pod after the flower withers. Therefore, in the study of reproduction it is convenient to begin with the flower. Flowers differ greatly in color, size, and shape; but if complete, they all have **petals, sepals, stamens**, and one or more **pistils**. The simplest flowers have these parts quite separate; but some flowers, such as the bean, show some of these parts united.

The garden bean plant has five petals, usually white, two rather closely placed petals being below the other three. On the back or under side of the flower there are five green sepals, partially united. The flower has also ten yellow stamens and a single pistil. The knobs, called **anthers**, at the ends of the stamens are really hollow sacs producing a large

number of fine yellow grains, called **pollen**. The rather stout basal part of the pistil, called the **ovary**, contains small white rounded bodies, called **ovules**. The beans are fastened at the sides of the ovary; some seeds are fastened at the middle. The bean pod shows the place of attachment very plainly. (LABORATORY MANUAL, Exercise XXIX.)

313. Pollination. — The pollen from the stamens is transferred to the tip of the pistil by some agency, such as gravity, insects, birds, or wind. This process is termed **pollination**. Small birds searching for insects, and insects looking for food, thrust their heads or even their entire bodies into a flower and rub the pollen from the stamens upon their bodies. As they withdraw, they sometimes leave some pollen upon the **stigma**, which is the top of the pistil; but more often they carry it to the next flower and, entering, scatter it upon the stigma, thus securing pollination for that flower.

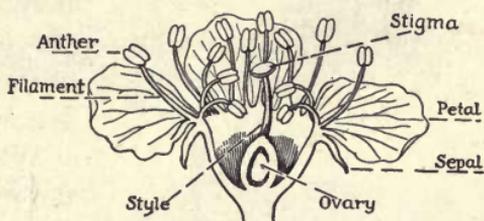


FIG. 144. — FLOWER

1. The ovary of this flower contains only one ovule. How is it kept in place?
2. How can you tell whether this is a cherry or an apple blossom?
3. What is grown inside the anthers of a flower?
4. What is the most common color in anthers?
5. What reason can you give for the pistil's position in a flower?

314. Fertilization. — Microscopic study of an ovule shows it to be composed of cells, one of which is called the *egg cell*. The pollen grain contains a special cell called the *sperm cell*. When a pollen grain is left on the tip of the pistil, a long delicate tube grows from the pollen grain down through the pistil till it comes to an ovule. It pierces the ovule and thus reaches the egg cell. Through this tube the sperm cell of the pollen grain travels, till it reaches the end of the tube and meets the egg cell. The two cells, coming together, unite and form a single cell. This union of egg cell and sperm

cell, to form a fertilized egg cell, is known as **fertilization**. Pollination may occur without resulting in fertilization, but fertilization *never* occurs without previous pollination.

315. The Result of Fertilization.—Soon the fertilized egg cell divides to form two cells and, after growth, these new cells divide. This process of cell division is repeated until an **embryo**, or baby plant, is formed within the ovule. At the same time, food is being furnished by the plant which bore the flower and is stored in the ovule for the nourishment of the young plant. The ovule is now known as a **seed**.

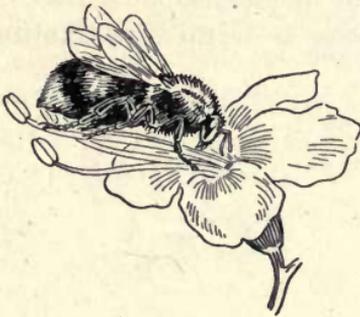


FIG. 145.—BUMBLE-BEE GOING INTO A FLOWER

Describe the way in which the bee will assist in pollination of this flower.

While the ovules in a bean flower are developing into seeds, the ovary elongates and becomes the pod. Long before this, the petals and stamens have withered away and later the sepals also, until now nothing remains but the **fruit**, which

consists of the ovary and the seeds. When the fruit is ripe, the seeds easily become detached and drop out of the dry pod. Examination of a bean seed shows on one edge an oval-shaped scar made by its connection with the ovary.

316. Structure of the Bean Seed.—The seed coat is easily stripped from a bean soaked in water over night. The body within, called the embryo, is seen to consist of two thickened halves, **seed-leaves**, filled with proteid and starchy food. They could be tested for the starch by means of iodine. The presence of proteid in the seed may be shown by the orange color given to it on adding a drop of nitric acid, followed by ammonia.

A short, stubby, rod-like body is joined to the two seed-leaves. From its free pointed end grows the root, and the

part next to the seed-leaves becomes the stem. Upon carefully separating the two seed-leaves, there is found a pair of small thin leaves, with a bud between them, attached to a very short stem, which is joined to the stem part of the rod-like body. (LABORATORY MANUAL, Exercise XXX.)

317. Process of Germination. — To see what becomes of the parts of the embryo, let us plant a bean seed. If the seed is put in a warm, moist place, where there is air, it will soak up water and swell, and presently the embryo or baby plant inside, which has been dormant while the seed was dry, will continue its growth.

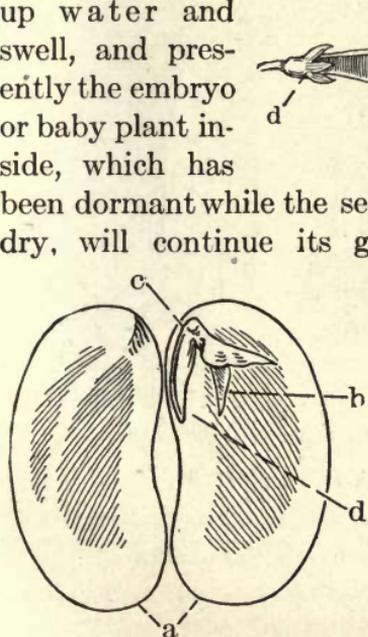


FIG. 146. — THE BEAN EMBRYO

1. What are the names of the parts *a*? What will grow from *d*? 2. How do you know that *c* will grow to be a stem? 3. What becomes of the two large parts of the embryo?

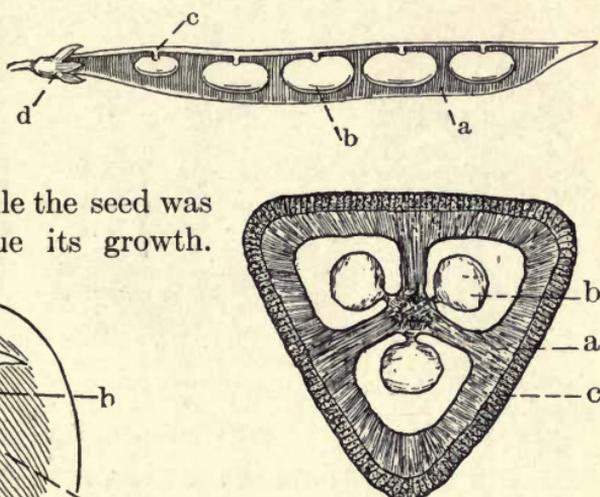


FIG. 147. — SEED PODS

The bean pod represents a lengthwise section of an ovary; the triangular figure represents a cross-section of the ovary of a lily. In both cases, *a* represents the wall of the ovary; *b* represents an ovule. 1. Where are the ovules attached in the bean pod? Where are they attached in the lily pod? 2. How many divisions are there in the lily pod? How many in the bean pod?

This "awakening" and growth into an independent plant is called **germination**, and the seed is said to germinate.

318. The Result of Germination. — The embryo bursts open the seed coats, and as the seed-leaves absorb moisture from the soil, a chemical change takes place in the starch and proteid stored in the seed-leaves. They become soluble and furnish food and energy for the young plant to live on until it has a root capable of taking water from the ground, and leaves to take carbon dioxide from the air. When it can make its own food in this way, the seedling has become “self-supporting.” In time it will become a mature plant

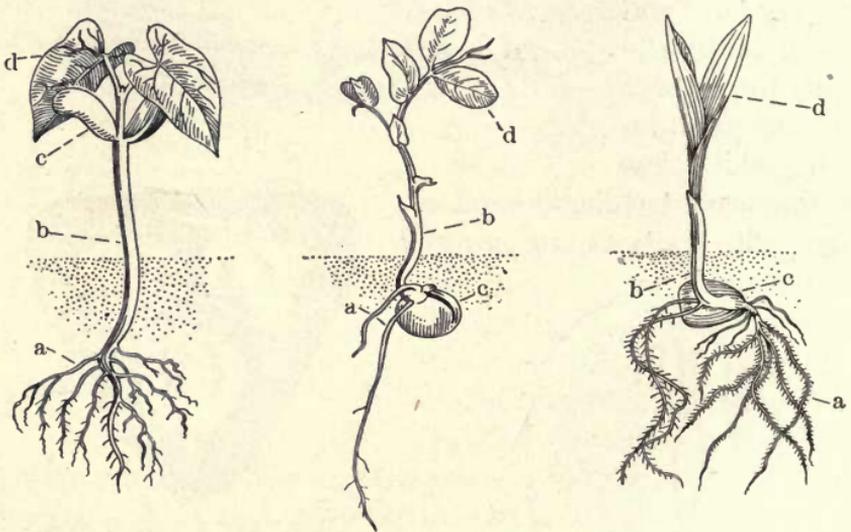


FIG. 148. — BEAN, PEA, AND CORN SEEDLINGS

1. Give the name of the organ designated by each letter in the picture of the bean. 2. What difference is there in the position of the corresponding organs in the pea? 3. What differences are there between the corn seedling and both of the others? 4. What peculiarity of the corn seedling is explained by the fact that from 10 to 20 tons of water are required to raise a bushel of corn?

having flowers, fruit, and seed of its own. Thus the family of bean plants is continued by the process of reproduction.

319. Flowerless Plants. — There are some plants which do not have flowers containing reproductive organs. In such plants the function of reproduction is accomplished in one of two ways. In some of the simplest microscopic forms

of plants, there are no organs of any kind. A single cell is the whole plant. Reproduction takes place when the cell separates into two cells, thus forming two plants. In higher flowerless plants, **spores** are produced and from these bodies new plants grow. Spores are very small bodies which look like dust. They do not have an embryo—a complete, minute plant within the covering—as a seed does,



FIG. 149. — THREE FLOWERLESS PLANTS

The letter *a* indicates the part of the plant which bears the spores. The mushroom is never green. What does that imply in regard to its food making?

but contain only a minute portion of protoplasm. Ferns, club-mosses, and puff balls, when dry, discharge thousands of spores on being shaken.

Some flowerless plants find food material in the leaves and fruit of other plants, as do molds and yeast; and some in decaying organisms in the soil, as the mushroom; ferns and mosses, however, usually require soil for development. Mosses and ferns have chlorophyll in their leaves; mushrooms, yeast, and bacteria have none.

There are some plants, like palms and rubber plants, which

do not blossom under the artificial conditions in which they are grown. These should not be called flowerless plants.

320. The Influence of Light. — One of the most remarkable things about protoplasm is its sensitiveness to its surroundings and its power to respond in certain definite ways to varying outside conditions. For example, protoplasm is stimulated or roused to activity by light. If a bean plant is grown in the dark, the stem will increase in length more quickly than usual, but the leaves will be small and will lack the usual green color. If a ray of light is admitted into the dark place, the stem will immediately grow toward this light. The stems of house plants, which receive a comparatively small amount of light from windows, are more slender and paler than the stems of those grown out-of-doors and not shaded by neighboring plants. Moreover, plants grown indoors always turn in one direction — toward the light.

321. Growth Movements. — Only the younger, growing parts of plants move under the influence of light, as it is difficult for the older and somewhat rigid parts to change their position. This response by movement is brought about by the more rapid growth of the stem on one side than on the other. When the bean plant is unequally lighted, growth is most rapid on the side away from the brightest light, and this makes the top curve toward the light.

322. — Another Response to Light. — The behavior of the tips of young shoots of English and Japanese ivies, which are often seen covering the walls of stone or brick buildings, is quite the reverse of that of the bean plant. They turn away from the light, though the leaves still face the light. The ivies hold themselves in position by short root-like growths on the stems, which attach themselves to the rough stone. If the tip of the stem turned toward the light, the hold of the vine on the stone would be weakened. Different parts of the plant thus make different responses to the stimulus of the light.

323. The Behavior of Flowers.—Certain flowers, such as the crocus and dandelion, open in the light and close in the dark, whether it be at night or in cloudy weather. This makes them ready to admit by day insect visitors, which in their search for nectar receive pollen on their bodies to be carried to other flowers. It also enables the flowers to protect their pollen from dew by night or from possible rain on a cloudy day.

324. Motor Organs.—The old parts of some plants, being too rigid to move easily, are usually provided with special structures to produce movement. Examination of the base of the leaf stalk of the bean, and also of the tiny stalks of the separate leaflets, will show slight enlargements, which are called motor organs. These organs are composed of cells containing much water. Variations in the intensity of light to which the bean plant is exposed will cause rather prompt changes in the amount of water in the cells of one part or another of the motor organs. In the dark, the cells of the upper part of the motor organs of the leaflets become full of water and so the leaflets are made to droop. In the light, the reverse conditions occur.

325. Change of Response.—The kind of response to light stimulus may change at different stages of development and growth. The flower stalks of a certain plant turn toward the light when the buds first open and remain so until after the pollination by insect visitors. Then, as they grow longer, the stalks turn away from the light, and push their

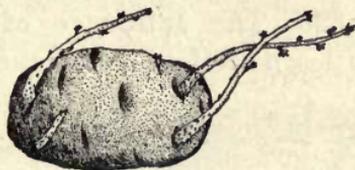


FIG. 150.—POTATO SPROUTS GROWN IN A CELLAR

This picture illustrates the fact that a potato is an underground stem. The "eye" of the potato contains a little bud which will develop into a branch bearing leaves and blossoms above the ground. 1. From which side does the light come? How do you know? 2. Why are the branches ("sprouts") white? 3. Men cut a potato into pieces before planting. Will every part of a potato make a branch? Why?

seeds into the crevices of the rock on which the plant grows.

The flower of the peanut plant opens and is pollinated in the light, but after pollination its stalk turns downward and pushes the young seed pod into the ground, where it ripens. Although peanuts are pulled from the ground, they are not roots nor stems, but ripened ovaries and seeds.

326. The Influence of Gravity. — We are not surprised to learn that plants make use of a constant and universal

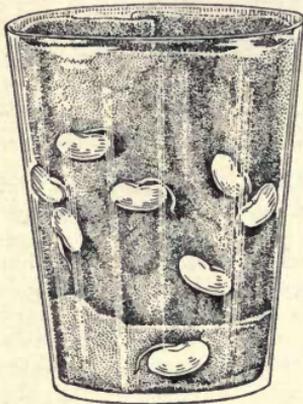


FIG. 151. — THE INFLUENCE OF GRAVITY

force such as gravity in guiding their organs into suitable positions. The fact that roots grow downward is so familiar that we do not usually think of it as needing explanation. No matter in what position a bean seed is planted, the primary root will grow down and the stem up. We could demonstrate that the direction of growth is determined by gravity if we could study a plant in some region where gravity did not exist. This, of course, cannot be done; but we can place several germinated seeds with the root tips pointing in different directions and watch their growth.

These beans were all sprouted under the same conditions and were placed, when the sprouts were very short, between moist blotting paper and glass. 1. Describe the change of direction in some of the sprouts. 2. In which cases has there been no change of direction? 3. What conclusion in regard to the influence of gravity could be drawn from these two answers?

Bend a piece of wet blotting paper to fit the inside of a tumbler like a lining. Place several germinated beans or peas between the paper and the glass, one with the root pointing up, one to the right, one to the left, one downward, and others in different directions. After a few days every tip will point downward, some roots having made a short turn, and some having wound around the seed before it was possible to turn downward.

Experiments on bean seedlings placed in a horizontal position in the dark show that the stems turn and grow upward, while the primary root turns and grows downward. This shows that it is gravity and not light which gives direction to the growth of stems.

Some parts of plants may respond to gravity by growing in a horizontal direction or at any intermediate angle, as is shown by the branches of the main stem and by secondary roots. Thus gravity seems to act as a pointer or directive force, so to speak. More rapid growth on one side of the stem or branch is the power that sends that part of the plant into the required position.

327. The Influence of Water. — Whenever any external force or substance is important to the life of a plant organ, the organ develops a corresponding sensibility to the influence of that force or substance. Thus roots respond to water. If water is evenly distributed, roots develop equally on all sides; otherwise roots grow only in the direction of greatest moisture. An example is found in the fact that roots of trees often enter and block up tile drains laid in wet ground, long distances from the tree itself.

In watering house plants, water should be placed in a saucer under the pot rather than on the surface. The roots turn toward the water, and if that brings them near the surface, they are more likely to become dry between waterings.

328. The Influence of Contact. — Irritability of protoplasm to contact with objects is almost universal. Tendril climbers, such as the pea, a near relative of the bean, make use of this irritability with the result that they attach themselves to supports. In this way they are enabled to elevate their leaves and flowers into more favorable situations. When the tendril touches the solid body, growth on that side is stopped, while growth on the opposite side is increased and the tendril curves.

The folding together, when touched, of the leaflets of the sensitive plant is brought about by differences in amount of water in the cells of the motor organs. Contact or even a sudden jar of the plant is a stimulus to which protoplasm responds by regulating the water in the motor organs. The closed leaf has a smaller surface exposed to the wind or to voracious enemies.

It is thus seen that responses are made by the plants themselves, the external influence or force acting simply as a signal

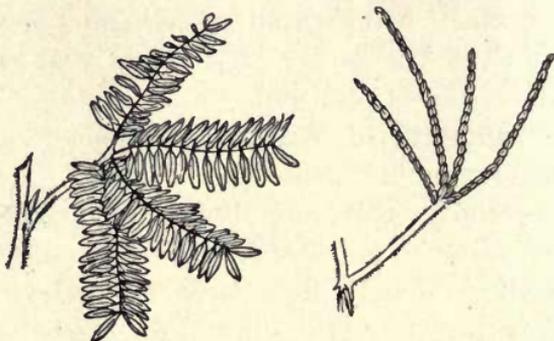


FIG. 152. — LEAF OF A SENSITIVE PLANT

1. Measure in mm. the length and width of one of the leaflets in the open leaf and give an estimate of the area. 2. Give the total area of the leaflets of one division of the four-parted leaf. 3. Compare it with the exposed surface of one of the divisions of the closed leaf. 4. What would be the advantage of the closed leaf in regard to heat, air, or plant enemies?

or stimulus. The result is the bringing of organs into better positions for doing their work or for protecting themselves from injury.

329. Internal Cause of Movement in Plants.—The movements of plants so far studied are brought about or guided by some external force, although in all cases the living protoplasm causes the useful movement. There is, however, another class of movements which do not appear to result from external conditions, and are hence thought to be due to some internal cause—although just what this cause is has not yet been determined.

Under the microscope the protoplasm in cells is seen to be constantly flowing around inside the cell wall. The growing tips of roots and stems are almost constantly in motion. These movements are usually very slight, though one example may be quoted to show that they are sometimes easily seen. On the banks of the Ganges River there grows a plant related to the bean, the tips of whose leaves make constant movements in the air, so that they describe a complete circle in less than three minutes.

330. The Sun, the Source of Energy for Life Processes.

How the living protoplasm is able to carry out the life processes of nutrition, reproduction, irritability, and spontaneous motion is a mystery. We know in regard to it, however, that the protoplasm ceases its activity and dies unless a certain amount of internal energy is available.

This energy, in the form of heat, is derived from oxidation of the protoplasm itself and of food material not needed for growth and reproduction. No amount of energy supplied *externally* can take the place of the necessary internal energy. If growth and movement are rapid, more energy is required — and therefore a greater amount of material is consumed — than if movement is sluggish or growth slow.

The sun is the main source of energy for living bodies. The internal energy, heat, set free during respiration is obtained from the oxidation of tissues made from food. This food is largely starch, — made only under the *influence of light*, — and proteid made from starch and from salts taken from the soil. When the tissues of the body are broken up or decomposed in the process of oxidation, this energy is set free and is used by the plant. Thus it appears that the most important thing about food making is that it is a process of *storing up the sun's energy* by the plant, just as the coal making of the past stored energy for present use. The plant requires energy by night as well as

by day, and throughout all seasons; so in the sunshine it stores energy for future need.

EXERCISES

1. What is the reason that the petals of a flower are generally showy?
2. Of what use to a flower is its odor?
3. What two parts of the flower do you consider most important? Why?
4. Why do not snowdrops and lilies of the valley open and close their flowers as tulips do?
5. (a) How could you show that starch was present in the seed-leaves of an embryo? (b) For what purpose is food stored in a seed?
6. (a) How is sensitiveness to the stimulus of contact of use to a nasturtium? (b) To a grape vine?
7. The beet and the turnip are two of the plants that do not blossom until the second summer after a seed is planted. What relation is there between this fact and the fact that they have thick roots?
8. Explain how a plant can grow and blossom from a bulb put into water only.
9. What does a plant gain by its response to the influence of light?
10. Of what advantage to a plant is the folding of its leaves at night?
11. Name all the steps in tracing man's energy back to the heat of the sun.

CHAPTER XXV

THE LIFE OF AN ANIMAL

331. Simple and Complex Organisms. — When we speak of organisms as *lower* and *higher*, *simple* and *complex*, we refer to the structure of the body. The simplest organisms consist of one cell, microscopic in size, and averaging about

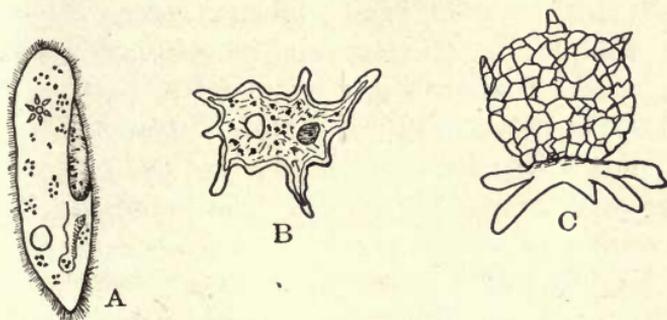


FIG. 153. — ONE-CELLED ANIMALS. (magnified)

These minute animals live in stagnant fresh water. Their food consists of microscopic plants and animals. The globular part of C consists of grains of sand which the animal gathers upon its surface for protection.

$\frac{1}{3000}$ of an inch in diameter. Such bodies possess no organs. Food is absorbed in liquid form at any part of the cell. Reproduction takes place by increase in the size of the cell, followed by separation into two cells. These simple organisms have all the physiological properties of protoplasm, which is their sole constituent. They are themselves food for organisms slightly more complex, which perhaps have one opening that serves both to receive food and to reject the insoluble residue, and a central cavity where digestion takes place.

For the most part we are ignorant of these simple organisms, because we can neither see them nor taste them. They exist even in drinking water, on the surface of fruits, in the air we breathe. Some are plants and some are animals, and these two classes sometimes have so close a resemblance that it is difficult for those who have not studied them very minutely to determine "which is which."

The one-celled animal in its general daily life performs all the functions which the higher and more complex animals perform. That is, the one cell carries on the many processes which in the higher animal are divided among various organs.

As we go somewhat higher in the scale, we find such animals as worms, oysters, snails, lobsters, and insects, which are more complex. They have special organs adapted to the functions of motion, nutrition, and reproduction.

The highest group of all, the **vertebrates**, or back-boned animals, is the one to which fishes, reptiles, birds, and the familiar domestic animals belong. Man is the highest type of the vertebrates.

332. The Nervous System. — In the simplest animals, irritability does not belong to any particular part of the body, but is possessed equally by all the protoplasm. But in the higher, many-celled animals, only special groups of cells respond to external conditions. These groups are set apart to take charge of the relation of the animal to its surroundings, and of the relation of one part of the animal to other parts. They perform no other work. Some groups of cells direct the organs of motion; some groups control the work of nutrition; others are concerned with sensation and, in the higher animals, with thinking, remembering, willing, and the like. All these groups taken together constitute the **nervous system**.

333. The Divisions of the Nervous System. — The nervous system consists of three divisions: the sense organs, the nerves, and the nerve centers. Each of these

parts is composed of groups of cells. A nerve cell consists usually of an angular body with thread-like branches. It has one very long outgrowth, called an **axon**. Thousands of nerve cells grouped together make a **nerve center**, and the axons of these cells form bundles of nerve fibers called **nerves**. Each fiber is protected by a covering or sheath. The nerves serve to connect the nerve centers with the sense organs, muscles, and other active organs of the body.

334. Sense Organs. — Some cells of the nervous system are highly sensitive to external changes, and are found on or near the surface of the body. These constitute **sense organs**. The eye is a sense organ. In the tips of the fingers there are sense organs.

335. Nerves. — There are two classes of nerves: sensory and motor nerves. The sensory nerves are so arranged in the body as to form a connection between the sense organs and the nerve centers, such as the brain and the spinal cord. The motor nerves connect nerve centers with the different organs of the body. Both kinds of nerves are found in all parts of the body.

A **sensory nerve** carries *inward*, to a nerve center from some sense organ, an impulse caused by an external change or stimulus. **Motor nerves** carry *outward*, from a nerve center, answering impulses to different organs. Because motion so often results from these answering impulses, the nerves which carry them are called motor nerves.

Illustration: a footfall jars the ground near a toad. The vibration of the ground arouses or gives stimulus to sensory nerves in the toad, which convey the information as an

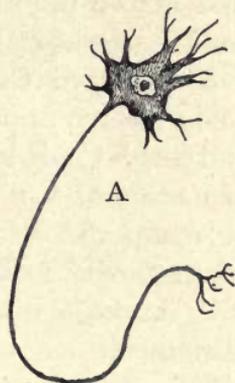


FIG. 154. —
A NERVE CELL.
(magnified)

The thread-like projection from the main body of the cell is one of the fibers of thread-like sensory and motor nerves.

impulse to a nerve center. The nerve center sends another impulse through a motor nerve to a group of muscles, and the toad jumps. These impulses are conveyed so rapidly that before the foot which caused the stimulus is lifted, the toad is a yard away.

336. Nerve Centers. — Nerve centers are groups of cells. They receive impulses brought to them over sensory nerves, and they send out answering impulses over motor nerves. The brain and spinal cord are nerve centers. The brain may be compared to an operator in a telephone exchange; it receives calls from a distant part of the body and connects with a muscle which, on contracting, moves an organ in response to the return message.

337. The Importance of the Nervous System. — The nervous system is of great importance, since it provides for the harmonious working of all the organs of the body. Among the higher animals, no cell of the body does any work except under the direction of the nervous system.

338. Study of a Vertebrate. — Observation of some living vertebrate animal will help greatly in the study of the organs and motions of higher animals. For this purpose a goldfish may be used. It is easily procured from a dealer in household pets, and with a little care, will live a long time in a jar of water. Part of the water should be removed and fresh water supplied once a week. If green water plants are living in the jar, the water need not be changed so often. Prepared fish food, as well as the water plants, can usually be procured where the fish is bought.

339. The Sense Organs of the Fish. — Two parts of the fish's body are specially fitted to receive impressions caused by light. These are the eyes. There is one eye on each side of the head. They are somewhat convex, but do not protrude much beyond the horny frame in which they are set. Experiments show that fish are nearsighted, so they probably cannot perceive objects at any great distance.

Experiments in feeding fishes show that they become aware of the presence of food by smelling it as well as by seeing it. The nostrils of a fish are sensitive to substances dissolved in the water in which the fish lives, as our nostrils are sensitive to gases carried by the air. Their nostril openings end in little pits which do not connect with the throat, as do ours.

The sense of taste is located on the tongue of the fish, and the sense of touch is located in the skin. Both of these appear to be less developed than the other senses.

The fish has an ear under the skin back of each eye and lying wholly within the skull. It is like the internal parts of our ears, and is sensitive to vibration in the water, just as the ears of land animals respond to vibrations of the air. (LABORATORY MANUAL, Exercise XXXI.)

340. The Relation of Sensation to Motion.—In order to live and reproduce its kind, an animal must be able to protect itself from danger and to secure food. Therefore it is provided with the means of defense or the means of escape from enemies, and with the power of motion. When any change of surroundings affects the sense organs, the nerves send impulses to the brain or spinal cord, and they in turn send impulses to the muscles.

341. Useful Responses.—If animals respond to external conditions in a way advantageous to themselves, they will succeed in getting food and in escaping from danger. Hence they are the more likely to live long and to leave descendants. There is a probability that the young will inherit from the parents the inclination to respond in the same way. As a result, instincts may originate and be perpetuated.

Instinct may be defined as an inherited habit. For example, a little kitten that has never seen a mouse is at once on the alert at the sound of a slight scratching. It sits motionless watching the point from which the sound comes. The kitten is trying to catch its prey in the

same way that its parents, its grandparents, and all its ancestors did. They lived to adult life because they succeeded in their methods. The kitten has inherited the habits of the race.

342. The Structure of Muscles. — In the simplest animals, the entire body is concerned with the process of moving.

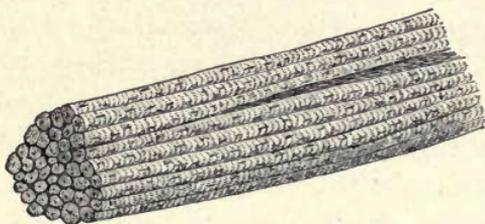


FIG. 155. — A BUNDLE OF MUSCLE FIBERS. (*much magnified*)

This picture represents a "string," such as one sees in boiled lean meat. Each string is composed of hair-like threads, represented by one of the small parts of this bundle.

and arranged in small bundles, which also lie parallel to one another. These bundles may easily be seen in boiled meat, where they tend to separate from one another as strings or fibers. Each end of a muscle is firmly attached by a tough gristly cord, called a **tendon**, to some part of the body — generally to a bone.

The involuntary muscles are not fibrous in structure and are not under the control of the animal. The muscles of the digestive organs show the structure of involuntary muscles.

343. The Work of Muscles. — In the division of labor which exists among the cells of animals, the muscle cells have been given the work of contraction, or shortening and thickening, but they act only under the direction of the nervous system. In most muscles, all the cells contract at the same instant, when so directed by some part of the nervous system. The muscle itself, therefore, shortens and grows

In the higher animals, movements are brought about by organs called muscles. Muscles are **voluntary** or **involuntary**, according to their control by the animal. The muscles which may be controlled by the will are voluntary muscles. They consist of masses of elongated cells lying parallel to one another

thicker, and pulls equally on the parts to which each end is attached. Movement occurs in the part which offers least resistance. The elbow is bent by a muscle attached at one end to a bone below the elbow, and at the other to a bone above. When this muscle contracts, the forearm and hand move up, unless opposed by outside force.

344. Antagonistic Muscles. — A part of the body that has been moved by a muscle is returned to its original position by a pull exerted by another muscle. The second muscle is so attached as to pull in an opposite direction from the first. Such a pair of muscles are called **antagonistic muscles**. For example, the knee is bent by the contraction of a muscle on the back of the leg, attached at one end to a bone below the joint, and at the other end to a bone above the joint. The knee is straightened by the contraction of another muscle on the front of the leg attached to the same bones. One of the antagonistic muscles must relax when the other contracts, if movement results; but there is nothing in the *relaxing* of a muscle to exert a push and so to cause movement. Any motion of any part of the body is caused by a *pull*. Of the pair, the muscle which bends the joint is called the **flexor**, and that which straightens it is the **extensor**.

345. Organs of Locomotion. — The organs which are specially designed for the moving of an animal from place to place are **organs of locomotion**. The fins of a fish, the wings and legs of a bird, and the legs of a quadruped and of man are organs of locomotion. Animals designed for rapid motion have, as a rule, somewhat wedge-shaped bodies with the edge of the wedge projected forward. The fish is propelled by a movement of the tail fin and the hinder part of the body, similar to the movement of an oar used in the stern of a boat for sculling.

The turning movements of a fish are brought about by the use of the paired fins. One pair of fins corresponds to the arms of man, to the forelegs of a dog, and to the wings of

a bird. The other pair corresponds to the legs of man and to the hind limbs of the other animals mentioned. The single fins on the upper and lower parts of the body of the fish are useful for balancing and for steering.

In the nervous system and in the muscles, animals have

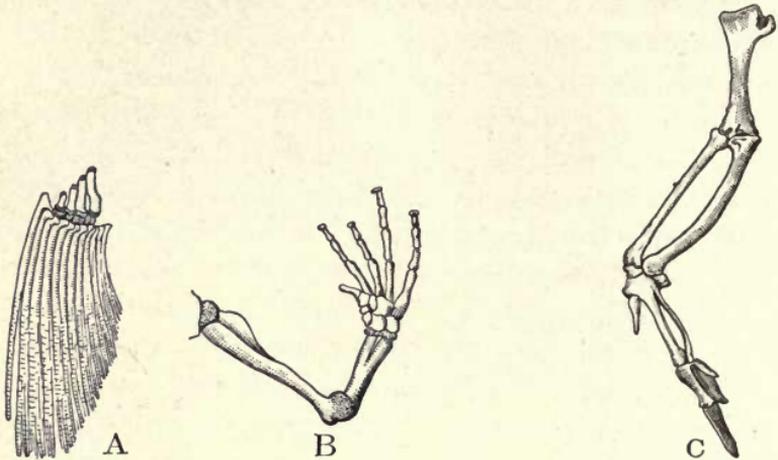


FIG. 156. — ORGANS OF LOCOMOTION

Figure A represents the skeleton of a fin of a fish; B that of the fore leg of a frog; C that of the wing of a bird.

special organs which make *evident* use of the properties of irritability and spontaneous motion. These properties are not less necessary to the plant, but they are not so easy to observe in plants as in the higher animals. Responses to external influence on the part of animals are more immediate than in the case of plants, and the motion is more rapid and greater. Very few land plants move from place to place; most land animals do so. In the case of animals, there may be not only spontaneous motion of protoplasm within the cell wall, and of the organs of the body, but also locomotion, — that is, motion of the whole body from one place to another.

EXERCISES

1. Name three differences between simple and complex organisms.
2. What is the function of the nervous system?
3. Name three sense organs.
4. Of what use are the sense organs in our finger tips?
5. Give an example of an animal that has a keen sense of smell; of hearing; of sight.
6. (a) Give an example of instinct shown by a bird. (b) An example which shows that some animal has been taught by man.
7. What are vertebrates? Name four different examples.
8. How do muscles act to produce motion of a part of the body?
9. Give some illustration of antagonistic muscles not mentioned in the text.
10. On which side of a fish's body is the muscle which moves the tail to the left? What is that kind of muscle called?

CHAPTER XXVI

REPRODUCTION AND DEVELOPMENT OF ANIMALS

346. Reproduction. — In animals, as in plants, the function of reproduction is a function belonging to maturity. The power of reproduction is not essential to the life of an individual animal but is essential to the continuance of a race of animals.

347. Reproductive Organs. — In the higher animals, as in the higher plants, there are certain organs the function of which is to provide for the making of other animals. These organs are called reproductive organs. As in the higher plants, these organs are of two kinds: one kind producing inactive cells, called egg cells or eggs, such as are formed in the ovule of the flower; the other kind producing very small active cells, called sperm cells or sperms, such as are found in the pollen grains of the stamen of a flower. Fertilization, that is, the bringing together of the cells of the two kinds, is generally necessary for the development of a new animal organism. The number of eggs produced varies with different animals, just as the number of seeds varies with different plants. Insects and common fishes deposit many eggs at a time; birds, a few. Some animals reproduce many times in a season, some once a year, and some higher animals less frequently.

348. Sex. — In animals, as in some plants, both kinds of reproductive organs may exist in one individual organism, but generally there is only one kind of organ in an individual. Animals having only egg-producing organs, ovaries, are called **females**; those having only sperm-producing organs, spermaries, are called **males**. With the egg cell, the female furnishes

nourishment for each developing animal. This nourishment, when attached to the egg cell and enclosed in an egg covering, is known as **yolk**.

349. The Care of the Young. — As a rule, the animals which have small eggs produce many. Worms, lobsters, insects, fishes, and frogs deposit small eggs in immense numbers; birds and reptiles produce larger eggs in fewer numbers. The care given to the eggs is greater when a small number is produced. Some reptiles and all birds have eggs with a tough or hard covering. Fishes, worms, and other water animals have soft, jelly-like eggs.

The development of the embryo begins in the same way as in the plant: the egg cell divides and subdivision continues until the young animal is completely formed. In the case of the highest class of vertebrate animals, the egg cell remains and is nourished in the body of the female for a longer or shorter time. After the birth, the female continues to furnish protection and nourishment for weeks and even months. This nourishment, the milk, contains proteid, fat, sugar, and mineral matter dissolved in water. This is all the food the young animal needs until it is able to digest solid foods.

Birds care for their eggs during the period of development of the embryo, and a few species of fishes make nests and guard them, but usually the eggs of fishes are left to develop alone. The same is true of reptiles and insects. As soon as the food provided in the yolk is used up, the eggs hatch and

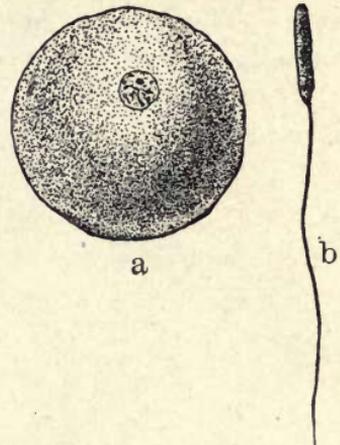


FIG. 157.—REPRODUCTIVE CELLS (magnified)

a is an egg cell of a frog, *b*, a sperm cell. The union of such cells results in the formation of an egg, such as is shown in *B*, Fig. 158.

the little animals begin to seek their own food. Only a very small proportion of the eggs deposited ever hatch, because large numbers of the eggs are food for other animals. Of those that hatch, only a small percentage lives to reproduce, because the young become the prey of other animals and man. The shad lives upon small organisms, vegetable and animal, and the bluefish eats young fish, even its own kind.

In order to preserve wild game, it has been found necessary to make laws prohibiting the hunting of animals at cer-

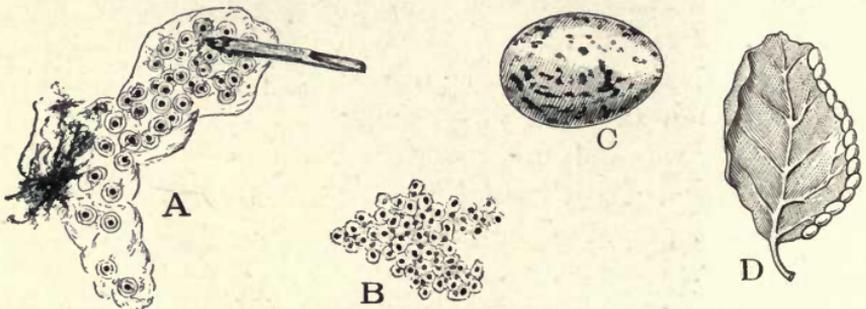


FIG. 158. — Eggs

Figure A is a cluster of eggs of a salamander; B, eggs of a frog. These eggs are surrounded by a transparent jelly-like covering. They float in the water of ponds and swamps until hatched. Figure C is the egg of a bird; D, eggs of a katydid.

tain times in the breeding season. At that season, usually spring and early summer in northern latitudes, fish come from the ocean into the rivers and birds go to cool climates, seeking places to deposit their eggs. The United States Bureau of Fisheries studies the habits of fishes and the relative food values of different fishes and recommends the making of laws for the protection and artificial hatching of food fishes. The Department of Agriculture provides for the study and protection of useful birds. Larger game may safely breed in public forest reservations.

350. How Fishes Take Food. — A fish has no structures for grasping its food, except teeth. The teeth are usually small, sharp, and numerous, well adapted for holding



FIG. 159. — LOUIS AGASSIZ: ZOOLOGIST. 1807-1873

And Nature, the old nurse, took
The child upon her knee,
Saying, "Here is a story-book
Thy Father has written for thee."

"Come wander with me," she said,
"Into regions yet untrod,
And read what is still unread
In the manuscripts of God."

And he wandered away and away
With Nature the dear old nurse,
Who sang to him night and day
The rhymes of the universe.

And wherever the way seemed long
Or his heart began to fail,
She would sing a more wonderful song,
Or tell a more wonderful tale.

HENRY W. LONGFELLOW
in *The Fiftieth Birthday of Agassiz*

living prey. Birds and most fishes do not chew food in the mouth, and so the tongue — which in many animals is used to move and hold the food in chewing — is lacking or is developed only to assist in swallowing.

351. Breathing Movements. — The mouth of the fish makes certain movements which look like biting, though there is no food present. If we put some grains of colored matter into the water, we can see them being drawn into the mouth and passing out through slit-like openings on the side of the head, back of the mouth. These movements are breath-

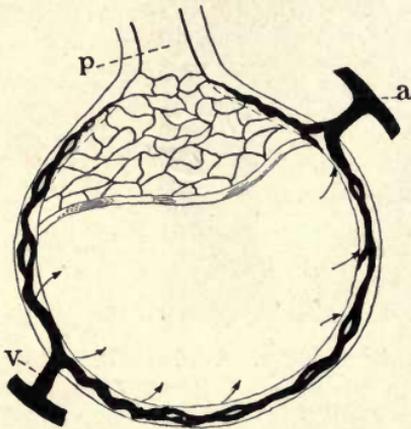


FIG. 160. — AIR SAC IN THE LUNGS

a, an artery; *v*, a vein; *p*, air tube.

The direction of gases passing between the air sac and the blood vessels is shown by arrows. Which represent the oxygen?

ing movements which allow the water, containing dissolved oxygen from the air, to pass over the breathing organs, called gills.

352. Breathing Organs. —

The gills of water animals are covered by thin plates, one on each side of the head, called gill covers, which lift at one side to let the water pass out. The gills look like fine red fringes attached to curved bony frames. In the “threads” of the fine fringes, blood is flowing all the time.

It receives oxygen through the

membranes by osmosis, and discharges into the water the waste product, carbon dioxide. The work of the gills of water animals is similar to the work done by the lungs of land animals.

The breathing organs of vertebrate animals that live in air are lungs. They are elastic bags of spongy tissue contained in a cavity in the forward or upper part of the body. An air passage leads from the nostrils into the lungs, where

it divides again and again into minute tubes. At the end of every tube is a little air sac. The walls of the air sacs are very thin and on their surface lie blood vessels of minute size. Oxygen from the air passes by osmosis *into* the blood vessels from the air sacs. Carbon dioxide and water vapor pass *out* of the blood vessels into the air sacs. In this manner, these waste products are excreted from the body by the same organs which receive the oxygen.

353. The Need of Digestion. — As in the case of plants, so in animals, it is necessary that the food be changed into soluble substances and then dissolved, in order that it may be distributed to all parts of the body. Digestion is carried on in a tube called the **alimentary canal**, which extends through the body. It has two openings: one, the mouth, for the reception of food; the other, the anus, for the expulsion of any indigestible residue. The walls of the alimentary canal contain circular involuntary muscles, which by contracting slowly push the food along. There is no opening from this tube into the other parts of the body. The substances that enter the tissues of the body from this tube, must pass *as liquids* through its walls, which are non-porous. Hence, food must be digested, that is, made soluble and capable of osmosis.

354. The Parts of the Alimentary Canal. — Behind the mouth, the gullet of a fish and of other vertebrates broadens into a baglike stomach, an important part of the alimentary canal, where the food is thoroughly mixed with digestive fluids formed in the walls of the stomach. These liquids produce chemical changes in the food whereby some of it becomes soluble. It is then dissolved and in part soaks through the walls of the stomach into blood vessels and is carried by the blood currents to the different organs that require it. Food not digested in the stomach passes into the small intestine, the next portion of the tube. Here the food is mixed with other liquids formed by

other digestive organs, so that further digestion may be accomplished. From the small intestine the contents are pushed into the large intestine, where digestion is completed. In this part of the canal, the water which is no longer needed for solution is absorbed through the walls.

355. Indigestible Residue. — Whatever parts of the food have not been digested before reaching the end of the alimentary canal are expelled through the anus, or posterior opening. These parts are not waste products but an indigestible

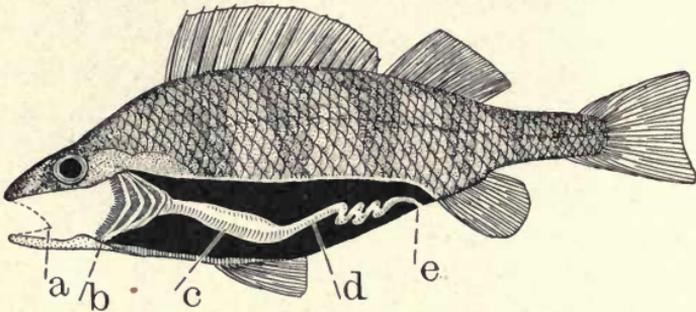


FIG. 161. — THE ALIMENTARY CANAL OR FOOD TUBE OF A FISH

Observe the continuous passage from the mouth (*a*), through the stomach (*c*) and the intestine (*d*), to the anus (*e*). *b* shows the gills and gill rakers.

residue. Though they have passed through the body, they have never been a part of the body. Grains of sand might enter the mouth with other food, but being insoluble, would pass unchanged through the stomach and intestines and be expelled.

Animals living mainly upon plant food take, with the nutritious part, much that is indigestible. This is not an injury but a benefit, because it prevents the close packing together of the substances which must be acted upon by the solvents. Pure starch is not so good a food as a potato, whose bulk is mainly pith cells containing starch. After mastication, the starch is mixed with the covering of the

cells, called cellulose, making a spongy rather than a pasty mass. The digestive fluids can readily attack the starch, while the cellulose becomes a part of the indigestible residue.

356. Blood. — In all the higher animals there is a liquid, the blood, that is driven through the body by a force pump, the heart. The blood travels through a system of tubes called blood vessels. This liquid is useful in distributing food and oxygen among the cells, and in collecting and carrying away from them the waste products from oxidation. The blood carries the carbon dioxide and water vapor to the breathing organs, and nitrogen compounds and water to the kidneys. The kidneys of vertebrates are two organs located inside the body near the anus, and opening by tubes to the outside of the body.

357. Body Temperatures. — In the body of such animals as worms, fishes, and frogs, oxidation is slower than it is in many other animals, and so the heat generated in oxidation does not raise the temperature of the blood perceptibly above that of the water in which these animals live. For this reason certain animals have commonly, though inaccurately, been given the name "cold-blooded." The actual temperature of the body of a cold-blooded animal changes with the temperature of its surroundings.

In warm-blooded animals, the body maintains a certain relatively high temperature all the time, regardless of the temperature of the surroundings. The temperature of the blood in the human body in health is slightly above 98° F. In some birds it is higher than that.

358. The Two Uses of Food. — The oxygen and digested foods that are distributed by the blood are taken up by the different cells and are transformed into living protoplasm, resulting in *growth*. Then as each cell does its work, part of the substance is oxidized to release the *energy* for this work and the temperature is kept at the degree required.

359. The Processes of Animal Nutrition. — Thus it is seen that in animals and in plants nutrition consists of the same essential stages:

The taking in of food and oxygen.

The digestion of food.

The transforming of food into live tissues.

The oxidation of that tissue to yield energy.

The excretion of the waste products resulting from oxidation.

The elimination of the indigestible residue left from digestion.

EXERCISES

1. What is the importance of reproduction?
2. Why is it not necessary that a bird should lay as many eggs as a fish, in order to continue the race?
3. What similar provision is made by plants and animals for the early development of their offspring?
4. What relation has the amount of nourishment in an egg to the size of the animal that hatches from it? Illustrate.
5. Does the care of a few young, or the production of a large number of offspring that receive no care, give better results to the race? Give instances that illustrate your answer.
6. (a) Suggest a reason why grass cannot serve as food for a dog.
(b) Why cannot a horse subsist on meat?
7. Why does the loss of much blood cause death?
8. (a) Account for the different amounts of food required by cold-blooded and by warm-blooded animals. (b) What is the value of the hair or the feathers covering the bodies of most warm-blooded animals?
9. To what organisms are the excreted waste products of animals useful, and for what purpose?
10. What waste product of plants do animals require?
11. Explain how some hibernating animals are able to live without food for a long time.
12. Through what organs do animals excrete carbon dioxide?

INDEX

(An asterisk following a page number indicates an illustration.)

- Acids, 160
Agassiz, Louis, 301 *
Agriculture, science of, 164
Air, composition, 149
 density, 96 *
 how warmed, 77
 humidity, 107
 sac, 302 *
 saturated, 107
 solution in water, 94 *
Aldebaran, 15, 19
Alimentary canal, 303
 of fish, 304 *
Alloy, 153
Altitude, 117
Aluminum, 154
Amalgams, 155
Analysis, chemical, 158
Animals, care of the young, 299
 carnivorous, 260
 herbivorous, 260
 need of food, 259
 omnivorous, 260
 one-celled, 289 *
 processes of nutrition, 306
 relation to plants, 260 *
 reproductive organs, 298
Antagonistic muscles, 295
Antares, 16
Anthers, 276, 277 *
Anthracite, 186
Antidotes, 165
Apparatus, 62
Arc lights, 136
Arctic circle, 25
Asbestos, 172
Asphyxiation, 141
Astronomy, ancient, 13, 19
Atmosphere, variations in composition, 107
Atmospheric pressure, 95
 differences, 96 *, 98
Atmospheric pressure, direction, 100
 on the body, 98
Atom, 156
Axle, 59, 60
Axon, 291
Balance, equal arm, 63, 64 *
 spring, 63 *
Barometer, 97, 98
Bases, 161
Bean plant, 265
 flower, 276
 ovary, 278, 279 *
 structure of seed, 278, 279
Bell, electric, 135
Belt of Calms, 113
Big Dipper, 16, 17 *, 18 *, 19
Blast furnace, 169 *
Block mountains, 203 *
Blood vessels, 305
Body, definition, 47
 temperatures, 305
Boiling point, 68
Boulders, 248
Brittleness, 54
Brownstone, 180
Bunsen burner, 142 *, 143
Calcite, 172
Calendar, 28, 29
Caloric, 77
Camera, 125, 126 *
Candle power, 120
Canis Major, 16
Capacity, measurement of, 52, 53 *
Capillarity, 90, 91 *
Carbon, 150
Carbon dioxide, an important oxide, 159
 excretion of, 160, 258
 fire extinguisher, 144 *, 145

308 FIRST YEAR COURSE IN GENERAL SCIENCE

- Carbon dioxide, in the lungs, 303
 - in water, 94
 - relation to life, 160 *
- Carbonated water, 94
- Carbonates, 163
- Care of the young, 299
- Cassiopeia, 17, 18 *, 19
- Cast iron, 153
- Celestial meridian, 27 *
- Cells, division, 263, 264 *
 - growth, 264
 - in surface of a leaf, 268 *
- Centigrade thermometer, 73 *
- Changes of level, 193
- Charcoal making, 71, 72 *, 150
- Chemical, change, 48, 138
 - engines, 145
 - symbols, 155
- Chlorine, 150
- Chlorophyll, coloring in plants, 259
 - grains, 268 *, 270
 - in starch making, 270
- Clay, 171
- Climate, 78, 116
 - changes, 118
- Coal, 150, 185
 - anthracite, 186
 - bituminous, 186
 - fields, 186 *
- Colorado Canyon, 237 *
- Combination, 139
- Combustion, 140
 - spontaneous, 140
- Compass, magnetic, 133 *
- Compounds, 47
 - classes, 159
- Condensation, 68
- Conduction of heat, 74 *
- Conductivity, 152
- Conductors, of heat, 75
 - of electricity, 129
- Conglomerates, 180
- Conservation of Matter, Law of, 142
- Constellations, 15, 18 *
 - reasons for studying, 18
- Continental block, 191 *
- Continents, 190
 - changes of level, 193, 194 *
 - changes in size, 192, 240
 - location in relation to history, 195
- Continents, relation to water, 190
 - story told by rocks, 191
- Contour, intervals, 216, 218
 - lines, 216, 218, 220
 - maps, 216, 217 *, 220, 224 *
- Convection, 75
- Copper, 153
- Coral reefs, 192 *
- Corn seedling, 280
- Corona, 16
- Crystals, 168 *
- Currents, in convection, 75
 - electric, 133
 - ocean, 197
- Cyclonic movements, 112
- Dana, James Dwight, 171 *
- Day, 23, 25
- Decomposition, 139
- Definite Proportions, Law of, 142
- Degradation, 202, 205
- Density, definition, 63
 - of air, 96 *
 - of a liquid, 66
 - of a solid, 65 *
 - methods of determining, 65, 66
- Denudation, 205
- Dew point, 107
- Diffusion, 94 *, 95
- Digestion, in animals, 303
 - in plants, 272
- Dikes, 183 *
- Dissolving, 82
- Distillate, 68
- Distillation, 68, 69 *
 - fractional, 69
 - uses, 69
- Divers, 86, 87 *
- Dog days, 16
- Dog star, 16
- Drift, glacial, 248
- Ductility, 152
- Dynamo, 136 *
- Earth, age, 187
 - a planet, 33
 - axis, 24
 - crust, 167 *, 177
 - early beliefs, 13
 - revolution, 22, 34
 - rotation, 21
 - shape, 14

- Earthquakes, causes, 225
 effects, 225 *, 226, 227 *
 famous, 226
- Eclipses, of the moon, 42, 43 *, 44 *
 of the sun, 42, 43 *
- Eggs, 298, 300 *
- Elasticity, 54
- Electric, battery, 132 *
 cell, 132 *
 circuit, 132
 current, 133
 dry cell, 133
 lights, 136
- Electrical machine, 130 *
- Electricity, and magnetism, 135
 current, 131
 frictional, 128
 positive and negative charges,
 128
 statical, 129
 voltaic, 131
- Electrodes, 132
- Electrolysis, 148 *
- Elements, definition, 47
 number, 47
 principal, 47
- Elevators, 81
- Embryo, 278
- Energy, 58, 254
 and heat, 79
 transformation, 136
- Engines, chemical, 145
 cylinder of, 79
 gas, 61
 steam chest of, 79 *
- Equator, 25
- Erosion, 202, 237
- Eruptions, 229, 230
- Excretion, 258
 animal, 257, 306
 of carbon dioxide, 160, 303
 of water, 269
 plant, 257, 269, 273, 274
- Experiment, definition, 61
- Explosions, 140
- Explosives, 140
- Extension, 49
 measurement, 50 *
- Eye, 125, 126 *
- Eye glasses, 126
- Fahrenheit thermometer, 72
- Fault, 225
- Feldspar, 171
- Fertilization of flowers, 277, 278
- Fertilizers, 164, 165 *
- Fire extinguisher, 144 *, 145
- Fish, alimentary canal, 304 *
 a type of vertebrate, 292
 breathing organs, 302
 ears, 293
 manner of taking food, 300
 nostrils, 293
 organs of taste and touch, 293
 sense organs, 292
- Fissures, 183
- Flexibility, 54
- Flowerless plants, 280, 281 *
- Flowers, behavior, 283
 fertilization, 277
 pollination, 277, 278 *
 structure, 276
- Floods, 238 *
- Flux, 169
- Folded mountains, 203
- Folded rock, 182, 185 *, 204 *
- Food, 255
 amount required, 257
 need of, 257
 residue, 258
 stored in seed, 256 *, 272
 two uses, 305
- Force, 56
 pump, 104 *, 105
- Forces at right angles, 57, 58 *
- Forestry, 210, 211
- Forests, 209
 and rainfall, 212
 enemies, 212, 213 *
 importance, 214
- Formulas, chemical, 158
- Fossils, 188 *, 193 *
- Freezing point, 68
- Friction, 57
- Fruit, 278
- Functions, definition, 255
- Furnace, 143 *
- Fusibility, 152
- Garden of Gods, Manitou, Colorado,
 187 *
- Gases, definition, 67
 diffusion, 94 *, 95
 molecular motion, 93

310 FIRST YEAR COURSE IN GENERAL SCIENCE

- Gases, properties, 93
 relation between pressure and
 volume, 101 *
 solubility, 93
 Gems, 170
 Générateur of electricity, 136 *
 Germination, process, 279
 result, 279
 Glacial, drift, 248
 lakes, 248, 249 *
 Glaciated rock, 247 *
 Glacier, beginning, 244
 in Switzerland, 245 *, 246 *
 retreat, 246
 work, 245
 Gneiss, 182
 Gold, 153
 Granite, formation, 178
 quarry, 178 *
 use, 179
 Gray, Asa, 271 *
 Great Bear, 17, 18 *
 Growth movements, of cells, 263
 of plants, 282
 Gulf Stream, 197
 Gypsum, 174

 Hachure maps, 216, 217 *
 Hardness, 53
 Heat, absorbed by water, 78
 and energy, 79
 conduction, 74
 convection, 75
 effects, 67, 71
 intensity, 77
 quantity, 77
 radiation, 75
 sources, 71
 vertical and oblique rays, 116,
 117 *
 Henry, Joseph, 131 *
 Hornblende, 172
 Hot water heating, 76 *
 Hydraulic presses, 81, 82 *
 Hydrogen, 148 *

 Igneous rock, 178
 Ignition point, 141
 Incompressibility, 81
 Incandescence, 120
 Incandescent lights, 136
 Indigestible residue, 304

 Inertia, 52
 Inorganic matter, 55
 Instinct, 293
 Insulators, 129
 Iron, 152
 reduction, 169
 Irrigation, 242
 Irritability, definition, 54
 in animals, 254
 in plants, 254, 285

 Japan Current, 197
 Jupiter, 33, 34, 35 *, 36, 37

 Kindling point, 141

 Lakes, causes, 248, 249, 250
 glacial, 248, 249 *
 sources of rivers, 250
 uses, 250
 Lava, 179
 sheets and dikes, 231
 Latitude, 28
 Laws, of Conservation of Matter,
 142
 of Definite Proportions, 142
 of liquid pressure, 88, 90.
 Lead, 155
 Leaves, cells, 268 *
 chlorophyll grains, 268 *, 270
 compound, 267 *, 268
 functions, 268
 simple, 267 *, 268
 starch making, 269
 Lenses, 123, 125 *
 Leo, 16, 21, 33
 Lever, 59, 60 *
 Lift pump, 103, 104 *, 105
 Light, a form of energy, 121
 Light, absorbed, 121
 a form of energy, 121
 in starch making, 270
 influence on plants, 282, 283 *,
 284
 intensity, 120
 reflected, 121, 122 *
 refracted, 123 *, 124 *
 sources, 120
 transmitted, 121
 Lightning, 115, 129
 Limestone, 180
 quarry, 181 *

- Liquid pressure, 86
 direction, 88
 in a hot-water boiler, 89 *
 laws, 88 *, 90
- Liquids, definition, 67
 buoyancy, 90
 pressure, 86-90
 properties, 81
- Litmus paper, 160
- Little Bear, 17, 18 *
- Little Dipper, 17 *, 18 *
- Locomotion, organs, 295 *
- Longitude, 28, 29
- Lunar, eclipse, 42, 43 *
 shadow, 44 *
- Luster, 152
- Machines, 59, 60 *, 61, 62 *
- Magnesium, 155
- Magnetic compass, 133 *, 134
- Magnetic needle, 134 *
- Magnetism, 134
 and electricity, 135
- Magnifying glass, 125 *
- Malleability, 152
- Mantle rock, 167, 234
- Map making, 216
- Marine life, 199
- Marble, formation, 174
 uses, 174
- Mars, 33, 34, 35 *, 36, 37
- Matter, definition, 46
 divisions, 47
 inorganic, 55
 living, 254
 organic, 55, 254
 physical states, 67
- Measures, systems of, 49, 50 *
- Melting point, 67
- Mercuric oxide, 139
- Mercury (metal), 154
 (planet), 33, 35 *, 36
- Meridian, 27 *, 29, 30
- Metals, native, 153
 properties, 152
 specific gravity, 155
 uses, 155
- Metamorphic rocks, 182
- Metric system, 49
- Mica, 172
- Midnight sun, 25
- Mineral springs, 84
- Minerals, 167
 importance of studying, 175
 value, 184
- Mining, 206 *
- Mirror, 122 *
- Mixtures, 48
- Mobility, 81
- Molecules, composition, 156
 definition, 46
 motion, 93
- Moon, 38, 41
 apparent changes, 38
 eclipses, 42
 light, 39
 rotation and revolution, 39
 surface, 40
 time of rising, 40
- Moraine, terminal, 246
- Motor nerves, 291
- Mountains, barriers, 208, 209 *
 block, 203
 folded, 203
 influence, 207
 making, 202
 of erosion, 202
 railroads, 207 *, 208
- Muscles, antagonistic, 295
 extensor, 295
 flexor, 295
 structure, 294 *
 work, 294
- Neptune, 33, 35 *, 36
- Nerve centers, 291, 292
- Nerves, 291
 motor, 291
 sensory, 291
- Nervous system, 290
 divisions, 290
 importance, 292
 useful responses, 293
- Newcomb, Simon, 34 *
- Nickel, 155
- Night, 23
- Nitrogen, 149
- North point, 20
- North pole, 20
- North Star, 16, 17 *, 18 *, 19, 20
 importance of knowing, 20
 pointers, 16, 17 *, 18 *
- Northern sky, 18 *
- Nucleus, 263

312 FIRST YEAR COURSE IN GENERAL SCIENCE

- Nutrition, 54
 - of animals, 255, 257, 306
 - of plants, 255, 257, 274
- Oceans, composition, 195
 - currents, 197
 - depth, 195
 - first, 195
 - life, 199
 - relation to land, 190, 191 *
 - temperatures, 196 *
 - tides, 198 *
- Opaque substance, 122
- Ores, 168
 - reduction, 168
- Organic matter, 55, 254
- Organisms, 54
 - complex, 289
 - simple, 289 *
- Organs of locomotion, 295 *
- Orion, 15, 21
- Osmosis, 95, 302
- Ovary, 277 *
- Ovules, 277
- Oxidation, 139
 - relation to life, 141
 - waste products, 257
- Oxides, definition, 139
 - mercuric, 139
 - sulphur, 152
 - two most important, 159
- Oxygen, 147
 - burning wire in, 147 *
 - oxyhydrogen lamp, 147 *
- Pea seedling, 280 *
- Pen filler, 103 *
- Period of revolution, of the earth, 34
 - of the moon, 38
 - of the planets, 34
- Period of rotation, of the earth, 23
 - of the moon, 38
- Petals, 276, 277 *
- Petrifications, 174
- Petrified forest, 175 *
- Phosphorus, 151
- Photography, 162
- Physical changes, 48, 138
- Pistil, 276
- Pith ball, electrified, 128, 129 *
- Planets, 33
- Planets, brightness, 36
 - distance, 35 *, 36
 - motion, 33
 - revolution, 34
 - size, 36
- Plants, digestion, 272
 - excretion, 273
 - flowerless, 280
 - growth movements, 281
 - importance of chemical work, 271
 - influence of contact, 285
 - influence, of gravity, 284
 - influence of light, 282, 283
 - influence, of water, 285
 - internal cause of movement, 286
 - motor organs, 283
 - need of food, 257, 259
 - need of water, 259
 - nutrition, 255, 257, 274
 - presence of water in, 269
 - properties, 254
 - proteid making, 270
 - relation to animals, 260
 - respiration, 273
 - starch making, 269
 - storage of food, 272
- Plaster of Paris, 174
- Platinum, 155
- Pleiades, 15
- Poisons, 165
- Pole Star, 16, 20
- Pollen, 277
- Pollination, 277 *
- Potato grown in a cellar, 283 *
- Pressure in liquids, 87 *, 88 *, 89 *
- Pressure of the air, 95
 - differences, 96 *, 98
 - direction, 100
 - on our bodies, 98
- Prime meridian, 29
- Prisms, 123, 124*
- Properties, of all matter, 48
 - of living matter, 54
 - physiological, 254
 - special, 53
- Property, definition, 48
- Proteid making, 270
- Protoplasm, 258
 - behavior, 258
 - composition, 258
 - sensitiveness to light, 282

- Pudding stones, 180
 Pulley, 59, 60 *
 Pumps, 103
 air, 99 *, 100 *
 force, 104 *, 105
 lift, 103, 104 *
 suction, 103
- Quarry, 178 *, 180 *, 181 *
 Quartz, 168 *, 170
- Radiation of heat, 75
 Reduction of ores, 168, 169 *
 Reducing agents, 168
 Reflection of light, 121, 122 *
 Refracting bodies, 123
 Refraction of light, 121, 123 *, 124 *
 Regulus, 16, 19, 33
 Relief maps, 216, 217 *
 Reproduction, 54, 254
 object, 276
 of animals, 298
 of cells, 264
 of plants, 276
 Reproductive organs, of animals, 298
 of plants, 276
 Reservoirs, 221, 250, 251 *
 Respiration, 256
 of animals, 302
 of plants, 273
 Resultant, 56
 Retina, 125
 Rivers, absence, 241
 deposit, 238
 erosion, 237
 formation, 235
 load, 236
 usefulness, 240
 Rocks, 177
 folded, 182, 185 *, 204 *
 igneous, 178 *
 making, 177, 186
 metamorphic, 182
 sedimentary, 179, 180 *, 181 *
 value, 184
 water-worn, 177 *
 weathered, 234 *
 Roots, 265
 extent, 265
 functions, 265
 primary, 265, 266 *
 secondary, 265, 266 *
- Roots, uses, 266
- Salt lakes, 84
 Salts, 161
 uses, 162
 Sandstone, 180
 quarry, 180 *
 Saturn, 33, 34, 35 *, 36, 37, 38 *
 Scales, platform, 64 *
 Schist, 182
 Scorpio, 15 *, 16, 21
 Screw, 59, 60 *
 Seasons, 24
 Sedimentary rock, 179, 180 *
 Seed pods, 279 *
 Seed, 278
 bean, 278
 germination, 279
 Sensation, relation to motion, 293
 Sense organs, 291
 of a fish, 292
 Sensitive plant, 286 *
 Sensory nerve, 291
 Sepals, 276, 277 *
 Sex, 298
 Shales, 181
 Sickle, 16
 Silliman, Benjamin, 159 *
 Silver, 154
 Silver plating bath, 163 *
 Siphon, 102 *
 Sirius, 16, 19
 Slag, 169
 Snow line, 244
 Soda water, 94
 Soil, 234
 Solar system, 22
 Solids, definition, 67
 Solution, 82
 Solvents, 83
 Specific gravity, 66
 of metals, 155
 Spontaneous, combustion, 140
 motion, 54, 254
 Spores, 281
 Springs, 86
 fissure, 85, 86 *
 mineral, 84
 surface, 236 *
 Stalactites, 173 *
 Stalagmites, 173 *
 Stamens, 276

314 FIRST YEAR COURSE IN GENERAL SCIENCE

- Standard time, 30
 Starch making, 269
 light and chlorophyll necessary,
 270
 Stars, 14
 apparent motion, 21
 brightness, 19
 change in position, 22
 distance, 19
 number, 14
 visible all the year, 17
 Steam, expansion, 79
 in volcanic eruptions, 228, 230,
 231
 pressure, 101
 Steel, 152
 Stems, functions, 267
 Storms, 113
 cyclonic, 114
 local, 115
 tropical, 115
 Streams, cause, 84
 temporary, 233
 Substance, definition, 47
 Suction pumps, 103, 104 *
 Suffocation, 141
 Sulphur, 151
 oxide, 152
 Sun, 22, 23
 apparent motion, 24
 at noon, 27
 eclipses, 42, 43 *
 source of energy, 287
 Sunrise, 23, 26 *
 Symbols, chemical, 155

 Taurus, 15, 16, 21
 Telescopes, 43
 Temperature, conditions affecting,
 116
 Tenacity, 54
 Tendon, 294
 Terminal moraine, 246
 Test, definition, 158
 Thermometer, 71
 making, 71
 laboratory, 73 *
 Thunder, 115, 129
 Tides, 198, 199 *
 Time, 29, 30
 belts, 28 *, 30
 standard, 30

 Tin, 155
 Topographic maps, 216, 222 *
 of the U. S., 221
 uses, 223
 Topography, definition, 216
 Tornado, 112, 114 *
 Torricelli's experiment, 97
 Trade winds, 113
 Translucent medium, 121
 Transparent medium, 121
 Tropic of Cancer, 25

 Uranus, 33, 35 *, 36

 Vacuum, 100
 Valley contours, 220
 Vapors, 67
 Vega, 19
 Veins, in rock, 184
 of minerals, 205
 Venus, 33, 34, 35 *, 36
 Venus fly trap, 255
 Vertebrates, 290
 study of, 292
 Vesuvius in eruption, 229 *
 Viscosity, 81
 Vision, 121
 Volatility, 81
 Volcanoes, 228
 active, 228
 dormant, 228
 eruptions, 229, 230
 extinct, 228
 Volume, 49, 51 *
 unit of, 63

 Waste products from oxidation, 257
 Water, carbonated, 94
 composition, 149
 excretion by plants, 269
 influence on climate, 78
 in plants, 269
 natural, 83
 necessity for, 259
 soda, 94
 Water power, 84 *
 Water-worn rock, 177 *
 Weather, 108
 Bureau, 108 *
 maps, 110 *, 111
 records, 109
 Weathering, 233

- Weighing, 63
Weight, 51, 61, 63
 measurement of, 51, 52 *
Wells, 85, 86 *
Wheel and axle, 59, 60
Winds, 112
 constant, 112
 trade, 113
- Work, definition, 58
Wrought iron, 152
- Yolk of an egg, 299
- Zenith, 20
Zinc, 155
Zones of light, 25

LABORATORY MANUAL

TO ACCOMPANY

A FIRST YEAR COURSE IN
GENERAL SCIENCE

BY

CLARA A. PEASE

OF THE HIGH SCHOOL, HARTFORD, CONNECTICUT



CHARLES E. MERRILL COMPANY
NEW YORK CHICAGO

COPYRIGHT, 1915
BY CHARLES E. MERRILL CO.

[4]

CONTENTS

	PAGE
MATERIALS NEEDED FOR THE EXERCISES IN THE LABORATORY.	5
EXERCISE	
I. THE NORTHERN SKY IN SEPTEMBER	9
II. POSITION OF THE SUN AT DIFFERENT HOURS OF THE DAY	10
III. ORBITS OF SOME OF THE PLANETS.	11
IV. TO FIND THE VOLUME OF A REGULAR SOLID	12
V. TO FIND THE WEIGHT OF A BODY BY USE OF THE PLAT- FORM BALANCE, OR TRIP SCALE	13
VI. TO FIND THE DENSITY OF A SOLID	13
VII. TO FIND THE CAPACITY OF A BOTTLE OR FLASK BY WEIGHING	14
VIII. TO FIND THE DENSITY OF A LIQUID	15
IX. TO FIND THE SPECIFIC GRAVITY OF A SOLID WHICH IS INSOLUBLE IN WATER	16
X. TESTING THE ACCURACY OF A THERMOMETER AT THE FREEZING POINT	17
XI. QUANTITY OF HEAT	18
XII. WEATHER OBSERVATIONS	19
XIII. VARIATIONS IN TEMPERATURE SHOWN BY CURVES	20
XIV. THE SIMPLE ELECTRIC CELL	21
XV. STUDY OF GAS BURNERS AND FLAMES	23
XVI. HEATING WITH GAS FLAMES	24
XVII. A PRODUCT OF OXIDATION	24
XVIII. TESTS FOR ACID, BASIC, AND NEUTRAL SOLUTIONS.	25
XIX. STUDY OF ROCK FORMATIONS	27
XX. REPRESENTING ELEVATIONS BY CONTOURS	28
XXI. STUDY OF A TOPOGRAPHIC MAP	29

EXERCISE	PAGE
XXII. STUDY OF A STREAM AND ITS VALLEY	30
XXIII. THE WATER SUPPLY OF A CITY OR TOWN	31
XXIV. THE WHEAT SEEDLING	32
XXV. STUDY OF THE ROOTS OF A PLANT	33
XXVI. STUDY OF THE STEM AND LEAVES OF A PLANT	34
XXVII. ONE FUNCTION OF LEAVES	35
XXVIII. TEST FOR FOOD MATERIAL IN SEEDS	36
XXIX. STUDY OF A FLOWER	37
XXX. STUDY OF A SEED	38
XXXI. STUDY OF A FISH	40

MATERIALS NEEDED FOR THE EXERCISES IN THE LABORATORY

Below is given a list of materials and apparatus needed by one pupil, to perform all the experiments and exercises in the MANUAL.

Nearly all of these articles are possessed by a school which has courses in physics or chemistry. By coöperation and a little planning to avoid conflict as to time, balances, thermometers, compasses, and the like might be used by classes in different branches of science. It is far better, however, unless the work is all done in the same laboratory, that each department should have and should care for its own apparatus.

Many of the pieces can be used year after year. Some can be obtained from local dealers or from the homes of pupils.

It is not necessary that the exercises should be done at the particular place in the course to which they are assigned. If it is impossible to arrange for that, it is better that the exercise should follow rather than precede the study of a subject.

Drawing compass.

6-inch ruler divided into centimeters on one edge, inches on the other.

Wooden block, cut true about $7 \times 4 \times 3$ cm.

Platform balance.

Set of weights 200, 100, 50, 20, 10, 5 g.

Pieces of stone, glaßs, wax.

Measuring glass (cylinder) graduated to 1 cu. cm., capacity 250 cu. cm.

Glass-stoppered bottle, holding about 3 liquid ounces.

Battery jar, 8 inches in diameter.

Laboratory thermometer reading to 1° scale, — 10° to 110° C.

2 pieces of brass, iron, or zinc, weight about 200 and 400 g. May be cut from rods 1 inch in diameter.

Coördinate or "graph" paper.

6 MATERIALS FOR LABORATORY EXERCISES

Magnetic compass.

15-inch insulated copper wire.

2 binding posts.

Strip of zinc and of copper.

Bunsen burner.

Evaporating dish.

Combustion spoon.

Solutions of sulphuric or hydrochloric acid, ammonia, limewater, iodine, nitric acid (50 cu. cm. each).

Common salt.

Strips of litmus papers, pink, blue, lilac.

Dissected cone (base 3 inches).

Sheet of topographic map.

Wheat seeds; dried beans or peas.

Young plant (can be raised at school).

Low, wide-mouthed bottle.

Flower.

Fish.

FIRST YEAR COURSE IN GENERAL SCIENCE

LABORATORY MANUAL

The Laboratory. A laboratory is a place in which to do work and to observe and record the results and effects of things done. It may be a separate room, or part of a recitation room, fitted up with some ordinary flat-topped tables and chairs or stools of convenient height. It is desirable that there should be drawers in the table or in some other part of the room, or closed shelves where apparatus and materials can be kept. All apparatus should be returned to its place in good order by the pupil who has used it.

Apparatus. Everything used in the work of the laboratory is apparatus, whether it is a measuring ruler, a thermometer, a tumbler, a piece of wire, or a bottle. Every piece of apparatus should receive care, for no matter how common or inexpensive it may be, if it is not in condition for use when needed for an experiment the time of one or more pupils is lost while it is being made right or replaced.

The Laboratory Notebook. A notebook of the double-sheet, loose-leaf style is very well adapted to laboratory use. Each sheet may be laid flat on the table during the exercise, may be handed to the teacher for criticism, and after correction and approval may be filed away in the cover. If this plan is followed, there is no danger of soiling or injuring previous records in the book or new pages, while in the laboratory.

The first page of the sheet should bear at the top — always in the same order — the date of the experiment,

the pupil's name, and the number of the exercise. Below should be written the subject of the exercise. The remainder of the page may be occupied by an outline drawing of apparatus used. On the second page should be copied the directions for work, and below them, the record of observations. This record must be made by the pupil *while in the laboratory*, not afterward from memory. Observations include what he sees, hears, feels, or smells, that is, what comes to him through the senses. The pupil should be *thinking* while he is observing, but need not take time then to tell what he thinks. That can be done later; perhaps in the laboratory after his desk is in order, perhaps in the classroom the next day, or at home. He need not then try to *recall* what happened, because he has the record of observations to consult.

Results. The results of the experiment may be given in various forms: as answers to questions upon the work; or the working of a problem from measurements made in the laboratory; or an explanation based upon previous study of the subject; or, better still, a statement of what the pupil has *thought* about the experiment. The textbook may be consulted in answering questions on the "result" page.

It is best to write the results on the third page opposite the laboratory record, which can be consulted in answering questions. The fourth page of the sheet may be used for observations for which there is not room on page two, for "trial" work on problems, and for long mathematical work in cases where only the indication of processes is needed on the "result" page.

Composition. Attention should be given to penmanship and English. Illegible and inaccurate reports are not good work in science any more than in language or mathematics. Avoid the use of *I* as the subject. Let some apparatus or material be the subject and use its name instead of referring

to it as *it*. Good laboratory work is worthy of the best expression the pupil can give, and *good habits* of work are an aid to advanced study in any subject.

EXERCISE I (Textbook § 5)

THE NORTHERN SKY IN SEPTEMBER (OR ANY OTHER MONTH SELECTED)

APPARATUS: Compasses, hard pencil, sheet of notebook paper.

NECESSARY CONDITIONS: A clear evening without bright moonlight; state the hour of observation.

On the front page of the notebook sheet make a circle of three-inch radius. At the center place * and mark it *P* (Pole Star). Draw a dotted-line vertical diameter through the point (*). Draw a horizontal line across the page touching the lower part of the circle at the diameter's intersection. Letter the horizontal line *H* at both ends and place *N* at the diameter.

HH is a part of the northern horizon, *N* is the north point, and the line *PN* is part of the celestial meridian. If the line were continued upward on the sky, it would pass through the zenith and down to the south point on the horizon.

Within the circle, place the groups of stars you observed in the northern sky. Indicate the brighter stars by *, the fainter ones by \times . Locate carefully the position of each group with relation to the Pole Star and to the celestial meridian. Estimate carefully the space occupied by each group.

RESULTS

1. Write neatly the name of each constellation under the proper group on your map. (Consult the textbook on "Stars Visible all the Year," p. 17.)
2. Which group as a whole is nearest the Pole Star?
3. Which group is highest above the horizon?

10 FIRST YEAR COURSE IN GENERAL SCIENCE

4. Which *star* of all the groups is farthest from the Pole Star?

5. How will the position of the groups have changed in six hours?

6. Which group or groups will then be east of the meridian?

7. Through what points of earth and sky does the celestial meridian pass?

8. What meridian of the earth lies directly under the celestial meridian, that is, passes through the place where you are?

EXERCISE II (Textbook § 18)

POSITION OF THE SUN AT DIFFERENT HOURS OF THE DAY

APPARATUS: Hard, sharp pencil; needle about No. 5 or No. 6; sheet of notebook paper.

NECESSARY CONDITIONS: Sunshine and access to a south exposure.

DIRECTIONS FOR WORK: Put N, S, E, W, at the margins of the second page as on a map. Place the sheet of notebook paper on a south windowsill, or on a south piazza floor with the *lower* edge of the paper toward the south and in an east-west direction. Stick a long needle or pin into the paper in a *vertical* position near the south edge, and with a sharp pin or needle prick a hole at the end of the shadow it casts:

- (a) two hours before noon; (d) one hour after noon;
- (b) one hour before noon; (e) two hours after noon.
- (c) at noon;

Connect each of these points with the point made by the large needle, using a light ruled pencil line.

RESULTS

1. State the direction of the first shadow from the pin.
2. State the direction of the second shadow from the pin.

3. State the direction of the noon shadow from the pin.
4. State the direction of the afternoon shadows from the pin.
5. In what direction would you look for the sun at noon?
6. Before noon?
7. What differences in the length of shadows do you observe?
8. Were any two shadows nearly equal in length? Which ones?
9. Give directions for making a sundial which "tells time" by the direction of sun shadows.

EXERCISE III (Textbook § 26)

ORBITS OF SOME OF THE PLANETS

APPARATUS: Hard pencil, ruler, compasses.

DIRECTIONS FOR WORK: In the middle of the space below [on p. 2 of notebook sheet], place the letter *S*. Construct three circles (with the same center, *S*) having a radius of $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $2\frac{1}{4}$ in., respectively. On the left, place *V* (Venus) on the smallest circle, *E* (Earth) on the second, *J* (Jupiter) on the largest, all in the same line from *S*. Let the circles represent the orbits or paths of one revolution of the earth and these two other planets about the sun. (NOTE. The orbits of the planets are ellipses, not circles, but it is not possible to represent their form correctly in small drawings.)

RESULTS

1. What fraction of its orbit represents the earth's journey for six months?
2. How many degrees does the earth pass over in that time?
3. How long does it take the earth to pass over 90° ?
4. How long does it take Venus?

5. How long does it take Jupiter?

6. Compare the distances in miles traversed by the three planets in advancing 90° each.

7. (a) If the direction from E to S is westward, in what direction is *J* from *E*? (b) In what part of the sky would Jupiter be at sunset?

8. (a) In what part of the sky would Venus be at sunset? (b) Would it be likely to be visible? Why?

9. Place \times at the point on its orbit where each planet would be three months after the positions indicated in your diagram.

EXERCISE IV (Textbook § 47)

TO FIND THE VOLUME OF A REGULAR SOLID

APPARATUS: Centimeter rule, rectangular wooden block.

DIRECTIONS FOR WORK: Measure the length of the block along the grain on the four sides. Read and record each length to .1 cm. Measure and record the width and thickness in the same way.

Kind of wood.....Number of block.....

	<i>Length</i>	<i>Width</i>	<i>Thickness</i>
(1) .....	.....cm.	.....cm.	.....cm.
(2) .....	.....cm.	.....cm.	.....cm.
(3) .....	.....cm.	.....cm.	.....cm.
(4) .....	.....cm.	.....cm.	.....cm.
Sum .....	.....cm.	.....cm.	.....cm.

RESULTS

1. Calculate and record the average length, width, and thickness to the nearest .1 cm.

2. Find the volume of the block to the nearest centimeter.

NOTE. If the average width should work out 4.125 cm., record it as 4.1 cm.; if 4.175 cm., record it as 4.2 cm. Since we do not measure more closely than to .1 cm., it is unreasonable to give the result in hundredths or in thousandths.

EXERCISE V (Textbook § 64)

TO FIND THE WEIGHT OF A BODY BY USE OF
THE PLATFORM BALANCE, OR TRIP SCALE

APPARATUS: Platform balance, bodies to be weighed (blocks of wood used in previous experiment, pieces of stone or metal).

DIRECTIONS FOR WORK: Place the body to be weighed upon the *left*-hand platform. Have the sliding weight at the 0 point of the scale. Upon the right-hand platform, place weights that will nearly balance the body. Move the sliding weight to such a position that the platforms are at the same level. Record the weight in grams to .1 g.

Platform balance, number.....

<i>Body</i>	<i>No.</i>	<i>Weight</i>
.....g.
.....
.....

RESULTS

1. What change in the apparatus occurred when the block was placed on the left platform? Explain.
2. When the "weighing" is accomplished, what keeps the platforms at the same level?
3. Describe some other kind of balance.
4. What force is measured in weighing a body?

EXERCISE VI (Textbook § 66)

TO FIND THE DENSITY OF A SOLID

APPARATUS: Balance, jar of water, metric measure, various solid bodies.

DIRECTIONS FOR WORK: If the body is a regular solid, find its volume by measurement (Ex. IV), and its weight by use of the balance (Ex. V). If the body is irregular and

14 FIRST YEAR COURSE IN GENERAL SCIENCE

insoluble, find its volume by means of a measuring glass (see Textbook § 66).

<i>Name</i>	<i>Volume</i>	<i>Weight</i>
.....	.....cu. cm.	.....g.
.....

RESULTS

(Indicate the operation by which your answers are obtained.)

1. If 36 cu. cm. of matter weigh 72 g., what is its weight per cu. cm.?

2. Find the weight per cu. cm. of each solid used. (Do the figuring on p. 4 and arrange the results in the tabular form below.)

<i>Body</i>	<i>Volume</i>	<i>Weight</i>	<i>Density</i>
.....	.....cu. cm.	.....g.	.....g. per cu. cm.
.....
.....

EXERCISE VII (Textbook § 67)

TO FIND THE CAPACITY OF A BOTTLE OR FLASK BY WEIGHING

APPARATUS: Balances, small bottle having a ground glass stopper, a jar of water.

DIRECTIONS FOR WORK:

(1) Weigh to .1 g. a dry, empty bottle with its stopper. Record the number of the bottle and its weight.

(2) Hold the bottle in a jar of water until it is filled, and while it is under water, insert the stopper firmly. Wipe the outside, weigh again, and record.

Weight of empty bottle No.....g.
 Weight of bottle full of waterg.

RESULTS

1. How many grams of water does the bottle hold?
2. What is the weight of 1 cu. cm. of water?
3. How many cu. cm. of water will the bottle hold?
4. How many cu. cm. of molasses will the bottle hold?
5. Give directions for finding the capacity of a pitcher in metric units, by this method.
6. How could you find the capacity of a pitcher in English units by this method?
7. State the difference in meaning between *volume* and *capacity*.

EXERCISE VIII (Textbook § 67)

TO FIND THE DENSITY OF A LIQUID

APPARATUS: Balances; bottle; various liquids, such as alcohol, kerosene, strong solution of blue vitriol, and sal ammoniac.

DIRECTIONS FOR WORK: Use a bottle whose weight and capacity have been determined by the method used in Ex. VII; fill it with a given liquid and weigh.

- (1) Weight of bottle empty (from Ex. VII)g.
- (2) Capacity of the bottle (from Ex. VII)cu. cm.
- (3) Weight of bottle filled withg.
- (4) Weight of bottle filled withg.
- (5) Weight of bottle filled withg.

RESULTS

Calculate and record in tabular form the density of each liquid used.

<i>Name of Liquid</i>	<i>Volume</i>	<i>Weight</i>	<i>Density</i>
.....	.....cu. cm.	.....g.	.....g. per cu. cm.
.....
.....

EXERCISE IX (Textbook § 68)

TO FIND THE SPECIFIC GRAVITY OF A SOLID
WHICH IS INSOLUBLE IN WATER

APPARATUS: Balance, sink or jar containing water, thread, solids (such as pieces of stone or coal), glass stopper, cake of wax.

DIRECTIONS FOR WORK:

- (1) Weigh the solid in air.
- (2) Weigh the solid in water. To do this, tie a thread around the object and suspend it from the balance in a jar of water. Do not allow the object to touch the side or bottom of the jar nor to come to the surface of the water.

<i>Name of Solid</i>	<i>Wt. in Air</i>	<i>Wt. in Water</i>
.....	.....g.	.....g.

RESULTS

1. Do the solids weigh more in air or in water?
2. How much was the difference in weight, in the case of the first body weighed?
3. What change occurred in the level of the water when the solid was immersed? Why?
4. If the volume of a solid used was 50 cu. cm., how many cu. cm. of water did it displace when it was immersed in water?
5. What is the weight, in grams, of the water displaced? Why?
6. What is the relation between the weight of the solid in air and the loss of weight in water? Express as a fraction.
7. Compute to two decimal places these ratios and thus get the specific gravity of each solid.

<i>Name of Solid</i>	<i>Ratio between Weight and Loss in Water</i>	<i>Specific Gravity</i>
.....
.....

EXERCISE X (Textbook § 75)

TESTING THE ACCURACY OF A THERMOMETER
AT THE FREEZING POINT

APPARATUS: Broken ice and water in a tumbler; a laboratory Centigrade thermometer; a common Fahrenheit thermometer brought from home.

DIRECTIONS FOR WORK:

(1) Make a drawing of the laboratory thermometer, on the first page of notebook paper.

(2) Place the bulb of the thermometer in the ice and water; keep it there until the mercury in the tube is stationary, read to .5 of a degree, and record in degrees C. If below 0° , record with the minus sign, as -1° C. Dry and return the thermometer to its case.

(3) Place a common thermometer in the ice and water as directed in Case 2. (If it has a wooden or metal frame, it will not be injured.) Record the reading in degrees F. to the nearest whole degree.

Reading of the laboratory thermometer.....°C.
Reading of the common thermometer°F.

RESULTS

1. What difference did you note between your thermometer and the laboratory thermometer —

(a) in regard to construction?

(b) in regard to scale?

(c) in regard to **range** of temperature (that is, the difference between the lowest and highest readings)?

(d) Which of these differences affect its usefulness for ordinary purposes? Why?

2. What is the temperature of melting ice?°C?
.....°F.?

18 FIRST YEAR COURSE IN GENERAL SCIENCE

3. Was the laboratory thermometer accurate as judged by your answers to (2)?

4. Was your own thermometer accurate, judged in the same way?

5. Tell how the accuracy of a thermometer at the boiling point might be tested.

EXERCISE XI (Textbook § 83)

QUANTITY OF HEAT

APPARATUS: Pieces of brass or iron of about the same weight; some pieces about twice as heavy; thermometer; tumbler of water which has been standing in the room for some time; kettle of hot water (about boiling). The metals should have a thread tied around them so that they can be lifted from the hot water.

DIRECTIONS FOR WORK:

(1) Place the small metal objects in hot water until thoroughly heated. Fill the tumbler $\frac{2}{3}$ full with water at room temperature. Observe and record to $.5^\circ$, in the table below, the temperature of water in the tumbler. Quickly transfer one hot metal to the water in the tumbler, and while stirring the water carefully with the thermometer, read the highest temperature indicated.

(2) Repeat with fresh water at room temperature in the tumbler. This time place a larger body of the same metal, or two of the same size as in (1) in the water. Record data in tables below.

<i>Temp. of water before adding hot metal</i>	<i>Temp. of water after adding hot metal</i>	<i>Difference between temperatures</i>
1. ....°C.	.....°C.	.....°C.
2. ....°C.	.....°C.	.....°C.

RESULTS

1. Did the greater change in temperature take place when the large or small mass was used?
2. Which gave the greater quantity of heat when placed in water, the small or the large mass?
3. If the tumbler contained 400 g. of water in Case 2, how many calories did the water absorb from the heated metal, as shown by your observation?
4. A man wishes to heat his house with steam at 212° F., and can get two sizes of radiators. If he wishes to keep the house as warm as possible, should he buy the large or the small radiators? Why?
5. Why are hot-water radiators necessarily larger than steam radiators?

EXERCISE XII (Textbook § 115)

WEATHER OBSERVATIONS

APPARATUS: A thermometer; ruler.

CONDITIONS NECESSARY: A thermometer placed out of doors where the sun does not shine upon it at any time, and not in contact with the wall of the house.

DIRECTIONS FOR WORK: Prepare a page of your notebook in six vertical columns, the first three narrower than the others, with the following headings, and in the proper column make your record.

<i>Date</i>	<i>Hour</i>	<i>Tem.</i>	<i>Sky</i>	<i>Wind</i>	<i>Rain</i>
-------------	-------------	-------------	------------	-------------	-------------

Under *sky*, report clear, if blue with here and there white clouds; cloudy, if nearly the whole sky is covered; overcast, if of one uniform gray with sun invisible.

Under *wind*, give the direction; and light, variable, strong, or steady as case may be.

Rain, light or heavy.

20 FIRST YEAR COURSE IN GENERAL SCIENCE

Make three observations at least three hours apart each day for a week. If you have access to a barometer, give its reading also.

RESULTS

State the relation (if any) shown by the record between —

1. The temperature and the time of day.
2. The condition of the sky and the wind.
3. The condition of the sky and rain.
4. The direction of the wind and rain.
5. Why is it necessary that the thermometer should not be in contact with the wall of a building?

EXERCISE XIII (Textbook § 127)

VARIATIONS IN TEMPERATURE SHOWN BY CURVES

APPARATUS: A thermometer hung out of doors not in contact with a warm wall of a house, and not in the sunshine; a sheet of coördinate paper at least 16×20 cm. ruled in 2 mm. spaces, with heavy rulings 1 cm. apart. (This can be procured from dealers in draughtsmen's supplies.)

DIRECTIONS FOR WORK:

(1) Prepare the paper by dating the heavy vertical lines with 15 consecutive dates, placing at the left the date of first observation. Place the number of degrees at the left end of the heavy horizontal lines. If in the winter season north of the 40° latitude, let -20° F. be the lowest; if south of 40° , let 10° F. be the lowest; and number up by successive fives. If in summer, begin with 30° at the lowest line.

(2) Read the thermometer at what you consider the warmest part of the day, and make a dot at the intersection of the date line and the line of the degree read. Place another dot on the same date line at the line of lowest temperature *which you can observe* for that date (probably in evening). Repeat for each date for two weeks or more.

Connect by light straight lines the successive points indicating maximum temperatures, and by another set of lines the minimum temperatures.

The official record of maximum and minimum temperatures may be obtained on application to the local office of the Weather Bureau. If secured, make another set of records and lines, and compare with your records.

RESULTS

NOTE. Such a series of lines as you have made is called by scientists a *curve*. The *range of temperature* is the difference between the highest and lowest temperatures of a period.

1. What is the highest reading recorded by the temperature curve? The lowest?
2. Are the variations from day to day alike?
3. What was the range of temperature for the period of observations?
4. What was the greatest daily range? Give date.
5. What was the least daily range? Give date.
6. What was the highest average temperature? Give date.
7. What was the lowest average temperature? Give date.

EXERCISE XIV (Textbook § 142)

THE SIMPLE ELECTRIC CELL

APPARATUS: A small strip of copper, a strip of zinc, insulated copper wire, binding screws, compass, tumbler of water containing a little acid (about 1 part acid to 12 parts water).

DIRECTIONS FOR WORK: *Caution:* Sulphuric acid, which is heavier than water, should always be poured into the water; never pour the water upon the acid. In the latter

case, steam is formed, and it is liable to push out and scatter the mixture. Even weak acid is injurious to the skin and clothing.

Record what happens in each of the following cases. If no visible action occurs at once, continue to watch closely for half a minute. Note differences in *degree* as well as in *kind* of changes.

<i>Place in the acid solution</i>	<i>Observation</i>
1. A strip of copper alone.	
2. A strip of zinc alone.	
3. Copper and zinc together without contact outside or in the acid.	
4. Copper and zinc together connected by a wire outside.	
5. Remove the metals from the liquid; wind the wire twice around a compass from N to S. Note any effect on the needle.	
6. With the compass in the coiled wire, replace the metal strips in the liquid and observe the position of the needle.	

RESULTS

1. Upon which of the two metals used does the weak acid act more readily?
2. What effect upon the position of a magnetic needle is produced by an electric current passing around the needle?
3. How do you know that it was the current and not the wire that produced the effect?
4. Name, in order, all the substances which made the circuit for the current in Case 6.
5. Name a case in which the circuit was broken.

EXERCISE XV (Textbook § 155)

STUDY OF GAS BURNERS AND FLAMES

Gas flames are of two kinds, *luminous* (light-giving) and *non-luminous*. A laboratory burner is called a *Bunsen burner* (from the name of the German chemist who invented it). Use these terms whenever appropriate in this exercise.

APPARATUS: A Bunsen burner, a porcelain evaporating dish, a laboratory thermometer.

DIRECTIONS FOR WORK:

(1) Examine the Bunsen burner carefully and write a brief description of it. Make a drawing of it on the first page.

(2) Adjust the brass ring at the base of the burner so that the holes are covered. Turn on the gas full head, and then bring a lighted match over the burner. Turn the stopcock until the flame is about two inches long, and describe it.

(3) Hold the outside of an evaporating dish in the upper part of flame for a few seconds and describe any change in the appearance of the dish.

(4) Turn the brass ring at the base of burner until the flame is entirely changed in appearance. Describe this flame.

(5) Hold a clean evaporating dish in the flame for a few seconds and record observations.

RESULTS

1. What kind of flame has an ordinary gas burner?
2. How can a similar flame be made with a Bunsen burner?
3. What kind of flame has a gas stove or range?
4. How can a similar flame be made with a Bunsen burner?
5. Which is the cleaner of the two flames, the one in Case 2 or Case 4?
6. Give a name for the coating formed on the evaporating dish.

EXERCISE XVI (Textbook § 155)

HEATING WITH GAS FLAMES

APPARATUS: Bunsen burner, thermometer, evaporating dish.

DIRECTIONS FOR WORK:

(1) Put into a porcelain dish 100 cu. cm. of water, after noting its temperature; record its temperature after heating 5 min. with a luminous flame. (Stir the water with the thermometer while heating and keep the bulb of the thermometer in the water until after reading and recording the temperature.)

(2) With fresh water, repeat the work of Case 1, using a non-luminous flame.

Case 1. Temp. of water at start Temp. at end

Case 2. Temp. of water at start Temp. at end

RESULTS

1. What kind of flame is best for cooking purposes? Why?
2. Why does the flame give more heat if air can enter the gas tube and mix with the gas before burning?
3. The lampblack deposited on the porcelain comes from the flame. Is its color the same while in the flame? Why?
4. From this, give an explanation of light from a flame.

EXERCISE XVII (Textbook § 164)

A PRODUCT OF OXIDATION

APPARATUS: A piece of charcoal (which is nearly pure carbon), a combustion spoon, a bottle of air, limewater, a beaker or tumbler.

DIRECTIONS FOR WORK: If no change is observed in the following work, the record should be "no apparent change."

(1) Put a little limewater into a clean empty bottle and shake it.

(2) Place a piece of charcoal on a combustion spoon and hold in a gas flame until it glows (i.e. burns without flame). Lower it then into a bottle of air and keep it there as long as it glows. After removing the spoon and coal, pour into the bottle a little limewater; cover the mouth of the bottle and shake it. Describe any change in the limewater.

(3) By means of a glass tube, breathe through some fresh limewater in a beaker. Describe the effect.

RESULTS

1. What compound is made when carbon is burned in air or in oxygen?

2. Give two other names for "burning."

3. What physical effect did the burning of the charcoal have on the air in the bottle?

4. How did the gas made by burning carbon affect the appearance of the limewater?

5. In what other case was a similar effect produced?

6. What proof did your experiment give that exhaled air differs from air inhaled?

7. What chemical process must occur in the body to cause this difference?

8. Why is the living body warmer than the outside air?

EXERCISE XVIII (Textbook § 181)

TESTS FOR ACID, BASIC, AND NEUTRAL SOLUTIONS

MATERIALS: Solution of an acid (sulphuric), a base (ammonium hydroxide), and a neutral substance (common salt), a glass rod, narrow strips of pink, blue, and lilac litmus papers.

DIRECTIONS FOR WORK:

(1) Pour 25 cu. cm. of water into an evaporating dish and add a *few drops* of an acid. Place the three litmus papers on a clean paper. With a clean rod, put a drop of acid on one end of each paper. Record any or no change of color observed, in the table below.

(2) Wash the dish and rod clean and dry them. Pour 25 cu. cm. of water into a dish and add a few drops of ammonium hydroxide (ammonia solution). Put a drop on each paper where it will not touch the spot made in Case 1. Record change in the table below.

(3) Make the apparatus clean and repeat the above tests with a solution of common salt, a neutral substance.

(4) Take home 2 sq. in. of lilac paper (provided by the teacher) and test as many other solutions as possible.

<i>Litmus papers</i>	<i>Blue</i>	<i>Pink</i>	<i>Lilac</i>
Acid Solution
Basic “
Neutral “
Soap “
Molasses “
Vinegar “
Milk (sweet)
“ (sour)
Sugar solution
Starch “
Baking soda “
.....
.....

RESULTS

1. Describe the behavior of each of the three litmus papers with each of the first three solutions.

2. Which is the best paper to use if only one can be had? Why?

3. Arrange a table to show the character of all the substances tested.

<i>Acid</i>	<i>Basic</i>	<i>Neutral</i>
	⋮	

EXERCISE XIX (Textbook § 208)

STUDY OF ROCK FORMATIONS

PLACE: A hill or mountain where the rocks are exposed; or a cut made through a hill for a road; or rocks on sea, lake, or river shore.

Upon an *extra* sheet of paper take notes (to be transferred neatly to the notebook and used in writing results) on each of the topics given below:

1. The extent of the rock exposed.
2. The position of the rock.
3. The color of the rock.
4. The hardness of the rock.
5. Difference in color of a freshly broken and a long exposed rock.
6. The direction of any cracks or natural breaks.
7. Division of the rocks into horizontal layers.
8. Presence of crystals or crystalline formations.
9. Signs of action of air or water, past or present.

Tell where you found any of the following rocks or minerals: sandstone, shale, limestone, conglomerate, granite, trap, quartz, feldspar, mica.

State the length of time spent in studying the rocks and making notes.

RESULTS

Write, in ink, in well chosen words, a two-page description of the rocks you studied, using your notes on every topic given above. The order of the topics need not necessarily be followed.

EXERCISE XX (Textbook § 239)

REPRESENTING ELEVATIONS BY CONTOURS

MATERIALS: A wooden cone cut into three or more horizontal sections, or a turnip, large carrot, or parsnip of somewhat conical shape; a knife; a sharp pencil; a hatpin or long pin; a measuring ruler; an extra sheet of paper.

DIRECTIONS FOR WORK: Remove the small tapering end from the body selected. Cut the object across at its largest part at right angles to its length, so as to give it a flat base.

(1) Take the part which is nearest to a cone in shape and measure its height; the length and width of its base.

(2) Pass a long pin, or wire, through the body from top to bottom, letting the point come through the base. Place the body on a sheet of paper (not notebook paper) and draw its profile, natural size.

(3) Draw a line upon the paper completely around the base. This is the contour line of the base. Press the pin enough to make it prick the paper.

(4) Remove the object, draw out the pin a little way, and cut off from the bottom of the object about $\frac{1}{4}$ of its height. Replace upon the paper, so that the pin will prick the same place as before. Draw the contour line of the new base.

(5) Repeat until the object is in four pieces. Draw the outline of each base and at last the outline of the top.

(6) Replace the sections and show the place of each cut by dotted lines on the profile (Case 2 above). Number the lines, beginning with 0, the base. Letter the several base outlines, beginning with *a*, the first.

RESULTS

Consider the body in position as in Case 6.

1. What is the elevation of the first section line above the base? (This is the contour interval.)

2. The elevation of the third section line?
3. By what contour lines are these elevations represented?
4. What is the elevation of contour line *a*? Contour line *c*?
5. Compare the area of the base of the object with that of the other sections.
6. Which of your drawings represents this comparison?
7. If an insect crawled by the shortest line up the side of the object you have studied, what line on the profile would represent his path?
8. How would his path be represented on the contour lines?

EXERCISE XXI (Textbook § 243)

STUDY OF A TOPOGRAPHIC MAP

MATERIALS: A sheet of a topographic map of the region in which you live. (Such maps are made by the U. S. Geological Survey in connection with the state. They can be procured at ten cents each, cash or money order, from the Director U. S. G. S., Washington, D. C.)

DIRECTIONS FOR WORK: Select a portion of the map in which there are streams, highways, railroads, and two towns a few miles apart. (Choose the portion that is most familiar to you.) Note the horizontal scale as indicated at the bottom of the map.

- (1) What is the meaning of white areas on a topographic map?
- (2) What is the meaning of few contour lines to the inch?
- (3) How would you describe a region where contour lines were near together?
- (4) A road crosses contour lines; how can you tell whether it is up hill or down?
- (5) Find an up-hill road on the east side of the ——— River. Locate it.
- (6) How many miles is it from the center of ——— to the

center of —? (Use a measure and compute from the scale on the map.)

(7) Does the — River cross any contour lines between — and —?

(8) Does the highway? The railroad?

(9) What do your answers show in regard to the elevation of these two places?

(10) Why are roads more likely to follow than to cross contour lines?

(11) What is the significance of the straight lines crossing the map from north to south?

(12) How much of the surface of the earth is included in this map? (Answer in degrees or parts of a degree.)

EXERCISE XXII (Textbook § 259)

STUDY OF A STREAM AND ITS VALLEY

PLACE OF WORK: Any locality where a stream, preferably a brook, can be studied for a length of half a mile or so. (A teacher can usually indicate an accessible stream and perhaps accompany the class to visit it.)

DIRECTIONS FOR WORK: Begin at the lower end of the portion of the stream selected (at the mouth, if possible), and make notes on the following points:

(1) The direction and velocity of the current.

(2) The character of the banks, whether alike in material and form on both sides.

(3) Evidences of erosion or deposit.

(4) Signs which tell of higher water earlier in the season.

Follow the stream toward its source, observing any changes in any of the respects observed.

(5) Is the course of the stream straight or wandering?

(6) Is its valley broad or narrow?

(7) Has it any tributaries?

(8) Are there rapids or falls at any place?

(9) Are there islands? If so, were they formed by deposit by the stream?

(10) Has the stream or its valley been altered in any way by man?

RESULTS

Write, in descriptive form, an account of this stream so far as your notes give you information. Do not try to follow the exact order of the points called for in your notes.

EXERCISE XXIII (Textbook § 272)

THE WATER SUPPLY OF A CITY OR TOWN

MATERIALS: The annual report of a city or town from the Board of Water Commissioners or the Water Department, annual report of the Board of Health, daily newspapers.

(1) Where does the water supply of your city or town come from?

(2) How is the business of supplying the water attended to?

(3) How is the expense paid?

(4) How is the amount of water used in each building ascertained?

(5) What is the price of water to the consumer?

(6) What are the uses of water besides those of the household?

(7) The average amount of water used per person is greater than it was ten years ago. Give some reasons.

(8) (a) What is a distributing reservoir? (b) A water main? (c) A gate in a water main?

(9) If a distributing reservoir is 250 ft. above sea level, how much fall is there from it to a part of the town whose level is 60 ft.?

(10) What advantage would there be in a greater fall?

(11) What is meant by "the catchment basin" of a reservoir?

(12) What precautions are needed to keep the reservoir water clean and harmless?

(13) A community now uses about 8 million gallons a day, which is more than its present system can supply in a dry season. What must be the situation of a basin that would furnish more water to be turned into the present distributing reservoir?

(14) How can water be safely transferred from one reservoir to the other?

(15) Supposing a river or a mountain lay between the two reservoirs, how could those obstacles be overcome?

EXERCISE XXIV (Textbook § 279)

THE WHEAT SEEDLING

APPARATUS: A piece of clean blotting paper, colored preferred; a plate or saucer; a tumbler; some wheat seeds, morning glory seeds, or any other garden seeds of moderate size.

DIRECTIONS FOR WORK: Soak 20 seeds for 24 hours.

(1) Make a drawing of a dry seed.

(2) Make a drawing of the seed which changed the most while soaking.

(3) Select twelve of the most perfect seeds and place them on damp blotting paper on a plate under an inverted tumbler. If after a day or two the paper begins to look dry, put a few drops of water on the corners and the moisture will spread. The paper should be kept moist, *not* wet. Examine and record observations from time to time. *Do not remove the tumbler.*

(4) Bring the paper with the seeds to school after five days.

RESULTS

Answer the following questions from your own observations:

1. What was the first sign of life which the seeds showed?
2. How many days after the seeds were soaked did this change occur?
3. How many roots sprang from a single seed at first?
4. How many, by the end of the time given for the experiment?
5. Did the roots start from about the same place or from very different places?
6. Describe the surface of a single root.
7. What is the color of young roots?
8. What else seemed to come from the seed besides the roots?
9. What color was that body?

EXERCISE XXV (Textbook § 298)

STUDY OF THE ROOTS OF A PLANT

MATERIALS: A seedling plant grown from a bean or pea; a low wide-mouthed bottle containing water; a slender stick a few inches long.

DIRECTIONS FOR WORK: Do not remove any part of the plant. In pulling it from the ground, loosen the soil around the roots with a slender stick. Leave the plant in a bottle of water at the close of the exercise.

- (1) Name the organs of the plant which you see above ground.
- (2) What plant organ is below the ground?
- (3) Try to pull up a plant without breaking it. Why is this a difficult task?
- (4) Where does the plant sometimes break in your attempt to pull it up?

(5) Can you pull up the *entire* plant without breaking any part of it, if you are careful?

(6) From this observation (No. 5), what do you conclude to be one of the uses of roots to the plant?

(7) Are the pulled roots clean?

(8) What is their color before washing?

(9) How do the roots look after they have been washed in the bottle?

(10) Can you account for this by recalling the description of root hairs, or those on the young plant which you studied at home?

(11) Is one root larger and thicker than the others?

(12) If so, how does it seem to be related to the stem?

(13) What position do the small roots have in relation to the large root?

(14) What would the roots of your plant measure if cut off and placed end to end? (Measure two or three roots and then estimate the total root length.)

EXERCISE XXVI (Textbook § 300)

STUDY OF THE STEM AND LEAVES OF A PLANT

MATERIALS: The same plant used in the previous exercise; it should be kept in a bottle with enough water to cover the roots.

(1) Make a drawing of the plant, on the first page of your notebook sheet.

(2) What organs are borne on the stem?

(3) What organ serves as a connection between root and leaves?

(4) What, then, do you conclude to be two uses for stems?

(5) How would a plant change in appearance if the soil should remain dry for a short time?

(6) Then if the soil is watered, what is the result?

(7) What, then, is the chief agent in keeping young stems rigid?

(8) Each group constitutes a leaf. How many leaves are there on your plant?

(9) Do the leaves shade each other much or little?

(10) How does the arrangement of leaves on the stem affect the shading?

(11) Hold the leaf up to the light and describe the distribution of veins.

(12) Describe a cell from the interior of a leaf as seen under the compound microscope. (This should be arranged by the teacher.)

(13) Examine with the microscope a portion of the exterior of the leaf, showing the leaf pores. Describe what you see.

EXERCISE XXVII (Textbook § 301)

ONE FUNCTION OF LEAVES

MATERIALS: A plate or saucer; leaves from a growing plant; balances; a thin sheet of rubber; a potted plant; a glass jar or a box with one glass side, large enough to cover the plant.

DIRECTIONS FOR WORK:

(1) Weigh the dish. Place several leaves from a growing plant in the dish and weigh them together, to .1 g. Leave the dish uncovered in a moderate temperature for 24 hours and weigh again. Continue this for several days, recording each weight taken.

(2) Cover the pot and the earth around the stem of a growing plant closely with a sheet of rubber. Place the plant thus prepared under a dry glass cover and leave it standing. From time to time, observe any change occurring under the glass.

If the plant is in a warm room, cool the glass after 24

hours, by opening a window near it or laying upon it for a few minutes a cloth wrung out in cold water.

1. Weight of the dishg.
 - (a) " " " " and leavesg.
 - (b) " " " " " "g.
 - (c) " " " " " "g.
 - (d) " " " " " "g.

RESULTS

1. What change in the weight of the leaves occurred? What do you think was the cause of the change?
2. Would there be as great a change in the weight of leaves left on a plant? Why?
3. What per cent of the original weight was lost the first day? Was it the same per cent every day?
4. Supposing no further change to occur after you finished weighing, from your figures calculate the per cent of weight of water in green leaves.
5. In Case 2, why should the pot be enclosed in rubber?
6. What was the evidence of escape of water from the plant leaves?
7. In what form did the water escape? Tell how you know.
8. Where does the water enter the plant?
9. What becomes of the mineral matter dissolved in water which plants take up?
10. What function of leaves has this experiment illustrated?

EXERCISE XXVIII (Textbook § 307)

TEST FOR FOOD MATERIAL IN SEEDS

MATERIALS: Concentrated nitric acid; ammonia solution; solution of iodine; some means of warming and pressing (flatiron); various seed foods such as oatmeal, peanuts, beans, nuts.

DIRECTIONS FOR WORK:

(1) To test for proteids: Add a little nitric acid to crushed seeds; after a minute rinse with water and add a few drops of ammonia solution. A yellow color where the acid acted shows that a proteid is present. The deeper the color, the greater the quantity of proteid.

(2) To test for starch. Break open the seeds (if whole) and boil them. Then add a drop of iodine to the seed or even to the water in which it was boiled. A dark blue color shows the presence of starch.

(3) To test for oil. Place the seeds between two pieces of soft paper and press them with a warm iron. After a little while, remove the iron, shake off the seed, and hold the paper toward the light. A translucent spot (in this case, a grease spot) shows oil to be present.

Effect of Application of

<i>Seeds</i>	{ <i>Nitric Acid</i>	<i>Iodine</i>	<i>Warmth and Pressure</i>
	{ <i>Ammonia</i>		
Oatmeal			
Wheat Cereal			
Peanuts			
Beans			
Peas			
Corn (popped)			
Any nut			

EXERCISE XXIX (Textbook § 312)

STUDY OF A FLOWER

MATERIALS: Flowers, like the tulip or Easter lily, for a first exercise; needles in wooden handles or long slender pins; a sharp knife. (Sweet peas, primroses, or geraniums [single] are a little less simple and might be substituted or taken later.)

DIRECTIONS FOR WORK: Examine the whole flower and write fully the answers to the following questions:

- (1) What is the color of the outermost part of the flower?
- (2) (a) Of how many parts or **sepals** is it composed?
(b) Are they joined together?
- (3) In what respects are the sepals similar?
- (4) What is the color of the next circle of parts of the flower?
- (5) (a) Of how many parts or **petals** is it composed?
(b) Are they entirely separate?
- (6) In what respects are the petals alike?
- (7) Are any parts of the flower, besides the sepals and petals, visible? If so, where are they?
- (8) Carefully pull off the sepals and the petals, one at a time; examine them and lay them down on your paper. Make a drawing of one of each.
- (9) How many yellow or brown bodies, **anthers**, do you find attached to delicate stems, **stamens**, near the middle of the flower?
- (10) Pull off these stamens. Prick open one of the anthers. What do you find in it?
- (11) How many organs now remain? Describe the **pistil**, which is left in the center of the flower.
- (12) Cut across this last organ at its largest place. Describe what you find inside.

EXERCISE XXX (Textbook § 316)

STUDY OF A SEED

MATERIALS: A dry bean; one that has been soaked in water 24 hours; one that has been on moist paper or moss for a few days; a bean plant having several leaves; a dried or fresh pod containing beans.

DIRECTIONS FOR WORK: Number all drawings and the description or answer called for, to correspond with directions.

(1) Lay a *dry* bean on your paper and draw its outline as seen from the broad side. Compare length and width.

(2) Compare the thickness of the bean with the width.

(3) Describe the color. Is it uniform?

(4) Find a rough, light spot on the bean and describe its location.

(5) What does this tell of the previous history of the seed? (Look at the beans in the pod, if necessary.)

(6) Examine a *soaked* bean and compare it with a dry bean as to size and color. Can you find the light spot?

(7) Make a lengthwise scratch with a pin in the coat of the soaked bean on the side farthest removed from the light spot. Deepen the scratch until the coat is cut through and then remove the coat. The contents of the coat is termed the **embryo**. How many large parts or organs are readily distinguishable?

(8) How are these large organs or **seed leaves** held together?

(9) Carefully break off one of the seed leaves. Do you find something between them? This is a **leaf bud**; describe the number of parts, their shape, and their attachment to another organ of the embryo.

(10) Draw separately each of the organs of the embryo. Number the pointed body (the root) 1; the seed leaves 2 and 3; their connection with the stem 4; the leaf bud 5.

(11) Using a pin, try to spread out the tiny organs which you found in Case 9. What is their shape?

(12) Examine and make a drawing of a soaked bean seed which has been lying on moist blotting paper or in damp moss for a few days. Number the parts shown in the drawing to correspond with the parts of the embryo.

(13) Examine a bean plant growing in a pot in the school-room. What visible organs of this plant correspond to organs of the embryo in the seed?

EXERCISE XXXI (Textbook § 339)

STUDY OF A FISH

MATERIALS: A live fish in a jar of water. Goldfish can be purchased for a small sum, if minnows or other common fish cannot be obtained alive. If none of these is obtainable, a fish market might furnish smelt, perch, or butterfish which have not been "dressed."

DIRECTIONS FOR WORK:

- (1) Compare the length, width, and thickness of the fish.
- (2) Describe its shape as a whole. In what respects is it adapted to movement through the water?
- (3) Compare its two sides.
- (4) Compare its two ends. What advantage is there in their being different?
- (5) Compare the upper and lower sides of the fish. Is the same side always uppermost?
- (6) The head extends from the tip of the snout to the hinder part of the flap on the sides. (a) How many times the length of the head is the length of the body? (b) Is there a neck?
- (7) Describe the shape of a fin, stating the position of the fin selected.
- (8) (a) Locate all the fins. (b) How are the fins stiffened?
- (9) (a) Where must be placed the muscle that moves the tail to the right? (b) Where the muscle that moves it to the left? (c) What name is given to a pair of muscles so related?
- (10) The flaps on the side of the head are the *gill covers*. Describe their movements and tell why they move.

- (11) Describe the appearance of the eyes.
- (12) What advantages result from the position of the eyes?
- (13) (a) Does the fish have eyelids? (b) How are the eyes protected?
- (14) Where are the nostril openings?
- (15) Where is the anus or vent for indigestible residue?

UNIVERSITY OF CALIFORNIA LIBRARY
BERKELEY

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

Books not returned on time are subject to a fine of
50c per volume after the third day overdue, increasing
to \$1.00 per volume after the sixth day. Books not in
demand may be renewed if application is made before
expiration of loan period.

DEC 15 1917

JAN 28 1918

MAR 6 1918

FEB 23 1932

MAR 9 1923

APR 12 1923

JUL 12 1926

JUL 27 1926

JUL 15 1929

FEB 10 1932

MAR 16 1969 21

RECEIVED

MAR 16 '69 - 6 PM

LOAN DEPT.

359395 Q159
P4

Please

UNIVERSITY OF CALIFORNIA LIBRARY

