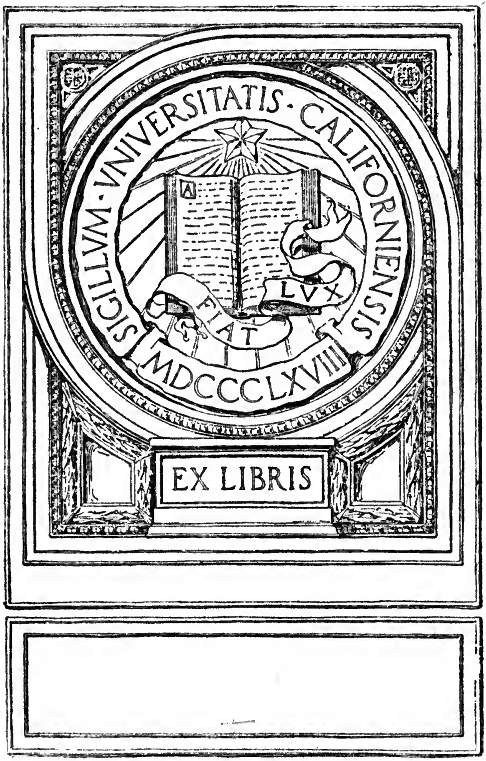
FIRST YEAR SCIENCE

SNYDER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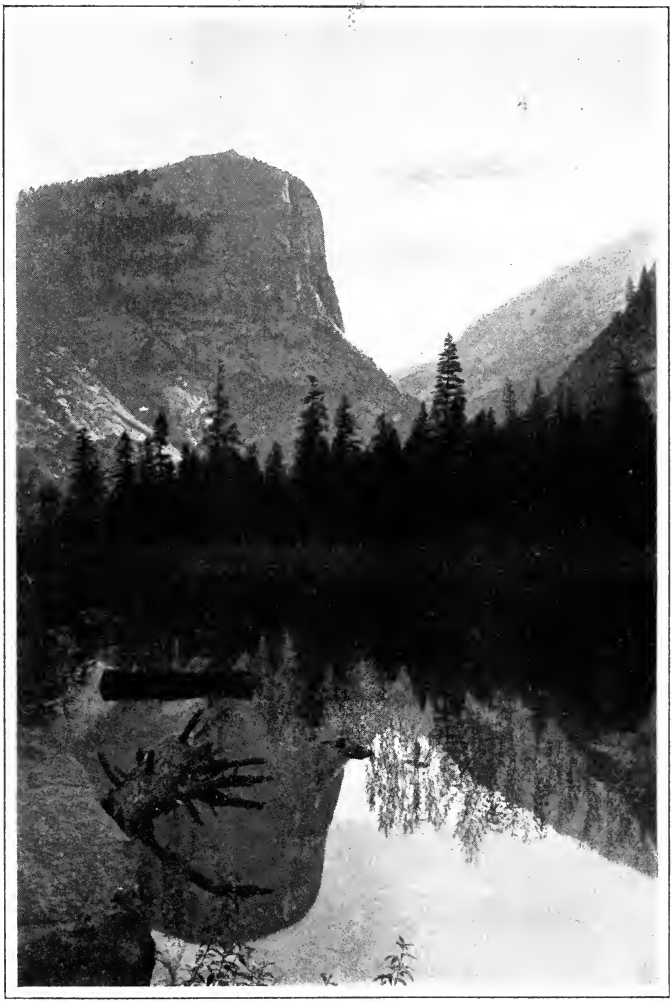

Mirror Lake, Yosemite.

FIRST YEAR SCIENCE

BY

WILLIAM H. SNYDER, Sc.D.

PRINCIPAL OF THE HOLLYWOOD HIGH SCHOOL
LOS ANGELES

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PREFACE

First Year Science deals with the earth and the sun in their relations to man. This treatment has three advantages: it gives the book unity; it gives practical interest; and it offers all the earth science needed to meet such requirements as those of the College Entrance Examination Board.

The book is meant for immature students. For this reason the language is simple, not technical, and the principles are thoroughly illustrated by experiments and pictures. A treatment too terse and condensed tends to confuse young students; hence the topics in First Year Science are sufficiently discussed to enable young pupils to master them with ease.

All subjects of elementary school science — physics, chemistry, meteorology, botany, zoölogy, physiology, astronomy, physiography, forestry, and agriculture — are treated, so that the pupil can find out for himself which ones he wishes to study later in the course.

The book is complete in itself; no reference library, no manual, is needed. The experiments require only the simplest apparatus. In most cases the mere reading of them is sufficient to illustrate the text.

The separate chapters, while forming links in the development of the whole subject, are in most cases separate units, any one of which may be omitted when time for it is lacking. Each chapter closes with a pithy summary and suggestive questions.

The book deals with the large and concrete things which surround boys and girls and in which they are naturally interested. There is little abstract theory, the effort being to call attention to things that can be seen and appreciated.

Practical things, and facts which their other studies have made familiar, are always used for illustration.

First Year Science is the outgrowth of the effort of a committee of the Los Angeles teachers to make a simple, unified course in General Science for the upper grades of the intermediate schools and the first year of the high schools. It has been carefully tested in the Los Angeles schools.

To the other members of this committee, Principal J. B. Lillard of the Gardena Agricultural High School and Principal Ralph C. Daniels of the San Pedro High School, and also to all the teachers of first year science in the intermediate and high schools of Los Angeles who carefully tried out the book in their classes, the author extends grateful acknowledgment. The proof was carefully read by J. M. Sniffen and Claude W. Sandifur, but the author wishes to absolve them from responsibility for any errors that may have crept in. Their assistance and suggestions were of the greatest service.

W. H. S.

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CHAPTER I

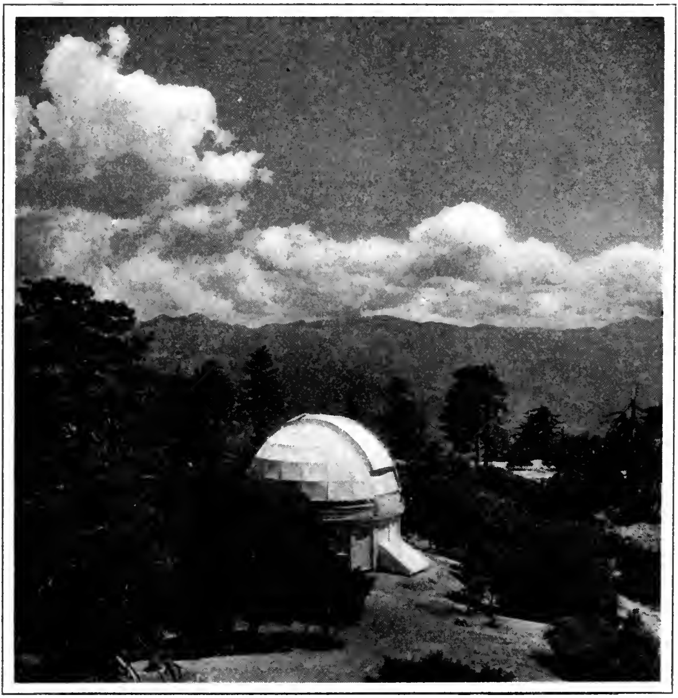
THE EARTH AND ITS NEIGHBORS

1. The Evening Sky. — As the light of the sun fades in the evening, we see the stars coming out one by one until

PART OF THE MILKY WAY.
The plate for this photograph was exposed ten hours and a quarter.

at last the sky is studded with them. We notice, too, that the brighter the star is, the sooner it appears. In the morning, just the reverse of this takes place, the stars begin gradually to fade, and the brightest stars are the last to disappear.

We know how brilliant the light of a match or candle appears in a dark room, and how a light of this kind



DOME OF THE 60-INCH REFLECTING TELESCOPE AT MT. WILSON SOLAR OBSERVATORY.
Pictures of the heavens are taken through a telescope.

seems to fade out when it is brought into the presence of a strong electric light. It would seem quite probable that the vast light of the sun might have the same effect upon the light of the stars. This supposition is also supported by the fact that when the sun is covered in an eclipse the stars begin to appear as in the evening. Astronomers are all agreed that if it were not for the greater brilliancy of the sun we should see the heavens full of stars all the time.

In the northern hemisphere the stars, except those at the north, which seem to go around in a circle, appear to rise in the east and to set in the west, just as the sun does. If we observe the stars which rise to the east, southeast, and northeast of us, we shall find that these are above the horizon for different lengths of time.

The ancients noticed these facts, and explained them by saying that the earth was at the center of a hollow sphere, upon the inner surface of which were the stars; and that this sphere was continually revolving about the earth and also slightly changing its position in respect to the earth. We of the present day know that it is the earth that is turning around on an imaginary axis, and also gradually changing its position in relation to the stars. We also know that this axis, if extended far enough, would almost strike a star in the center of the northern heavens, which we call the *North Star.* The points on the surface of the earth through which the axis passes are called the *poles.*

2. The Earth as one of the Planets. — If we carefully observe the bright points which appear in the sky at night, we shall see that almost all of them shine with a twinkling light. There are, however, three of the brightest which give a steady light like that of the moon. When the positions of these three bodies are carefully observed for some time, it will be seen that they are continually changing their places among the *stars*, whereas the positions of the stars do not appear to change relatively to one another.

One of these three brightest points has a reddish brown color and has been named Mars, from the Roman god of war. The other two bear the names Venus and Jupiter, one named from the goddess of beauty and the other from the king of the Roman gods. Astronomers call the earth and these three bodies, together with four others, *planets*, and tell us that they revolve around the sun as a center. They have no light of their own as do the true stars, but the light which comes to us from them is a reflection of the light of the sun.

MARS.
Most like the earth of all the planets. It is supposed to have a polar ice cap.

The unaided eye is able at some times to see five of these planets. Astronomers tell us that their change of place in relation to the stars is due to their motion about the sun. If we could stand upon one of these visible planets, our earth would appear to us like one of them. But the surface of some of these planets, like Jupiter or Saturn, is not solid like that of the earth. Our sun, if seen

THREE VIEWS OF SATURN.
The planet with the beautiful rings.

from the distance of one of the stars, would appear like a star.

The list of the planets in the order of distance from the sun is: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The sun, with the bodies revolving about it, is called the *solar system.* There is reason to believe that ours is only one of many similar solar systems that exist throughout space.

HALLEY'S COMET.

One of the most famous visitors from outer space. The small white dots are stars seen through the tail.

The planets are by far the nearest of all the starlike bodies, although the distance from the sun to the farthest of the planets is some 2700 million miles greater than the distance from the earth to the sun. The distance of the nearest of the stars however, is probably about 25,000,000,000,000 miles. This distance is so great that it takes light, which travels at the inconceivable rate of 186,000 miles in a second of time, over four and a half years to come to us from this star. From Arcturus, another of the stars, it takes light about 180 years to reach us, and from others very much longer. Sometimes from this outer space comets visit our solar system. Thus we see that our little earth is only a speck in the universe.

In the space between the planets Mars and Jupiter, there has been found a group of small bodies which are called *planetoids* or *asteroids.* The brighest of these is Vesta, not more than 250 miles in diameter.

A famous theory, called the *Nebular Hypothesis,* was suggested many years ago to account for the formation of our solar system. This theory supposes that the materials of which the members of the solar system are composed once formed a cloud or *nebula* of finely divided matter filling an enormous space, and that this matter, by reason of the mutual attraction of the particles, gathered together into what is now our sun with its planets and their satellites. No one knows in what way this matter originated or how matter can either be created or destroyed. But we do know many of the properties of matter.

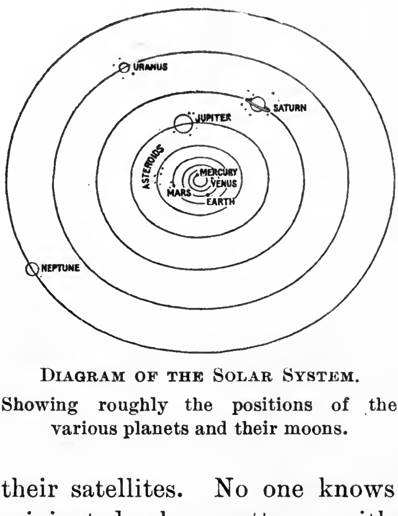


DIAGRAM OF THE SOLAR SYSTEM.
Showing roughly the positions of the various planets and their moons.

3. Properties of the Matter Composing the Universe. — **Experiment 1.** — Pull out the handle of a compression air-pump or bicycle pump. Close the exit valve or stop up the end of the bicycle pump. Now try to push in the handle. What keeps it from moving easily? Try to shove an inverted drinking glass into a pail of water. Why does not the water fill the glass?

All matter as we know it occupies room or space. In other words, it has *extension*. When we pump up a bicycle tire we find that even the air demands room for itself. In the experiment with the air compressor we found that the space occupied by the air could be reduced only to a limited extent. However great the pressure might have been the air would still have occupied a certain amount of space.

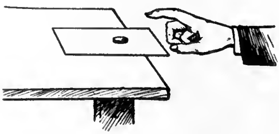


Fig. 1.

Experiment 2. — Place a coin on a card extending slightly beyond the edge of a table. Suddenly snap the card horizontally. Does the coin move?

Another of our common observations is that a body does not begin to move unless some force acts upon it, nor when moving does it stop unless some force stops it. When the card was snapped from under the coin, the coin did not appear to move because the friction of the paper was not sufficient to transfer any appreciable motion to it. If the coin had been glued to the card, both coin and card would have moved.

Experiment 3. — Revolve around the hand a small weight attached to a strong rubber band. Suddenly let go the band. Does the weight keep on moving in the circular path in which it was revolving?

When a car is moving along a level track we do not expect it to stop until the friction of the track or some other force stops it. When we revolved the weight attached to the rubber band and let go the band the weight started off in a straight line. It did not continue in this straight line because a force, *gravity*, pulled it down toward the earth. This property which bodies have of remaining at rest unless

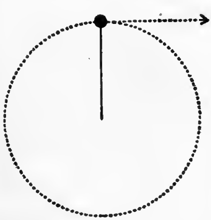


Fig. 2.

acted upon by some force, and when in motion of continuing to move in a straight line with the same speed, unless acted upon by an outside force, is called *inertia.* Sir Isaac Newton first stated this fact, and so it is sometimes called *Newton's First Law.* It is the force of inertia which throws one out of an automobile if it is suddenly stopped.

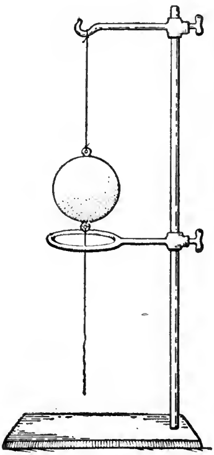
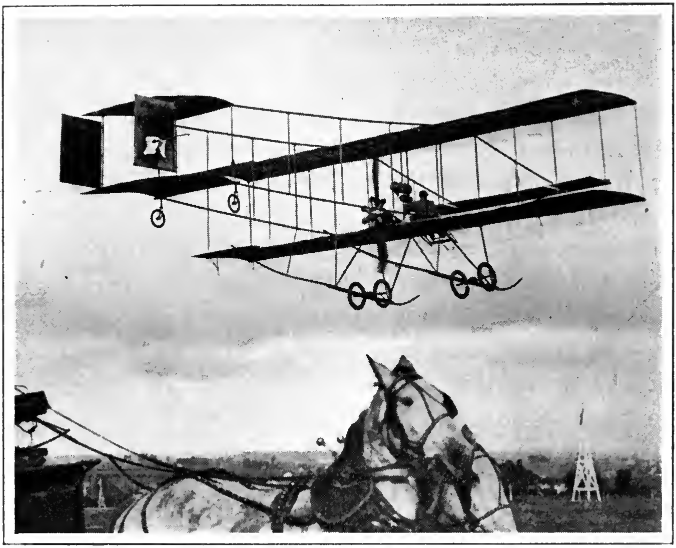


Fig. 3.

Experiment 4. — Suspend a heavy ball by a string not much too strong to hold it. (Place a pad beneath it to catch it if it drops.) Attach a similar string to the bottom of the ball. Attempt to lift it suddenly by the upper string. What happens? Suspend it again and pull down gradually on the lower string. What happens? Suspend it again and pull down suddenly on the lower string. What happens?

When we tried suddenly to lift the suspended ball the force of inertia was so great that it broke the string. When the string was attached to the bottom of the ball and the pull gradually exerted, the upper string broke, since it had both the weight of the ball and the pull of the string to withstand; but when the pull was suddenly exerted, the inertia of the ball was sufficient to withstand the pull, and the lower string broke.

It is the inertia of the water which enables the small, rapidly revolving propeller to move the big ship. The same is true of both the propelling and supporting of flying machines. The resistance which the particles of air offer to being suddenly thrown into motion, their inertia, enables the propeller to push the aeroplane along and keeps it from falling to the ground as long as it is moving rapidly. It is inertia which keeps the heavenly bodies



A Biplane.
The blur shows how swiftly the propeller is revolving.

moving in space. Once in motion they must keep on forever unless some force stops them.

Experiment 5. — Place a glass globe partly filled with water on a rotating apparatus. Rotate the globe rapidly. What does the water tend to do?

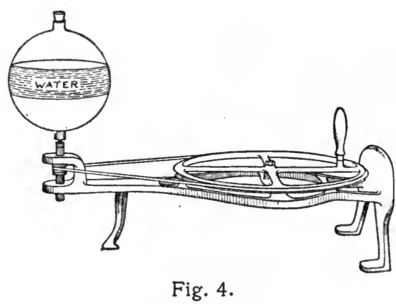


Fig. 4.

Inertia also manifests itself in the tendency of revolving bodies to move away from the center around which they are revolving. Inertia thus manifesting itself is called *centrifugal force*. An example of this was seen in Experiments 3 and 5.

Newton many years ago discovered that all bodies of matter have an attraction for each other and that this force of attraction varies as the masses of the bodies, that is, the more matter two bodies contain the more they attract each other. But this attraction becomes less as the distance between the bodies increases. This lessening of the force of attraction on account of the increase of distance is proportional not to the distance, but to the square of the distance. This means that the attraction between the same bodies when twice as far apart is only one fourth as great; when three times as far apart, one ninth as great, and so on. What causes this attraction no one knows, but the name given to this force of attraction is *Gravitation.* Gravitation is always acting upon all bodies, and their conduct is constantly affected by it. It keeps the heavenly bodies from wandering away from each other just as the rubber band kept the weight from flying away from the hand.

When this attraction is considered in relation to the earth and bodies near its surface the term *gravity* is used. We are constantly measuring the pull of gravity and calling it *weight.* This is the cause of bodies falling to the earth. It is the force which causes us to lie down when we wish to sleep comfortably, and frequently makes us fall if we try to fly.

If two forces act upon a free body, each will influence the direction of its motion and it will go in the direction of neither force, but in a direction between the two. If there are more than two forces, the path will be the result of the action of all the forces. In the case of the weight and the rubber band we found that the moving weight when not held by the force of the band flew away from the hand. The rubber band continually pulled it toward the hand. The result of these two forces, the inertia of the weight and the pull of the band, was to make the path of the weight lie between the two. In this case the forces at every instant almost balanced each other, and the path was nearly a circle. It is the force of gravitation acting against the inertia, or the centrifugal

THREE FORCES IN PLAY.

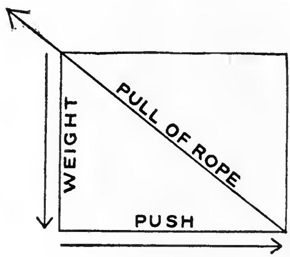
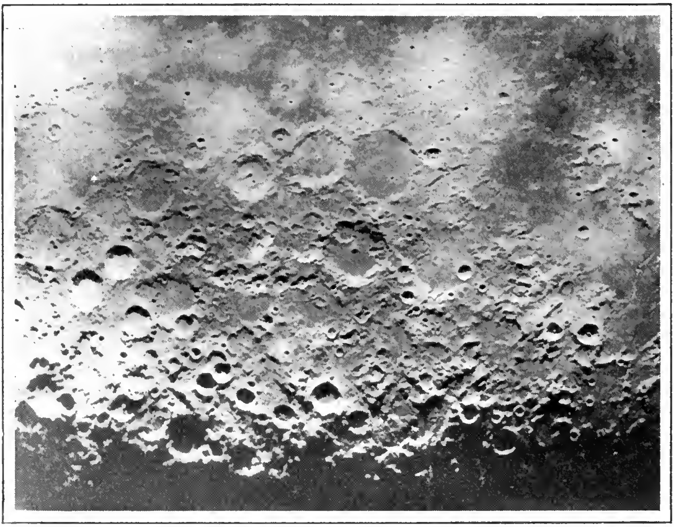


Fig. 5.

force, of the heavenly bodies which holds them in their orbits.

4. Relation of the Earth to Sun and Moon. — Not only do all the planets revolve around the sun, but certain of these themselves have other smaller bodies revolving around them. We call such small bodies *satellites* or *moons*. The earth has one of these satellites and Saturn has the greatest number of all, ten, one having been discovered as late as 1905. Our own moon has a diameter of about 2000 miles and a weight of about $\frac{1}{80}$ that of the earth. Its average distance from the earth is about 240,000 miles. Compared with the distance of the other heavenly bodies it is indeed very near.

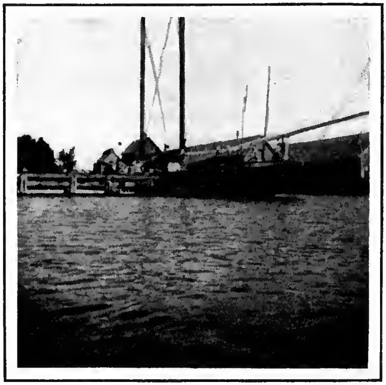
The sun, although a near neighbor as compared with the rest of the stellar community, is at an average distance of about 93,000,000 miles. It is so big that if it were hollow and the earth were placed at its center with the moon as far away as it now is, there would be almost as great a distance between the moon and the sun's surface as there is between the moon and the earth. A good way to get an idea of the relative size of these bodies is to let a pencil dot represent the moon, a circle an eighth of an inch in



Surface of the Moon.
Showing the great crater-like depressions.

diameter the earth, and a circle with a diameter of a little more than thirteen and one half inches the sun.

Both the sun and the moon are of the greatest interest to us, as they have much to do with our existence. If it were not for the sun, we should have almost no heat or light on the earth, and life could not exist. If the sun were much nearer, it would be too hot for life as we know it, and if much farther away, too cold. If it were not for the moon, the beauty and variety of our nights would be largely lacking, and we should have no tides strong enough to sweep clean our bays, removing the sewage, and to help vessels over the bars into some of our harbors. If the distance of the moon were changed, the height of the tides would be changed, and this would greatly affect our coast towns.

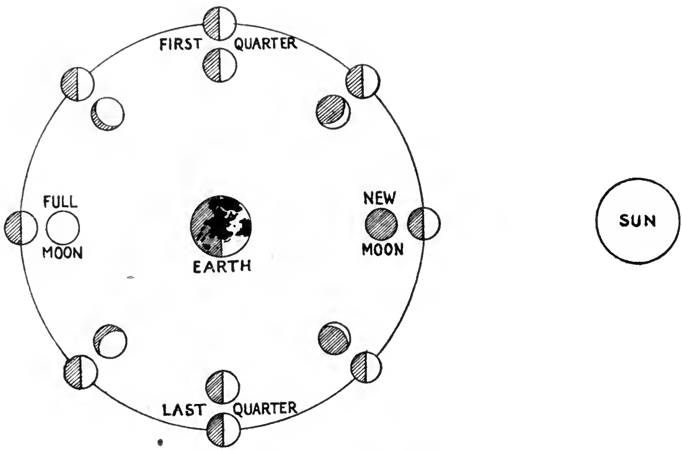


High Tide in Nova Scotia.

Although we see the moon as a very bright object at night for a part of every month, yet it has no light of itself, and all the light it gives us is reflected from the sun. It has a rough, barren, rocky surface, full of great crater-like depressions. As far as known, it has no air or water upon it. As the earth goes around the sun, and the moon around the earth, the position of these three in relation to each other is constantly changing, and it is these changes which give us the varying heights of the tides and the different phases of the moon. It is profitable to try to picture to oneself the changing phases of the moon. A

Low Tide at the Same Place.
Showing the clean swept sea floor.

good way to do this is to carry a ball around a bright light and observe what part of the surface is illuminated in the different positions.



THE PHASES OF THE MOON.

Showing roughly the positions of the sun, moon, and earth.

Summary. — We have seen that the earth is one of eight planets which revolve about the sun. The sun and the bodies revolving around it comprise the *solar system.* The fixed stars, which we see only at night because of the great brilliancy of the sun in the daytime, are suns and may — like our sun — be the centers of separate solar systems.

Everything in the universe is composed of *matter*, which has certain definite properties, like *extension*, *inertia*, *gravitation*, and so on. The action of some of these properties maintains the relation of the different heavenly bodies — keeps the earth revolving around the sun and the moon around the earth.

The sun and the moon have more influence upon the earth than do any other bodies. The sun gives us energy in the form of light and heat and so maintains all the life upon the earth. The moon, though shining only by light reflected from the sun, exerts a great attraction upon the earth, causing the tides, which help to keep the waters of our harbors clean.

Questions

Why do we see no stars in the daytime?

How is the appearance of the stars explained?

What is the difference between *stars* and *planets?*

What starlike bodies make up the solar system?

Name and illustrate three universal properties of matter.

What daily experiences of yours are explained by these properties?

What forces keep the moon moving around the earth in its orbit?

Draw circles illustrative of the size of the earth, moon, and sun.

Why are the sun and moon particularly interesting to us?

How long would it take an express train running thirty miles an hour and stopping neither day nor night to go over the distance from the earth to the moon? From the earth to the sun?

CHAPTER II

THE PLANET EARTH

5. The Shape of the Earth. — Men who have in different ways made careful measurements of the shape of the earth tell us that it is an *oblate spheroid* (Fig. 6), that is, a sphere which is somewhat flattened at two opposite points. An ordinary orange has this shape. The earth has been so little flattened, however, that its shape is very much nearer that of a perfect sphere than is that of an orange. Its polar diameter is only 27 miles shorter than its equatorial diameter, so when we consider that each of its diameters is nearly 8000 miles, a shortening of only 27 miles in one of these would not change its shape from that of a sphere enough to be noticed except by the most careful measurements.

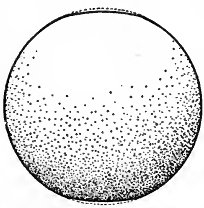
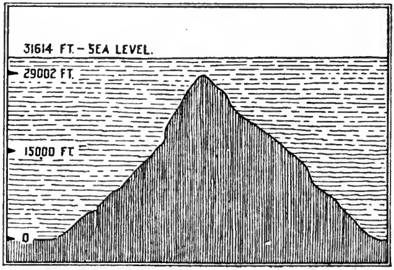


Fig. 6.

Experiment 6. — Attach a centrifugal hoop to a rotator apparatus and revolve. The hoop bulges at the center or point of greatest motion and flattens at the top and bottom or points of least motion. The earth revolves in a way similar to the hoop and is very slightly flattened at the poles.

Although some of the mountains of the earth rise above sea level to a height of over five miles, and there are depths in the sea which are somewhat deeper than this below sea level, yet these distances are so little in comparison to the size of the earth that the surface is comparatively less irregular than that of an orange.

In these days many men have sailed around the earth, but valiant indeed was that little company which in 1522 first proved that it was possible to sail continually in one direction and yet reach the home port, thus first demonstrating that the earth was globular. Long before, wise men had come to believe that the earth was a sphere, for it had been noted as far back as the time of Aristotle, the famous Greek philosopher, that when the shadow of the earth falls upon the moon, causing an eclipse of the moon, the boundaries of the shadow were curved lines. It was also later noticed that when ships are seen approaching at sea the masts appear first and then gradually the lower parts of the ship. The reverse was seen to be true when ships sailed away.



MOUNT EVEREST.
As it would appear if placed in the deepest part of the sea.

Experiment 7. — Add alcohol to water until a solution is obtained in which common lubricating oil will float at any depth. Insert with a glass tube a large drop of oil below the surface of the solution. The oil will float in the solution in the shape of a sphere. This illustrates the fact that if a liquid is relieved from the action of outside forces, it will take the form of a perfect sphere.

A spherical surface is the smallest surface by which a solid can be bounded, so the maximum distance which can separate places located on a given solid will be least when its surface is spherical. Thus the inhabitants of the earth, considering the surface over which they may scatter themselves, are brought into the closest possible relation to one another. One of the most noteworthy consequences of the earth's shape is the ease with which knowledge, news, and the products of both agriculture and manufacture are carried between its most distant parts.

6. **The Size of the Earth.** — It is easy to say that the polar diameter of the earth is 7900 miles, its equatorial diameter 7927 miles, and its equatorial circumference 24,902 miles, but a true conception of these distances is not so easy. There are, however, distances on the surface of the earth over which we have passed and about which we have real knowledge; and if we can translate other distances into terms of these, then the unfamiliar distances will become appreciable.

One of the best ways to do this is to draw a line which shall represent our known distance and then with this as

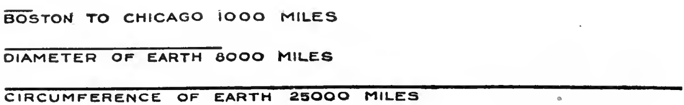


Fig. 7.

a measure draw other lines which shall represent the distances of which we wish to get an appreciation. Using as our standard any distance with which we are really acquainted, we shall find that the lines representing the different dimensions of the earth are very long. How vastly greater, then, must be the distances which were mentioned when treating of the stars.

7. **Effect on Life of the Irregularities of the Earth's Exterior.** — Although the irregularities of the surface of the earth, when considered in relation to its size, are insignificant, yet in relation to the size of the men and animals that dwell upon the earth they are very great. Some of the mountains rise to heights that are inaccessible, and the oceans in some places sink to depths which until recently

were immeasurable. The lofty mountains and broad oceans are barriers which plants and animals have tried in vain to cross and which man himself has had difficulty in surmounting.

THE HIMALAYA MOUNTAINS.
An insurmountable barrier in central Asia.

These regions have furnished protected spaces to different species of plants, groups of animals, communities of men, and unmolested in these protected places they have developed their peculiar characteristics. Where man has not succeeded in thoroughly overcoming the barrier, secluded and unprogressive peoples are still to be found. Such are the Highlanders of Scotland and of our own Appalachian plateau. The gentler inequalities of the earth's surface have by their lakes and rivers afforded easy means of transportation from one community to another and have opened paths into hitherto unexplored regions. These waterways have been from the earliest times arteries of

A Cottage in the Scotch Highlands.

commerce and progress, and largely through them have the interior lands been colonized and developed.

Where great plains and plateaus stretch their broad and level surfaces over vast areas, plants, animals, and men for ages, unimpeded by natural barriers, have been thrown together and have striven unrelentingly for mastery. They have here developed into great aggregations, not into small distinct communities. Here there has been no shelter for the weaker group except as its identity was lost in merging with the mass.

8. The Interior of the Earth. — Whenever borings have been made into the interior of the earth it has been found, after a depth had been reached where there was no effect from the heat of the sun, that the temperature rose as the boring increased. From this gradual increase of temperature, it must be that far down within the earth the temperature is very high. The pressure within the earth is so great, however, that there are probably no liquid rocks at great depths. If the earth had a liquid interior the attraction of the bodies about it in space would cause changes in its shape, but it is as rigid as steel.

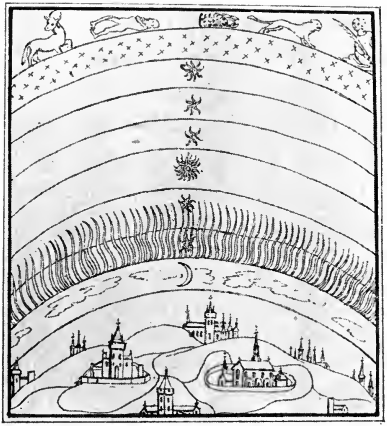
The outside cold part of the earth is called its *crust.* How thick this is no one knows. This is the part that is of particular interest to us, for it is the only part which we are able to observe and study.

9. The Cause of Day and Night. — **Experiment 8.** — (*a*) In a darkened room place a globe a short distance from a small but strong light. Revolve the globe with its axis at right angles to the line which joins the centers of the globe and light. How much of the globe is illuminated by the light? Is the same part of the globe illuminated all the time? Does any place on the illuminated part receive light for a longer time during a revolution than any other place? Remove the globe to the opposite side of the light without changing the direction of its axis. When revolved, is there any change in the globe's illumination? If so, what?

(*b*) Now make the axis on which the globe revolves parallel to the line joining the centers of the globe and light. Revolve the globe. How much of the globe is illuminated by the light? Is the same part illuminated all the time? Does any place on the illuminated part receive light for a longer time during a revolution than any other place? Remove the globe to the opposite side of the light without changing the direction of its axis. When revolved is there any change in the globe's illumination? If so, what?

(*c*) Place the axis of the globe so that it is inclined to the line joining the centers of the globe and light. Revolve the globe. How much of the globe is illuminated? Is the same part of the globe illuminated all the time? Do any places in the illuminated part receive light for a longer time during a revolution than other places? Remove the globe to the opposite side of the light without changing the direction of its axis. When the globe is revolved is there any change in the length of time of illumination of the places before noted? If so, what?

As has already been stated, the ancients considered the earth as the center of the universe and thought that the sun and stars revolved around it. We of the present day, however, know that it is the rotation of the earth from west to east that causes the appearance of the rising and setting sun and thus makes day and night.



Medieval Idea of the Universe.

From a fourteenth-century manuscript. Above the earth are the clouds and the moon; then the rays of the sun; next various planets; above these the stars; and finally the signs of the zodiac.

Of course it makes no difference about a person beginning to see a light whether the light is brought toward him or whether he goes toward the light. We are turned into and out of the sunlight by the rotation of the earth. We speak of the sun as rising high in the sky, but what really happens is that we are turned so that the center of the earth, our heads and the sun come nearer and nearer toward a straight line.

When we say *down* we mean toward the center of the earth, and when we say *up* we mean in the opposite direction. These are the only two directions that we could be easily sure of, if it were not for the rotation of the earth.

This gives the direction of the rising sun, which we call *east*, and of the setting, which we call *west*. A line which runs at right angles to the one joining east and west, *i.e.* one running parallel to the axis of the earth, is said to run *north* and *south*. Thus the points of the compass, as well as day and night, are determined for us by the earth's rotation. The north star, which is so important to the sailor in determining his direction, is simply a star which is almost in line with the axis of the earth. It is the rotation of the earth which gives us also our means of measuring time.

As was seen in the previous experiment, the direction of the axis of a revolving globe has much to do with the light which different parts of it will receive from a luminous object. The hemisphere which is inclined toward the luminous object will have a larger part of its surface illuminated and therefore each place on it will be longer in the light during a revolution than when the hemisphere is inclined in the opposite direction.

As the axis of the earth is inclined to a line drawn from the earth to the sun, the light the earth receives is similar to that received by the globe in the last part of the experiment. Thus the days and nights vary in length during the year, because in summer the northern hemisphere is inclined toward the sun and in winter away from it.

10. The Movement of the Earth around the Sun. — The earth not only turns on its axis every day, but it travels around the sun in a direction opposite to the motion of the hands of a watch. It moves with the tremendous average velocity of about 19 miles a second. It is this revolution around the sun which gives us our measure of time which we call a *year*. It takes 365 days and a fraction to complete this revolution, so we consider 365 days to be a year, and add a day practically every fourth year to make up the fraction.

In the journey around the sun the earth does not move in a circle but in an *ellipse*, which is a figure something like a circle but having one of its diameters longer than the other. This figure can be drawn by sticking two pins into a piece of paper, a little distance apart, and tying to each pin one end of a string, the length of which is several times the distance between the pins. Then put a pencil into the loop of the string and draw the curve which will be formed on either side of the pins by the pencil being moved over the paper in the extended loop.

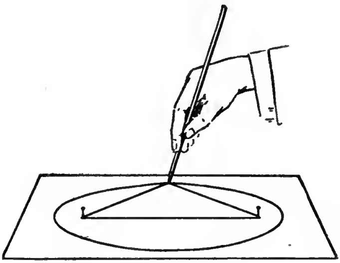


Fig. 8.

The points where the pins pierce the paper are called the *foci*, and, as will be seen, each of these points is nearer one half of the curve than the other. If a body were placed at one of these points and another body moved around it in the line of the curve, the two bodies would be nearest each other when passing one point in the line extending through the foci, and farthest apart when passing the opposite point in the same line.

Now the sun is at one of the foci of the ellipse in which the earth moves, so the distance between the sun and the earth varies during the year. This variation is about three millions of miles, the average distance of the earth from the sun being about 93,000,000 miles. Strange as it

Fig. 9.

may seem, we are nearest the sun in January and farthest away in July (Fig. 9). We are not warmest in the northern hemisphere in January because our hemisphere is then pointed away from the sun and therefore there are fewer heat rays falling upon a given area in this hemisphere than there are when we are farther away in July.

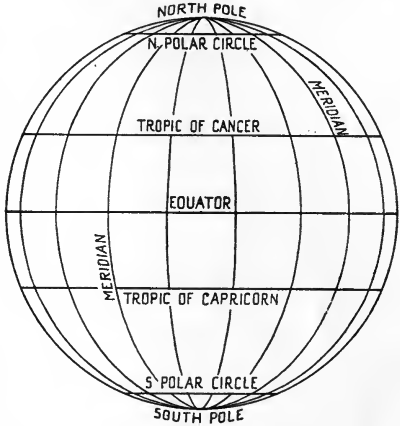


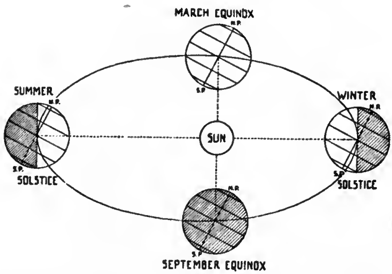
Fig. 10.

11. Latitude Zones. — As the axis of the earth is inclined $23\frac{1}{2}°$ from the perpendicular to the plane of its orbit, the rays of the sun will fall vertically at some times during a year upon all points within $23\frac{1}{2}°$ of the equator both north and south. To this region we have given the name of the *torrid zone.* There will be a day during the year when no direct sunlight will fall upon points within $23\frac{1}{2}°$ of the poles. The areas inclosed by lines drawn around the earth, $23\frac{1}{2}°$ from the poles, are called *frigid zones.* The areas between the frigid zones and the torrid zones are called the *temperate zones.* We live in the *north temperate zone.*


A LAPLANDER'S HUT.
Made of thick sod to keep out the cold of the frigid zone.

Although as far as the direct influence of the sun is concerned, these zones are easily separated and bounded by parallels of latitude, yet, on account of other influences, the temperatures of the zones thus bounded are very irregular. For instance, at some places like Hammerfest within the frigid zone the average temperature is much higher than at places like Labrador within the temperate zone, so that as regards temperature, the parallels of latitude are uncertain boundaries. This will be more fully discussed later.

12. The Cause of the Seasons. — Since the earth moves around the sun with its axis inclined to the plane of its orbit, the hemispheres will at different times be inclined toward and away from the sun. When the northern hemisphere is inclined toward the sun, the rays of the sun cover the north pole continuously for six months, so that at this point there is no night for all that time. The days are longer and the nights shorter throughout all the northern hemisphere, and more than this, the rays then fall upon this hemisphere more nearly vertically than during the rest of the year.



THE PATH OF THE EARTH AROUND THE SUN.

Showing roughly the four positions mentioned in the text.

The nearer vertical the rays, the greater the number that fall upon a given area and the greater the amount of heat received by that area. More heat is received in the northern hemisphere not only because the rays fall more nearly vertically but also because the length of the day is increased. The amount of heat received from the sun continues to increase as long as the sun appears to move north, or until its rays fall vertically upon the tropic of Cancer. This occurs on the 21st of June, which is called the *summer solstice.* At this time our days are the longest and our nights the shortest. But the days are not the hottest, as the heat gradually accumulates for some time, more being received each day than is given off.

As the earth proceeds in its orbit from this point, the inclination of the north pole toward the sun becomes less

Hut in the Tropics.

Made of thin walls but a heavy thatched roof to keep out the rain.

and less, until on the 23d of September the sun is directly over the equator. The north pole now begins to point away from the sun. On December 21 the direct rays of the sun fall upon the tropic of Capricorn, and the sun has reached its farthest point south, our days being then the shortest and the days in the southern hemisphere the longest. From this point until March 21, when the sun is again vertical over the equator, the inclination of the north pole away from the sun decreases. The days when the sun is over the equator are called the *autumnal* (Sept. 23) and *vernal* (March 21) *equinoxes*, since the days and nights are then of equal length all over the earth.

The greater heating of the hemisphere at one part of the year than at another gives us the changes which we call the *seasons*. Since the change in the length of the day and in the direction of the sun's rays is very small within the tropics, the change in the amount of heat received is very slight, so that in this region there is almost no change of seasons. But at the poles, where for six months there is continuous night and for six months continuous day, the change of seasons is exceedingly great. At middle latitudes the changes, though marked, are not excessive.

There are then two causes which combine to give us our change of seasons: the revolution of the earth around the sun, and the inclination of the earth's axis to the plane of its orbit.

13. The Measurement of Time. — **Experiment 9.** — On a fair day place a sundial in an exposed position, and after carefully adjusting it, compare its readings with those of an accurate watch. Probably your watch is set to railroad time and the readings therefore are not alike, unless you are on the time meridian.

Although the exact determination of time is a difficult task and requires great skill and very accurate instruments, yet it is not very hard to determine quite satisfactorily the length of a solar day. Before there were any clocks, people told the time of day by *sundial* (Fig. 11), which consisted of a vertical rod, the shadow of which fell upon a horizontal plane. From local noon, or the time the sun cast the shortest shadow on a certain day, until it cast the shortest shadow the next day, was considered a day's time, or a *solar day*, and was divided into twenty-four equal parts called *hours*.

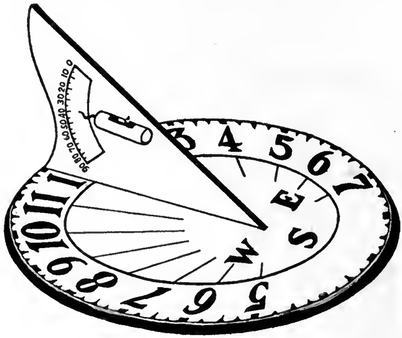
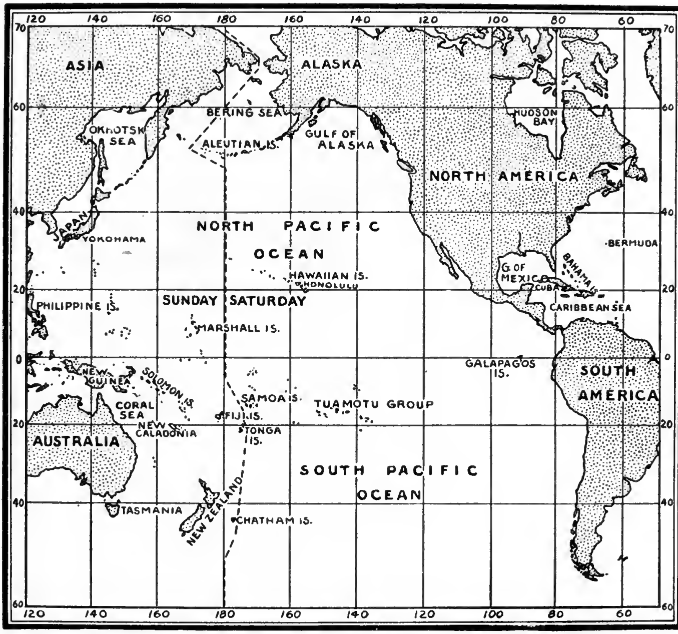


Fig. 11.

The direction of the shortest shadow is a north and south line, since the sun must then be halfway between the eastern and western horizon. As the lengths of these solar days vary slightly, for reasons which cannot be explained here, we now divide the mean length of the solar days for the year into 24 parts to get the hours. The civil or conventional day begins at midnight, not noon. The determination of the exact time is very important; for the United States it is done at the Naval Observatories at Washington and at Mare's Island, San Francisco, and telegraphed each day to different parts of the country.

A day may be measured by the interval between the successive passages of a star across the zenith. This would be called a *sidereal* day, from the Latin word for star. It might also be measured by successive passages of the moon across the zenith. This would be called a *lunar* day, from the Latin word for moon.

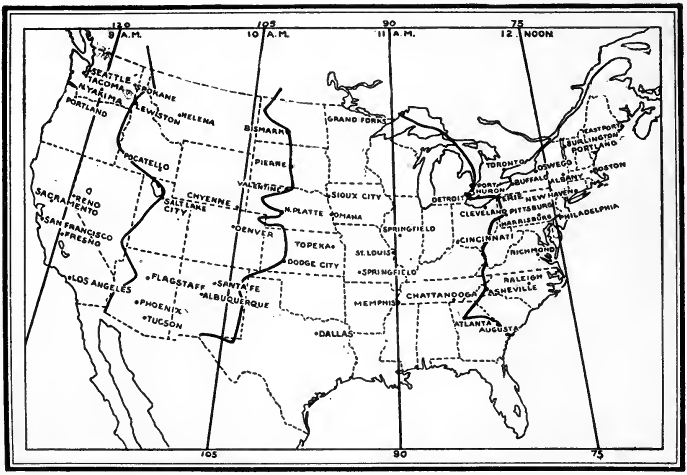
If a person should start at noon and travel around the earth from east to west as fast as the sun does, the sun would be overhead all the time and no solar day would have passed for the traveler, even though 24 hours would be required for the trip. But when he reached home he would find that it was the next day. Thus any one traveling around the earth must skip a day if going toward the west and add a day if going toward the east. The conventional place where this is done is at the International Date Line, a line extending through the Pacific Ocean and in general corresponding with the 180th meridian.



MAP SHOWING INTERNATIONAL DATE LINE (Dotted Line).

14. Standard Time. — When railways extending east and west became numerous in the United States and there were many through trains and numerous passengers, it became very inconvenient to use local time, since no two places had the same time. Each railway therefore adopted a time of its own, and when several railways entered the same city these different times became very confusing. Therefore in 1883 the American Railway Association persuaded the Government to adopt Standard Time.

A certain meridian was adopted as the time meridian for a definite belt of country. The meridians adopted were 75° for Eastern, 90° for Central, 105° for Mountain, 120° for Pacific Time. These meridians run through the centers of the time belts and for $7\frac{1}{2}°$ on either side the time used is the local time of the central meridian. When a person crosses from one belt to another he finds that the time makes an abrupt change of an hour. This system has been extended to all the United States posses-



MAP SHOWING STANDARD TIME BELTS.

sions, and is coming into general use over a large part of the world. In actual practice the changes of time are not made where the boundaries of the time belts are crossed, but at important places near these.

Experiment 10. — On a day when there appear to be indications of settled fair weather place a table covered with blank paper in an open space where the sun can shine upon it. Make the top of the table level and fix it firmly so that it cannot be moved. Fix vertically upon the table a knitting needle or a slender stick. Mark the line of the sun's shadow and note accurately the time the shadow fell on this line. On the next day note the time the shadow falls upon the same line. If your watch is right, the difference in time it shows between the falling of the shadows the first and the second days is the difference between this particular solar day and the *mean solar day*. This may be nearly a minute. The shortest shadow of the day marks noon. It extends north and south. (Your watch keeps mean solar time. But twelve o'clock by your watch will probably not be midday or high noon, as your watch is set to Standard Time.)

15. Meridians and Parallels of Latitude. — For purposes of measurement, circles of any size are divided into 360 equal parts called *degrees*. Thus the equatorial circle of the earth is divided into 360 parts. Through each of these divisions there is a semicircle drawn from pole to pole. These semicircles are called *meridians*. Each meridian is divided into 180 parts called *degrees of latitude*, and through these points of division are passed circles parallel to the equator. These circles gradually decrease in size as they approach the poles. They are called *parallels of latitude* and are numbered from 0 at the equator to 90 at the poles.

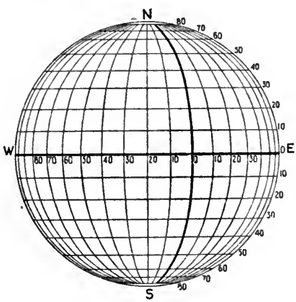


Fig. 12.

A certain one of the meridians, usually the one passing through Greenwich, England, is called the *prime meridian* and numbered 0. East and west of this the meridians are numbered from 1 to 180. The degrees thus numbered are called *degrees of longitude*. Thus we have a skeleton outline by means of which we are easily able to locate the position of any place upon the earth. To secure greater accuracy than could be obtained by giving merely the degrees of latitude and longitude, each of these degrees is divided into 60 equal parts called *minutes*, and each minute can be divided into 60 parts called *seconds*.

It will be seen at once that the lengths of the degrees of longitude decrease as the pole is approached, since all the meridians pass through the poles and the distance between the meridians, which is considerable at the equator, becomes nothing at the poles. Of course these lines are simply imaginary lines and do not really exist, but in making a map or a globe we draw them as if they existed. The length of a degree of latitude at the equator is 68.7 miles, at the poles, 69.4. The difference is due to the flattening of the earth near the poles. The length of a degree of longitude at the equator is 69.65 miles, at the poles, 0.

16. Determination of Longitude. — Since the earth turns on its axis once in 24 hours, the interval between the passage of successive meridians under the sun will be four minutes ($24 \times 60 \div 360 = 4$). At a point one degree east of us the noon by local time is four minutes earlier than it is with us, and at one degree west it is four minutes later. If an accurate clock were set to twelve o'clock when the sun was nearest vertical at a certain place, and were then carried to a place 15° west, it would indicate one o'clock at the more western locality when it was noon at the first place. Or, changing the statement, if the clock indicated one o'clock when the sun reached the highest point, the place must be 15° west of the place from which the clock started.

Thus we see that by means of an accurate timekeeper we can tell difference of longitude between different places. Every sea captain is provided with one or more accurate clocks called *chronometers*, which are usually set to the time at Greenwich. Thus all he needs to do to get the difference in degrees of longitude between his position and Greenwich is to determine when the sun has reached its highest point and to multiply by fifteen the difference in hours between the time as shown by the chronometer and twelve o'clock. If the chronometer is too slow he is east, and if too fast, west, of Greenwich.

The determination of latitude is more difficult, but can be easily done by one knowing how and having the proper instrument. The manner of its determination is described in the appendix.

17. Magnetism of the Earth. — There is a peculiar property of the earth which has been of the greatest assistance to geographical explorers and without which it would be very difficult to find a way over the sea. This property is called *terrestrial magnetism.* In very ancient times pieces of iron ore were found which had the property of attracting iron. Such pieces of ore are called *loadstones.* Artificial loadstones are called *magnets.* If a bar of loadstone or a magnetic needle is floated in a basin of water, or if freely suspended, it will invariably assume a definite position.

This discovery was made in the far east at a very early date, but it was put to no particular use in the sailing of ships until about the middle of the thirteenth century. Since then it has enabled sailors to go far out from the sight of land and yet always to know the direction in which they are going. It was supposed even up to the time of the first voyage of Columbus that the magnetic needle always pointed toward the north star or perhaps at some places a little to the east of it, and the sailors of Columbus were greatly alarmed when they found as they sailed west that the needle swung off to the west of the true north.

This difference in the direction of the needle from a true north and south line is called the *declination.* The westward declination was one of the great discoveries of

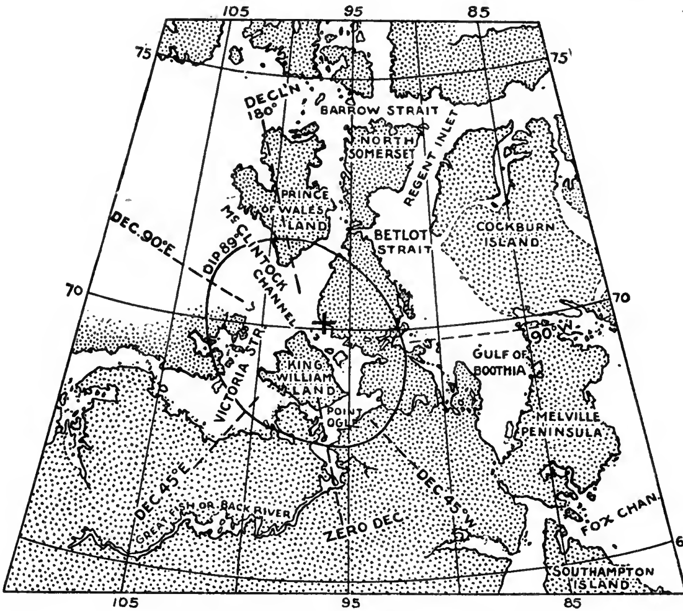
Columbus. We know now that the reason for the declination of the needle is that the north end of it does not point toward the north geographical pole as was at first supposed but toward a point in the southwestern part of

LINES OF EQUAL MAGNETIC DECLINATION IN THE UNITED STATES.

Boothia Felix which is called the *north magnetic pole.* The south magnetic pole as recently determined is a little to the east of Victoria Land.

These magnetic poles do not remain in the same place all of the time but swing slowly back and forth, so that the declination changes for the same place. On account of this it is necessary for surveyors, who use the compass, to find out the declination each year. The annual change in the United States varies from 0 to 5 seconds. In 1910 the declination at Eastport, Maine, was 19.4° west and for Seattle, Washington, 23.5° east. For intervening places there were intervening values. Maps are now made with lines upon them connecting places of equal declination. These lines are called *isogonic lines*.

18. **Magnetism.** — **Experiment 11.** Having pushed a long cambric needle through a small disk of cork so that it will float horizontally, carefully place the disk and needle upon the quiet surface of a



Region around the Magnetic Pole.

large dish of water. Does the needle assume any definite direction? Taking the needle from the water stroke one end of the needle from the cork out with the north end of a magnet and the opposite end with the south end of a magnet. When the needle is again floated on the water is it indifferent about the direction in which it points? What has caused the change, if there is any?

Experiment 12. — Suspend by a string a short bar magnet in a sling made from a bent piece of wire. Turn it around in several different directions. After each change allow it to come to rest in whatever position it will. Does it prefer any one position to all others?

Experiment 13. — Suspend a bar magnet horizontally in a sling and bring one of the ends of another bar magnet toward it. What is the effect? Reverse the ends of the magnet; is there any change in the position of the suspended magnet? Bring a large soft iron nail toward either end of the suspended magnet. What is the effect? Reverse the ends of the nail. (Be careful that the nail has not become permanently affected by the magnet.) Is the effect the same as when the ends of the magnet were reversed?

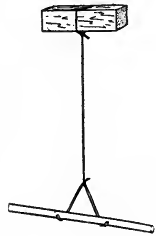


Fig. 13.

Bring pieces of copper, zinc, and other substances toward the magnet. Do these affect it? Notice that the ends of the bar magnet are marked. What can you state about the attraction or repulsion of similar ends of magnets? Of opposite ends? Does it make any difference in its effect on the suspended magnet toward which end the nail is brought? What substances do you find attracted by the magnet?

To the end of a small nail hanging by attraction to a magnet bring another nail. How does the first nail act in respect to the second?

So much were some of the ancients impressed with the property of loadstones for attracting iron that one of them suggested building a great arch of this material in a temple so that the iron statue of the goddess would remain suspended in the air without resting upon any support. There is an old legend that the iron coffin of Mohamet rose and remained near the ceiling of the mosque in which it was buried.

It was early discovered that when pieces of steel were rubbed on a loadstone they took on the properties of the loadstone and become *magnets*. In the experiments with magnets, it was found that like poles repelled and unlike poles attracted, and that iron or steel in contact with a magnet becomes magnetized. Iron and steel are practically the only substances attracted by a magnet, although nickel and cobalt and a few other substances have a little attraction. Thus steel and iron are always used for magnets.

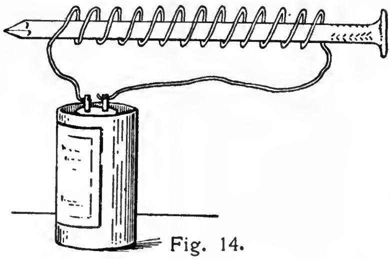


Fig. 14.

Experiment 14. — Wind twenty feet of No. 20 insulated copper wire around the nail used in Experiment 13 as you would wind thread on a spool. Attach one end of this wire to each pole of a dry cell. Bring the nail thus arranged toward a suspended magnet. Reverse the ends of the nail. Does the nail act as it did before it was placed within the coil of wire connected to the battery? Bring another nail in contact with its ends. What happens? What has the nail as arranged become? Disconnect one of the wires from the battery and try the test again. Does the nail act as it did when the battery was connected?

Magnetic Crane.
The electromagnet is lifting tons of scrap iron.

We found that if a nail is placed in a coil of wire connected with an electric battery it becomes magnetic, but only as long as the connection is maintained. Magnets of this kind are called *electromagnets.* If the nail had been hard steel and the battery exceedingly strong, the steel would have remained a magnet after being taken out of the coil.

Magnets are at the present time ordinarily made by electrical action and not by rubbing on other magnets. Magnetized steel bars are called *permanent magnets*. Electromagnets have become of almost inestimable use in modern life. The telegraph, telephone, magnetic crane, electric motor, and almost innumerable other mechanical devices are dependent largely upon the principle of electromagnetism for their usefulness.

19. The Magnetic Field of Force. — **Experiment 15.** — Place a thin piece of cardboard about the size of a sheet of writing paper above a bar magnet and carefully sprinkle iron filings over it. Describe the behavior of the filings. Sketch on a piece of paper their arrangement. Move a small compass about above the cardboard and note the directions the needle assumes. How do the actions of the needle and of the filings compare?

Holding the small compass two or three inches above the magnet move it parallel with the magnet from end to end. Gently tap the compass occasionally so that the needle will move freely. How does the needle act when it is over the ends of the magnet? How does the direction of the compass needle compare with the direction of the bar magnet?

In the above experiment we found that when iron filings were sprinkled above the magnet they arranged themselves in definite lines. The small compass needle also arranged itself along these lines when brought under the influence of the magnet. There is, then, around a magnet a magnetic *field of force* which affects magnets and magnetic substances brought within it. It is found that magnetic intensity, like the intensity of sound and light, varies inversely as the square of the distance.

When the compass was placed above the ends of the bar magnet one of the ends of the needle was pulled down toward the magnet, or it might be said to *dip* toward the magnet. When moved near the middle of the magnet it assumed a horizontal position, and when it approached the opposite end of the magnet the opposite end of the needle dipped. This same action is found when a magnetic needle is carried from north to south upon the earth. If a needle is carefully balanced and then magnetized, it will be found no longer to assume a horizontal position.

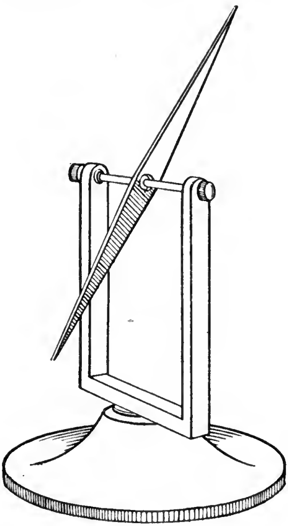


Fig. 15.

In the northern hemisphere the north end will dip and in the southern hemisphere the south end. In the northern hemisphere it is customary to make the south end of the needle a little heavier so that it will stay in a horizontal position. At the magnetic pole the needle would stand vertical. If a needle is accurately balanced on a horizontal axis and then magnetized, it will show the angle of dip in any locality. Such a needle is called a *dipping needle* (Fig. 15).

20. The Mariner's Compass. — In the ordinary mariner's compass a magnetic needle is arranged so that it will swing freely in a horizontal plane. A circular card is divided into four equal parts the dividing lines of which are marked with the cardinal points of the compass, the intervening spaces being divided into eight equal divisions. The card is attached to the needle and inclosed in a box called the *binnacle*. This box is arranged so that it will always remain horizontal.

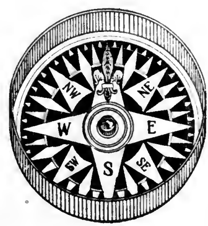


Fig. 16.

A fixed line on the binnacle shows the direction of the keel of the ship. The card being attached to the needle always has its "north" pointing toward the north. To determine the direction of the ship it is only necessary to notice on the card in what direction the keel line is pointing. The mariner of course must know the declination at the place where he is and make the proper corrections. The different governments furnish tables and charts showing these corrections.

21. Theory of Magnetism. — **Experiment 16.** — Heat a No. 20 knitting needle red hot and plunge it quickly into cold water. This tempers the needle so that it will break readily. Magnetize the needle as was done in Experiment 11. When it has become well magnetized, break it in the middle. Test each half with a suspended magnet, as was done in Experiment 13. Is each half a full magnet or only half a magnet? Break these halves again and test. What effect does breaking a magnet have upon the magnet?

In Experiment 16 it was found that if a magnet is broken in two, each half is a perfect magnet. If these halves are broken, each piece is a perfect magnet, and so on as long as the division is kept up. It is also found that if a magnet is heated or suddenly jarred or pounded it loses its magnetism. If a magnet is filed into filings and these filings are put into a glass tube the tube will have no magnetic properties but will act to a magnet like an ordinary iron bar.

If now the tube is held vertically and tapped several times on a strong magnet, the tube will be found to have acquired the properties of a magnet. The tapping joggled the particles so that they could arrange themselves under the influence of the magnetic pole and when they became so arranged a magnet was the result. If the filings are now poured out of the tube and then put back again, there will be no magnetization.

It was the arrangement of the tiny magnetized particles which must have caused the contents of the tube to become magnetic. It would therefore seem probable that magnetism must be a property of the exceedingly small particles or *molecules* of which the iron or steel as well as all other substances are supposed to be composed.

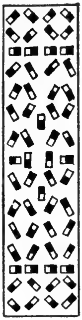


Fig. 17.

It is supposed that when a bar of steel becomes magnetized the molecules arrange themselves in definite directions, as do the filings in the tube. The molecules of magnetic substances are supposed to be separate little magnets. In the unmagnetized bar (Fig. 17) their poles point in all directions dependent upon their mutual attraction, and thus they neutralize each other. When the bar becomes magnetized the molecules tend to arrange themselves so that like poles lie in the same direction (Fig. 18). When the magnet is heated or jarred the molecules are moved out of this alignment and the magnetism is weakened.

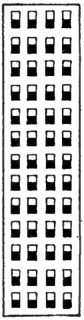


Fig. 18.

Summary. — The shape of the earth is spherical with very slight flattening at the poles. Its diameter is almost 8000 miles, more than four times the distance from New York to Denver; and its circumference is nearly 25,000 miles. Though the irregularities of the earth's surface are exceedingly small in comparison with its total area, they are great enough to have a vast effect upon the life of animals and plants.

The revolution of the earth upon its axis causes day and night, and gives us our measurement of time and our points of the compass. The movement of the earth around the sun, combined with the inclination of the earth's axis, gives us the seasons. The inclination of the earth's axis, combined with its revolution, and the movement just mentioned, gives us our latitude zones and causes the variation in the length of our days and nights.

Direction east and west on the earth is measured by meridians of longitude; direction north and south by parallels of latitude. There is about seventy miles between the different parallels and also between the different meridians at the equator. There is about the same distance between the parallels all the way to the poles, but as the meridians extend north and south, the distance between them grows less and less till they all meet at the poles.

To find the location of a ship at sea we use a compass, a magnetized needle which points toward the north magnetic pole, located northeast of Alaska. Thus, the magnetism of the earth is of infinite value to ocean commerce.

Questions

What simple reasons are there for believing that the earth is round?

What effects have the irregularities of the earth's surface had on life?

Draw diagrams illustrating what was discovered in Exp. 8.

Why do we have winter when the earth is nearest the sun?

If a man left Cairo, Egypt, on June 21 and traveled slowly to Cape Town, reaching there on Dec. 21, what changes of seasons would he experience?

How is the length of a day determined? If it were noon Thursday, Sept. 30, with you, what would be the day and date at Yokohama?

Why is Standard Time particularly advantageous in the United States? How much is the difference between local and standard time at your locality?

Suppose that a man at the north pole traveled a degree south and then a degree east. How far would he travel? Suppose he were a degree north of the equator and traveled a degree south and then a degree east. How far would he travel? In both cases he traveled a degree of latitude and a degree of longitude. Do the distances differ? If so, why?

If it is 12 o'clock local time at your home, what time is it at Paris? At Honolulu?

What practical advantages and applications of magnetism do you know?

Why is it necessary for a mariner to know the *declination?*

CHAPTER III

THE GIFTS OF THE SUN TO THE EARTH

22. Energy. — The capacity for doing work, for overcoming resistance, for causing change, is called *energy.* If the position of a body or its composition is such that it can exert force or overcome resistance, its energy is called *potential.* If the body is actually moving, it is said to have *kinetic* energy.

When a pendulum bob is pulled aside and held higher than the lowest point of its arc, it has potential energy. If it is allowed to swing, it will change this potential energy into kinetic. The potential energy it had when at its highest point is changed into the same amount of kinetic energy when it reaches the lowest point in its swing.

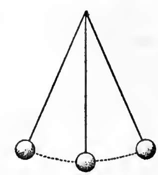


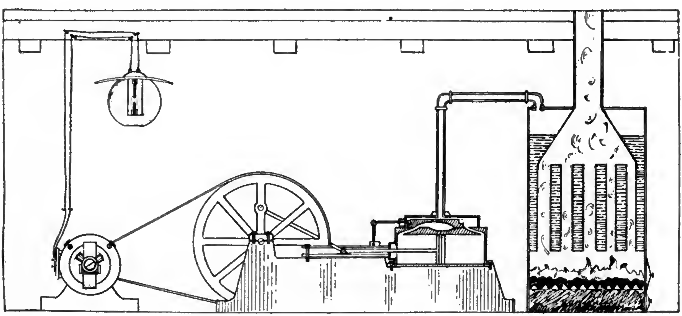
Fig. 19.

When a gun is loaded the powder has potential energy due to its composition, but when it explodes this is changed into kinetic energy which is imparted to the bullet. The smallest possible piece of nitroglycerine has potential energy on account of the arrangement of its molecules, and this is capable of being readily changed into kinetic energy.

The sun throughout its existence has been sending vast quantities of energy to the earth. This energy has been mostly in the form of heat and light. The ability of the earth to support plant or animal life or to furnish man the power necessary to carry on his industries is due to the energy furnished by the sun. Plants cannot grow without the energy furnished by the sunlight, and animals could not live were it not for the energy furnished them by the plants.

For untold ages plants utilized the sun's energy and stored it up. It was preserved in the remains of plants in the form of coal. This coal is now being burned to furnish power to carry on man's industries. The water which the sun has evaporated and carried by cloud and shower to the mountain lake is stored there and has potential energy. It is ready to run down the valleys changing its potential energy into kinetic and doing work. We often think that there are many different sources of energy such as wood, coal, oil, waterpower and others, but when these are traced back, their energy is found to have come from one source, the sun.

Energy may readily be changed into different forms, as when the steam engine transforms the energy in coal into



TRANSFORMATION OF ENERGY.

mechanical energy, or when this mechanical energy is changed by the dynamo into electrical energy. The most careful investigations have shown, however, that although its form may change, energy can never be destroyed.

Mechanical energy frequently changes into heat, as when two surfaces are rubbed together, but when these two kinds of energy are carefully measured there is found to be no loss. This great truth has been determined by a vast amount of most careful investigation and is called the *law of conservation of energy.*

23. Heat and Light. — Every one realizes the importance of the heat and light given to the earth by the sun. If plants or animals are where light is entirely excluded, they begin to sicken and die. If they are placed where it is very cold, they freeze and die. Although the sun gives both heat and light, yet these two are not inseparable. We feel the heat given out by boiling water but there is no light, and we see the light of the moon but there is no heat. We usually say that we feel heat but cannot see it and see light but cannot feel it.

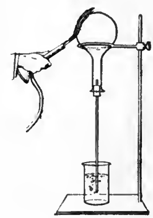


Fig. 20.

24. Heat. — **Experiment 17.** — Fit a glass flask with a one-hole rubber stopper through which passes a glass tube about 20 cm. long. Place this on a ringstand so that the end of the tube extends down into a bottle nearly filled with water. Gently heat the flask. The air expands and bubbles rise in the water. When the flask cools, the air contracts and water rises in the tube.

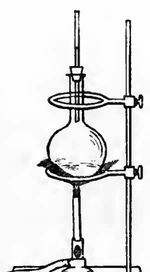


Fig. 21.

Experiment 18. — Fill the flask used in the last experiment with colored water. See that the end of the glass tube passing through the rubber stopper is just even with the bottom of the stopper. Smear the lower part of the stopper with vaseline and insert it in the flask, being careful that the flask and a few centimeters of the tube are filled with colored water and that there are no air bubbles in the flask. Mark, by slipping over a rubber band, the end of the water column in the tube. Heat the flask. The water expands. Why do water heaters always have a pipe at the top leading to a tank?

Experiment 19. — Pass the ball of a ball-and-ring apparatus through the ring. Notice how closely it fits. Heat the ball in a Bunsen flame for several minutes. See if the ball will now go through the ring. Explain why it does not.

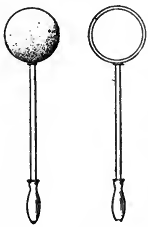


Fig. 22.

Experiment 20. — Heat a metal compound-bar. It bends over on one side. The more the bar is heated the more it bends. The two metals do not expand at the same rate. Why are the ends of steam pipes allowed to be free and not attached firmly? Why are the ends of the spans of long iron bridges placed on rollers? When iron tires are fitted to wheels they are heated and then placed on the wheels and allowed to cool. Why? Platinum is the only substance that can be used to pass through the glass in an incandescent lamp. Other metals do not expand the same as glass and when they are fused with it and allowed to cool they break it.

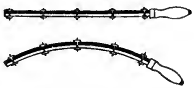


Fig. 23.

When heat was first studied it was thought to be an invisible fluid without weight which worked itself into bodies and caused them to expand in the same way that water affects a sponge or a piece of wood. This fluid was supposed to be driven out by pounding or rubbing. Even the primitive savages knew that fire could be obtained by rubbing two dry sticks together.

About the close of the eighteenth century an American, Count Rumford, who was boring some cannon for the Bavarian government, showed that the amount of heat developed seemed to be entirely dependent upon the amount of grinding or mechanical energy expended. The old theory of a fluid prevailed however until about the middle of the nineteenth century, when a great English experimenter by the name of Joule showed conclusively that the amount of heat developed was due entirely to the amount of mechanical energy which apparently disappeared into the heated body.

Every kind of matter is now believed to consist of little particles, or *molecules*, which are constantly moving about hitting and bumping against each other in the spaces which exist between them. The fact that minute invisible particles may be given off by a substance is readily shown by opening a bottle of ammonia or exposing a piece of musk in a room. Soon in every part of the room the presence of these substances can be recognized by the odor. Yet nothing can in any possible way be seen to have been added to the air.

The molecules are too small to be seen by the most powerful microscope. There are millions of them in a particle of matter as big as the head of a pin. When a substance is heated the molecules move more rapidly and strike each other harder. This causes the substance to expand. Heat is defined as being the motion of these molecules. If a condition could be reached where there was no molecular motion, there would be no heat. The effect of heat in causing expansion of gases, liquids and solids has been shown in the preceding experiments.

25. **Measurement of Temperature.** — From the experiments it has been seen that gases, liquids and solids expand when heated and contract when cooled. It has been found that most substances expand uniformly through ordinary ranges of temperature, so that if this expansion or contraction is measured, we are able to determine the change of temperature.


Fig. 24.

Experiment 21. — Slightly warm the bulb of an air thermometer tube and place the open end in a beaker half filled with inky water. Allow the bulb to cool. The tube will become partly filled with the water. When the bulb has become entirely cooled mark the end of the water column with a rubber band. Grasp the bulb with the hand, thus warming the air in it. The water column will run partially out of the tube back into the beaker. Cool the bulb with a piece of ice or a damp cloth. The water will come farther up in the tube than it did when simply exposed to the air. We have here an apparatus for telling the relative temperatures of bodies.

Instruments arranged to show the amount of the expansion or contraction of certain materials due to changes in their temperature are called *thermometers*. These may be gas, liquid or metal thermometers. There must be some uniform temperatures between which the expansion shall be measured if we are to have a basis of comparison. These definite points have been taken as the freezing and boiling points of water at sea level.

Experiment 22. — Fill a four-inch ignition tube with mercury and insert a one-hole rubber stopper having a straight glass tube extending through it and about 20 cm. above it. It may be necessary to cover the stopper with vaseline to keep out air bubbles. When the stopper was inserted the mercury should have risen a few centimeters in the tube. Mark with a rubber band the end of the mercury column. Gently warm the ignition tube. The mercury column rises. Cool the tube and the column falls. We have here a crude thermometer.

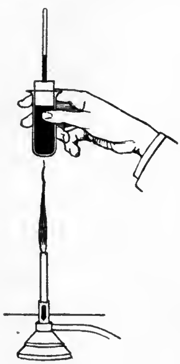


Fig. 25.

The substance whose expansion is most commonly used to measure the degree of temperature is mercury. This expands noticeably for an increase in temperature and the amount of its expansion can be very readily determined. The ordinary thermometer consists of a glass tube of uniform bore which has a bulb at one end. The bulb and part of the tube are filled with mercury. The remaining part of the tube is empty, so that the mercury can freely rise or fall. When the temperature rises, the mercury expands and rises, when the temperature falls, the mercury contracts and sinks.

There are two kinds of thermometer scales commonly used. In one, the point to which the mercury column sinks when submerged in melting ice is marked 32°, and the point to which it rises at sea level when immersed in unconfined steam, the boiling point, is 212°. The distance between the boiling and freezing points is divided into 180 equal parts. Each one of these parts measures a *Fahrenheit* degree of temperature. This is the common household thermometer of this country and England.

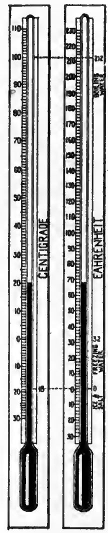
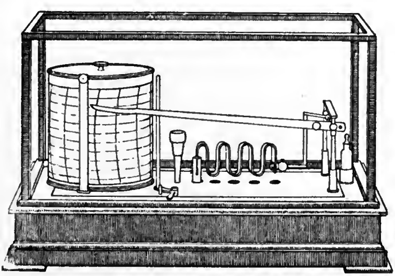


Fig. 26.

Another kind of thermometer scale, which is used almost exclusively in scientific work and in those countries where the metric system of weights and measures has been adopted, is called the *Centigrade*. In this scale, the point at which ice and snow melt is marked 0 and the point at which water boils, 100. A degree Centigrade then is $\frac{1}{100}$ the distance the column expands when heated from freezing to boiling, instead of $\frac{1}{180}$ of this distance as in the Fahrenheit scale. There are a number of different designs of thermometers. Some are for measuring very high, others for measuring very low, temperatures. Thermometers are also constructed so as to be self-recording.


THERMOGRAPH.
This device makes a continuous record of the temperature for a week at a time.

26. The Three States of Matter. — There are three states or conditions in which substances exist: solid, liquid and gas. Examples of these are: the solid metal ball, the liquid water, the liquid metal mercury, and the gaseous air. These have already been dealt with experimentally. Almost every one knows that water is a liquid, or a solid, ice, or a gas, steam, depending only on the temperature to which it is subjected. It is not so generally known that the state of all other substances depends also upon their temperature.

Many substances are capable of existing in all three states. Iron, for instance, may be solid as we ordinarily see it, or liquid as it comes from a blast furnace, or a gas, as it exists in the tremendously hot atmosphere of the sun. Substances usually expand in volume as they change from the solid to the liquid state and they always do as they change from the liquid to the gaseous. Ice is a notable exception to the general rule, since when water freezes its volume increases. If it were not for this, ice would not float. Metals that are suitable for casting must have the property of expanding when cooling or at least of shrinking but a trifling amount. This is a most valuable property of type metal and cast iron.

27. The Transference of Heat. — **Experiment 23.** — Cut off 15 cm. of No. 10 copper and No. 10 iron wire and the same length of glass rod of about the same diameter. Holding each of these by one end place the opposite end in the flame of a Bunsen burner. Which of the three conducts the heat to the hand first?

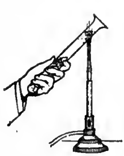


Fig. 27.

Experiment 24. — Fill a test tube about $\frac{3}{4}$ full of cold water. Holding the tube by the bottom carefully heat the top part of the water until it boils. Be sure that the flame does not strike the tube above the water, else the tube will break. A little piece of ice in the bottom of the test tube makes the action more apparent. A bit of wire gauze or a wire stuffed into the test tube will prevent the ice from coming to the surface. Water conducts heat poorly. The hot water does not sink. It must be lighter than the colder water.

Without the heat of the sun there would be no life upon the earth, no flowing streams, no changing winds, none of the restless energy which makes the world as we know it. It is therefore essential to understand how heat is transferred from one place to another.

Through solid substances, such as metals, heat travels quite readily, through others such as glass, less rapidly. In Experiment 23, we found that heat traveled along some rods faster than it did along others. In no case, however, was there any indication that there was a transference of the particles composing the rods. In the boiling of the water at the top of the test tube, there was no indication that the water particles moved to the bottom of the tube. In these cases, the heat is simply transferred from molecule to molecule.

This kind of heat transference is called *conduction.* Conductors may be good or bad, as was shown by the different materials used in the experiments. We use iron for our radiators so that the heat of the steam may readily be given out to the room, and we cover our steam pipes with asbestos when we wish to retain the heat, because asbestos is a poor conductor and will keep the heat in the pipes.

Experiment 25. — Hold a piece of burning paper under a bell jar held mouth downward. Notice the air currents as indicated by the smoke. Paper soaked in a moderately strong solution of saltpeter and dried burns with a very smoky flame.

Fig. 28.

Experiment 26. — Fill a 500 cc. round-bottomed flask half full of water and place on a ring stand above a Bunsen burner. Stir in a little sawdust. Some of it should fall to the bottom of the flask. Gently heat the bottom of the flask. Notice the currents.

When the water was heated at the bottom of the flask and when the burning paper was held under the bell glass, currents were seen to be developed. The heated and expanded water and air rose. Here the heat was transferred by the upward movement of the heated water and air. This method of heat transference is known as *convection*. The efficiency of the hot water and hot air furnaces which heat our houses is due to the convectional transference of heat. We shall find later that if it were not for convection there would be no winds or ocean currents.

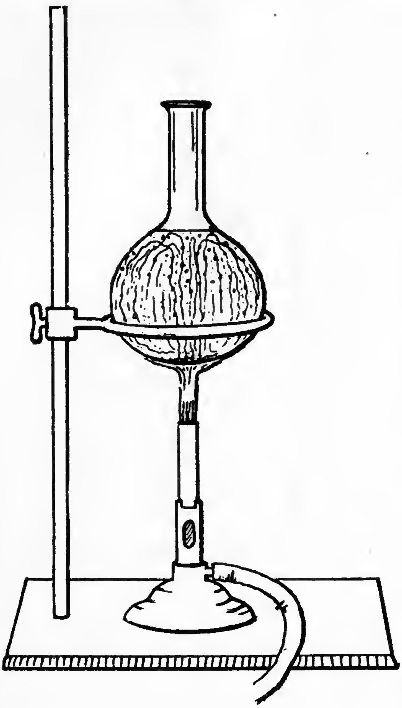
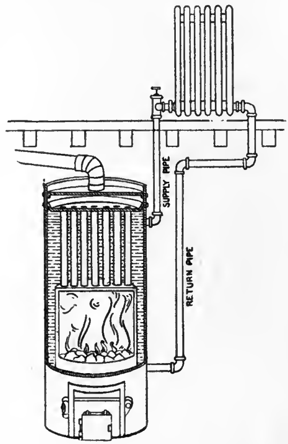


Fig. 29.

If an incandescent electric lamp is turned on and the hand held immediately below the lamp, it will be warmed, although the glass bulb itself, a poor conductor of heat, remains cool. The white-hot filament is surrounded by an almost perfect vacuum. It can set up no convection currents, neither does the cool glass. The sensation of heat cannot be due to conduction because the air which surrounds the bulb is not in contact with the filament. It is also a poorer conductor than glass and the glass itself does not become hot for some little time.

There must therefore be another mode of transferring heat beside conduction and convection. It also appears that in this method of transferring, no material substance is necessary, as the hot filament is surrounded by an almost perfect vacuum. Now astronomers tell us that there is no material medium between our atmosphere and the sun and that the heat of the sun travels to us with the tremendous speed of light, 186,000 miles per second, and does not warm the intervening space. The convection and conduction processes are, when compared to this, very slow. *Radiation* is the name given to this method of heat transference. If heat did not travel in this way the earth would be uninhabitable.



Hot Water Furnace.
The hot water rises from the top, passes through the radiator and returns as colder water to the bottom.

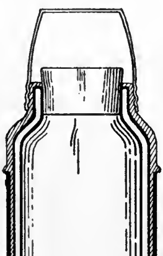


Fig. 30.

If a body, heated to ordinary temperatures, is surrounded by substances which do not readily permit of conductional or convectional heat transference, the heat is retained within the body. Application of this is made in the fireless cooker and the thermos bottle (Fig. 30). In one, the hot substance is surrounded by felt, wood fiber, asbestos or similar nonconducting substances, and in the other by glass and a space from which the air has been nearly exhausted.

Both of these arrangements prevent the transference of heat from the hot body. The cooking therefore continues in the fireless cooker and the liquid in the thermos bottle remains warm for a long time or, if cold when put into the bottle, it remains cold, as the heat from the outside cannot reach it. Clothing is placed upon the body in order to prevent the body heat from being conducted to the surrounding air.

28. The Measurement of Heat. — **Experiment 27.** — In each of two beakers or tin cups weigh out 100 g. of water. Carefully heat one of the beakers until the water when thoroughly stirred shows a temperature of 90° C. Cool the other beaker till the temperature of the water is 10° C. Pour the water from one beaker into the other, and after thoroughly stirring note the resulting temperature. Use a chemical thermometer to determine the temperatures.

Weigh out 100 g. of fine No. 10 shot in a tin cup and 100 g. of water in another. Place the cup containing the shot in boiling water and allow it to remain, stirring the shot occasionally, until its temperature is 90° C. Cool the water in the other beaker until its temperature is 10° C. Determine the temperatures exactly and then pour the shot into the water. After thoroughly stirring determine the temperature of the mixture. Which has the highest temperature, the mixture of water and water or the mixture of shot and water?

Since heat plays such an important part in the activities of the earth we need to know how to measure it. There is a great difference between temperature and the amount of heat. The amount of heat in a spoonful of water at 100° would be very much less than in a pailful of water at 10°. It would require more heat to raise a pond of water a small part of a degree than to raise a kettleful many degrees. That is why large bodies of water, although their temperatures never greatly change, exert so much influence upon the temperature of the surrounding air.

Not only does the amount of heat necessary to raise the temperature of different quantities of the same substance vary, but the amount of heat necessary to raise the temperature of equal quantities of different substances also varies. If a pound of water and a pound of olive oil were placed side by side in similar dishes on a stove, it would be found that the olive oil increases in temperature about twice as fast as the water, *i.e.* it takes about twice as much heat to raise water as it does to raise the same weight of olive oil one degree. In fact, it takes more heat to raise a given weight of water one degree than it does to raise the same weight of almost any other known substance.

In Experiment 27, the resulting temperature from the water mixture was much higher than from the shot mixture. The shot has much less capacity for heat. The quantity of heat required to raise the temperature of a certain mass of a substance one degree compared to the quantity of heat required to raise the same mass of water one degree is called the *specific heat* of that substance. The specific heat of olive oil is .47, of shot .03. That is it takes .47 as much heat to raise a given mass of olive oil and .03 as much heat to raise a given mass of shot one degree as it does to raise corresponding masses of water one degree. In order to compare different quantities of heat, physicists have taken as the unit of measure the quantity of heat required to raise the temperature of one gram of water through one degree C. This unit is called a *calorie*.

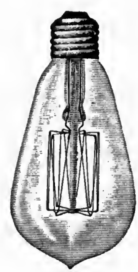


Fig. 31.

29. Light. — The sun is not only the source of almost all the heat of the earth but also of its light. We have developed artificial self-luminous bodies such as candles, lamps, electric lights, but none of these compares with the light given by the sun. The stars also furnish a little light. Most of the bodies that we know are dark and non-luminous. Sometimes some of these which have polished surfaces reflect the light from a luminous body and thus appear themselves to be furnishing light.

An example of this is often seen about sundown when the sunlight is reflected from the windows of a house, making them look as if there were a source of light behind them. Any dark body whose surface reflects light appears itself to be luminous as long as the source of light remains, but grows dark again when the source is removed. This is the case of the moon. At new moon, the moon is so situated with respect to the sun, that light is not reflected to the earth and we cannot see it. At full moon, half of the moon's entire surface reflects the sunlight, and it appears very bright.

30. Direction of Light Movement. — **Experiment 28.** — Point the pinhole end of a camera obscura or pinhole camera (this consists of two telescoping boxes, the larger having a pinhole at the end and the smaller a ground glass plate) at some object and move the ground glass plate back and forth until a sharp image of the object is formed. Sketch on a piece of paper the object and the image, showing the direction in which you think the rays of light must have traveled through the pinhole to form the image.

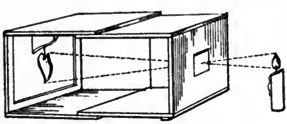
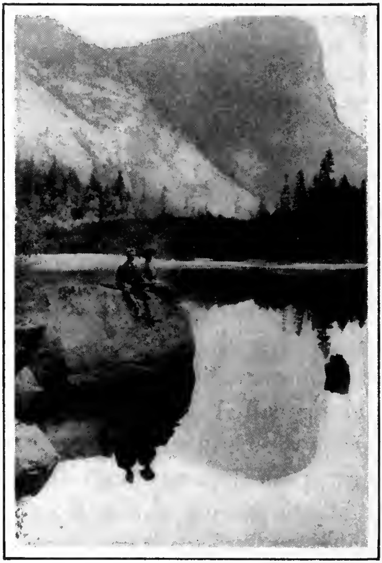


Fig. 32.

A photographic camera is constructed in the same way as this little camera, only a lens is placed behind the pinhole to intensify the image, and it is possible to exchange the ground glass plate for a photographic plate.

There are certain properties of light which seem readily apparent from our daily experiences. We cannot see objects in the dark, but if a light is brought into the room so that it can shine upon them, they become visible. We see them because the light is reflected to us from them. All objects except self-luminous bodies are seen by reflected light.

If a candle is held in front of a mirror and we look into the mirror, we see the candle behind it. We know that the candle is not there but that its light is reflected by the mirror in such a way as to make it appear to come from behind the mirror. We see the candle by the light the mirror reflects.



A LAKE MIRROR.

If we wish to see whether the edge of a board is straight, we sight along it. If we wish to hit an object with a bullet, we bring the rifle barrel into our line of sight. We therefore feel confident that if light is traveling through a uniform medium, such as air usually is, it goes in a straight line.

Experiment 29. — Place a penny in the center of a five-pint tin pan resting on a table. Stand just far enough away so that the outer edge of the penny can be seen over the edge of the pan. Have some one slowly fill the pan with water. How is the visibility of the penny affected?

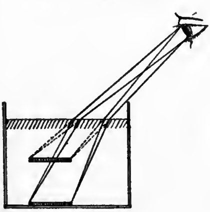


FIG. 33.

Experiment 30. — Fill a battery jar about two thirds full of water. Place a glass rod or stick in the jar. Does the rod appear straight? Pour two or three inches of kerosene on the top of the water. What effect does this have on the appearance of the rod?

Experiment 31. — Hold an ordinary spectacle lens such as is used by an elderly person, or any convex lens, between the sun and a piece of paper. Vary the distances of the lens from the paper. The heat and light rays from the sun are bent so that they converge to a point. Try the same experiment with a lens used by a short-sighted person, or a concave lens. This lens does not have the same effect as the convex lens. The rays are made to diverge. Why cannot long-sighted and short-sighted persons use the same glasses?

In the experiment of the penny in the dish, the water in some way bent the ray of light and made the penny come into the line of sight when it could not be seen before the water was there. This experiment shows that when light is passing from one medium to another it does not always travel in the same straight line. Certain media offer more resistance to the passage of light than others and are called *denser* media. It is this resistance which causes the bending of the ray.

Suppose that a column of soldiers marching in company front are passing through a corn field and come obliquely upon a smooth open field. The men as they come on to the open field are unincumbered by the cornstalks and will move faster, and thus the line of march will swing in toward the edge of the corn field. It can easily be seen that the bending of the line would be in the opposite direction if the soldiers were marching from the smooth field into the corn field. If the company front was parallel to the edge of the corn field, then the men would reach the open field at the same time and there would be no swinging of the line.

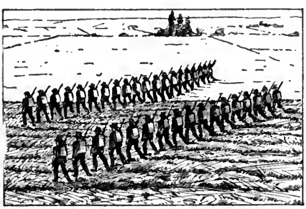


Fig. 34.

The above illustration roughly explains what happens when light passes from one medium to another. *Refrac-*

tion is the name given to this bending of light in passing through different media or through a medium of changing density. Twilight, mirage, the flattening of the sun's disk at the horizon and other appearances we shall find later are due to this property of light.

31. The Intensity of Light. — **Experiment 32.** — Take two square pieces of paraffin about an inch thick, or better two squares of parawax, and place back to back with a piece of cardboard or tinfoil between them. When a light is placed on either side of this apparatus the wax toward the light will be illuminated, but not that on the other side of the cardboard. If lights are placed on each side, it is easy to see when both pieces of wax are equally illuminated, or receive the same amount of light. In this way the strengths of lights can be compared.

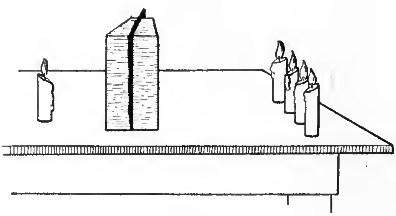


Fig. 35.

Place a candle about 25 cm. in front of one side of this apparatus, and 4 candles, placed close together on a piece of cardboard so that they can be readily moved, about 90 cm. away on the other side. Move these candles back and forth till a position is found where both pieces of wax are illuminated alike. Measure the distance of the four candles from the wax. How many times as far away are they than the one candle?

The brightness of the sun's light is so great that even an arc light placed in direct sunlight appears like a dark spot. So great, however, is the sun's distance that the earth receives only a minute portion, less than one two-billionth of the light and heat it gives out. It is impossible to express the greatness of this light in ordinary terms. The standard measure for intensities of light is the candle power. This is the light given out by a standard candle, which is practically our ordinary No. 12 paraffin candle. The ordinary incandescent electric light is sixteen candle power.

No comprehensible figures will express the intensity of the sun, using the candle power as a measure. The intensity of light, like that of heat and electricity, and all forms of energy which spread out uniformly from their point of origin, varies inversely as the square of the distance from the source. This rapid decrease in the brightness of light

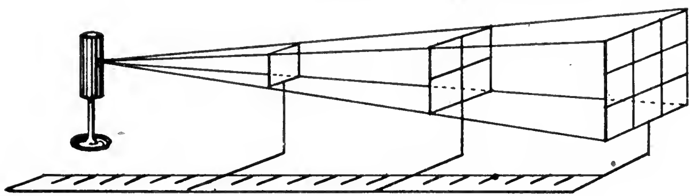
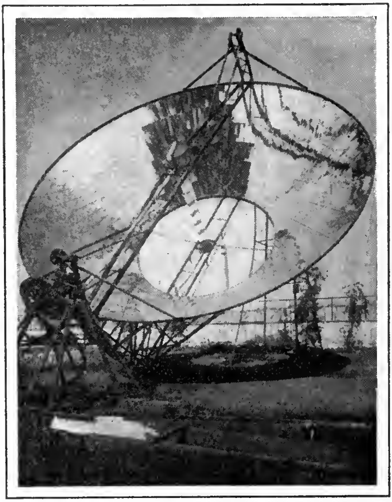


Fig. 36.

as the distance increases is the reason why so small a change in the distance of a lamp makes so great a difference in the ease with which we can read a book. If we make the distance to the lamp half as great, we increase the amount of light on the book four times (Fig. 36).

32. Reflection of Heat and Light. — **Experiment 33.** — In a darkened room reflect by means of a mirror, a ray of light from a small hole in the curtain, or from some artificial source of light, on to a plane mirror lying flat upon a table. If there is not sufficient dust in the air to make the paths of the rays apparent, strike two blackboard erasers together near the mirror. Hold a pencil vertical to the mirror at the point where the rays strike it. Compare with each other the angle formed by each ray with the pencil. Raise the edge of the mirror, and notice the effect on the reflected ray. Place the pencil at right angles to this new position of the mirror, and compare the angles in each case. How do the sizes of the angles on either side of the pencil compare?

It has already been stated that the moon shines by reflected light. It is a matter of common observation that objects on the earth reflect both heat and light. In the summer, the walls of the houses and the pavements of the streets sometimes reflect the heat to such an extent that it becomes almost unbearable. In countries where the sun shines brightly nearly all of the time, as in the Desert of Sahara, reflectors have been so arranged as to reflect the heat of the sun on to boilers and to run steam engines.



A REFLECTION ENGINE.

This engine used the rays of the sun instead of coal to heat its boiler.

The smooth surfaces of houses often reflect so much of the light falling upon them that the glare is thrown into the windows of surrounding houses into which the sun itself cannot shine. If one stands in the right position, the reflection of trees and other objects can be seen in a smooth lake. But the reflection cannot be seen if the position of the spectator is much changed. The reflected ray must therefore maintain a certain relation to the ray that strikes the surface from the object.

In Experiment 33, when the pencil was held perpendicular to the mirror at the point where the rays touched the mirror, it was seen that both the ray from the window and the reflected ray made about the same angle with it. These two angles are respectively called the *angle of incidence* and the *angle of reflection.* By most careful experimentation it has been found that the angles between each of these two rays, and the line drawn perpendicularly to the reflecting surface are always equal, or in other words *the angle of reflection is always equal to the angle of incidence.* This explains why, if you are standing in a room beyond one side of a mirror, you can see in the mirror only the opposite side of the room.

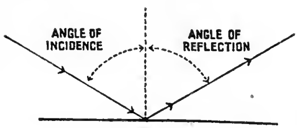


Fig. 37.

33. **The Speed of Light.**—In the latter part of the seventeenth century a Danish astronomer by the name of Rœmer, after carefully watching the brightest of Jupiter's satellites or moons as it revolved around the planet, noticed that the time of occurrence of its eclipses or passages behind the planet showed a peculiar variation. He accurately determined the interval between two eclipses or the time it took for a complete revolution of the satellite around the planet.

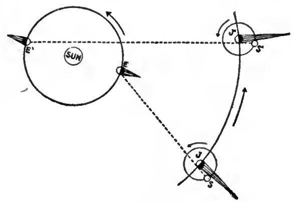


Fig. 38.

Using this interval he computed the time at which other eclipses should take place and found that as the earth in its revolution around the sun moved away from Jupiter the eclipses appeared to take place more and more behind time. Determining the exact time at which an eclipse took place when the earth was nearest to Jupiter, and computing the time an eclipse should take place six months later when the earth was farthest from Jupiter, he found that the actual time of the eclipse was 22 minutes behind the computed time. This slowness he said must be due to the time required by the light in crossing the earth's orbit.

Many determinations of this kind have been made since those of Rœmer, and it has been found that he was somewhat in error, as the time required by light in traveling across the earth's orbit is about 16 minutes and 40 seconds, or 1000 seconds. Since the diameter of the earth's orbit is about 186,000,000 miles the speed of light must be about 186,000 miles per second. Determinations of the speed of light have been made in several other ways with almost like results.

34. Theories Concerning Light. — Although it is very easy to perceive light and to examine many of its properties, yet to determine just what it is that produces the light sensation has been found vastly difficult. Sir Isaac Newton thought that light consisted of streams of very minute particles, or corpuscles, thrown off by the luminous body. Since about 1800, it has been considered a form of wave motion which is transmitted through the ether which fills all space.

35. Sound. — **Experiment 34.** — Arrange a large wide-mouthed bottle with a small bell suspended in it from the stopper and a delivery tube extending through the stopper. Attach the delivery tube by a thick-walled rubber tube to an air pump and exhaust the air from the bottle. Shake the bottle so that the bell can be seen to ring but does not strike the sides of the bottle. Can the sound be heard distinctly?

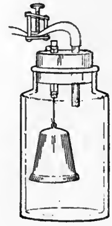


Fig. 39.

Although sound is not related to the sun's energy it seems best for certain reasons to consider it briefly in this place. In Experiment 34, it was found that if the air was exhausted and the bell did not touch the sides of the bottle, almost no sound was heard when the clapper of the bell showed that the bell was ringing. This shows that the sounds we usually hear are transmitted in some way by the aid of the air.

Sound has been found to be a wave motion in a material medium. If a scratch is made on the end of a long log, it can be heard if the ear is placed at the other end of the log, when it cannot be heard if the ear is away from the log. In this case the medium is the wood.

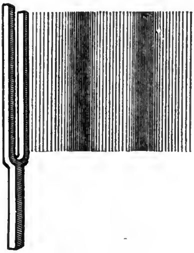


Fig. 40.

If a stone is dropped into a quiet pond, the rippling waves developed will extend often to the farthest shore of the pond, but a chip floating near where the stone fell will not be moved from its position except up and down. Thus the waves traveled outward from the point of origin, but there was no outward movement of the water. If a long rope, attached at one end and held in a horizontal position, is suddenly struck with a stick, a wave motion will travel along the rope from end to end, but the particles of the rope will simply move up and down. It is in a similar way to this that the sound waves travel, but the particles which transmit the sound only move back and forth through small distances.

Summary. — All *energy* upon the earth is due to the sun. There are two kinds of energy, kinetic and potential. Energy may be changed in countless ways but it cannot be destroyed.

Heat is a form of molecular energy. Heat is shown in changes in temperature and these are measured by *thermometers*, of which the Fahrenheit and the Centigrade are the commonest. Heat affects the state of matter: the same substance may be *solid*, *liquid* or *gaseous*, depending on the amount of heat to which it has been subjected. This is shown in ice, water and steam. Heat is transferred by *conduction*, *convection* and *radiation*. The unit for measuring the amount of heat is called the *calorie.*

Light moves at the almost unbelievable rate of nearly two hundred thousand miles a second. It goes straight except when passing at an angle through media of different densities. It is then *refracted.* Its intensity varies inversely as the square of the distance from the source. When light is *reflected* from any smooth surface like a mirror, the angle of reflection is equal to the angle of incidence.

Sound, like light, is a wave motion. But sound waves can travel through substances that shut out all light, and on the other hand light waves can travel through a vacuum that shuts out all sound. So the intensity of light or sound depends largely upon the medium through which it is conveyed.

Questions

Why would it be true to say that all artificial light is the sun's light?

Germany uses the Centigrade thermometer scale. If the temperature of Berlin is reported as 20° C. what would the corresponding temperature be in the thermometer scale generally used in the United States?

Why are iron and type metal better suited for casting than copper and zinc?

In what three ways is heat transferred?

Describe how you could prepare from the ordinary materials you have at hand a crude, inexpensive fireless cooker.

Ponds near the Great Lakes freeze entirely over. Why do not the Great Lakes freeze?

What experiences have you ever had illustrating *refraction?*

If a boy is reading two feet from a light and moves to a distance of eight feet, how much ought the light to be increased to enable him to read with the same ease?

When the sun is shining brightly, why is it hotter standing on a smooth pavement than on the grass?

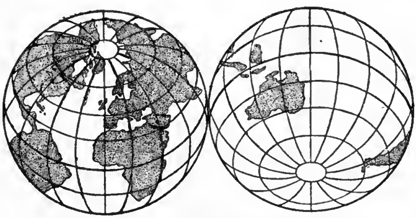
How long does it take light to come from the sun to the earth?

CHAPTER IV

THE EARTH'S CRUST

36. **Land and Water Areas.** — The surface of the earth has an area of about 197,000,000 square miles, about 28 per cent of which is land. Such areas are too vast for us to conceive, but it may help us toward a conception to know that the area of the United States, exclusive of Alaska and islands belonging to it, is about $\frac{1}{18}$ of the land area of the earth.

It is possible to divide the surface of the globe into two hemispheres, one of which contains the larger part of its land and the other the larger part of its water surface. This bunching of the land has brought the people of the earth near together and has greatly facilitated their intercourse, especially since land transportation has become so easy. Under the climatic conditions which exist, it is very advantageous also for the inhabitants of the earth that the greater part of the polar lands are around the north pole instead of the south. The fact that the land masses have irregular outlines and are separated by water areas instead of being in one continuous extent is also, as we shall see, of benefit to the earth's inhabitants.



LAND AND WATER HEMISPHERES.
Notice that London is about at the center of the land hemisphere.

37. **Interchange of Land and Water Areas.** — It has been found from numerous observations that the land and sea

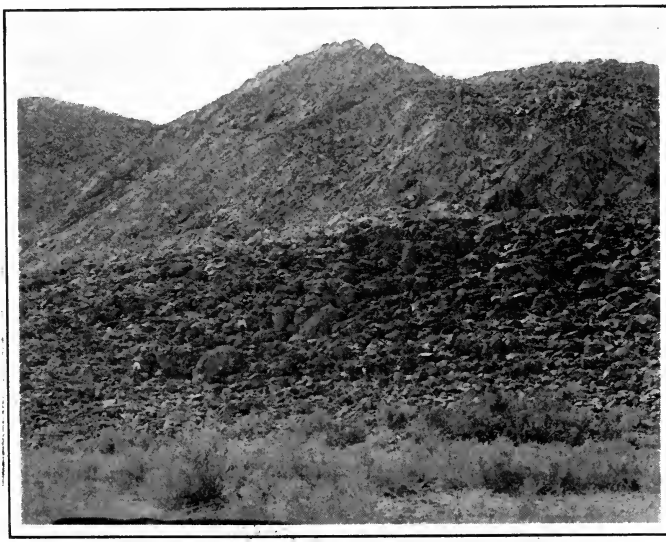
do not always maintain the same relation to each other. Areas which at one time were land have since become sea and those which were once sea are now land. Sea shells are found imbedded in the rocks far from the sea and old river valleys are found by soundings under the sea at considerable distances from the present mouths of the rivers. What were once sea beaches are now found hundreds of feet above the sea.

From some such marks on the coast of northern Sweden it appears that the coast has risen about seven feet during the last 150 years. The Netherlands are sinking. Observations along the coast of Massachusetts give reason to believe that it is sinking very slowly. Indications of the movement of the land in respect to the sea are found in all parts of the world.

Old Sea Beaches, San Pedro.
Three old beaches can be distinctly seen on the promontory.

Old sea beaches are found rising one above the other along the entire slope of a high hill at San Pedro, near the port of Los Angeles, California. Suess, the great Austrian geologist, thinks that the great changes of level between the sea and the land are due to a rising and falling of the sea and not a rising and sinking of the land. However this may be, there have been marked changes of level between the two and the boundary between sea and land has been a varying line. Sea and land areas have frequently interchanged, although deep sea bottoms were probably never dry land.

38. **Characteristics of Land Surfaces.** — The surface of the land differs from that of the sea in being at least com-



Old Rock Beach, Imperial Valley, California.
Formerly part of the coast line of the Gulf of California.

paratively immovable. It is rough and irregular, and is composed of many different kinds of rocks and soils. For the larger part of its area it rises above the level of the sea, but in a few places it sinks below, as in the Salton Sea, a part of Imperial Valley, California, and near the Dead Sea. Its surface is eroded by wind and water and is thus constantly but slowly changing its features. Travel upon the land, over most of the earth's surface, is difficult because of the irregularities.

SALT WORKS ON THE SHORE OF THE SALTON SEA.
In 1905 the Colorado River broke through into this depression, which is below sea level, and completely covered the salt works seen in the picture.

Surface conditions also vary greatly over small areas. Great temperature changes occur on the land between day and night and between summer and winter. Land animals must exert considerable muscular force to move about, yet they must all move to get their food. They must therefore be highly organized to maintain themselves upon the land. Water animals are not subjected to the same difficult conditions. In fact, the conditions of life on sea and land surfaces are entirely different.

39. Characteristics of Water. — **Experiment 35.** — Place in a dish of fresh water a density hydrometer, or stick loaded with lead at one end, so that it will float upright. Mark with a rubber band the point to which the hydrometer sinks in the water. In a dish sufficiently deep for the hydrometer to float dissolve a considerable quantity of salt in water. After the salt has become thoroughly dissolved taste the water at the top and then after pouring off the larger part of the water taste that at the bottom of the dish. The salt is present in all the water but the appearance of the water has not changed.

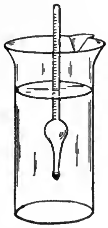


Fig. 41.

Now place the hydrometer in the water containing the dissolved salt. It does not sink to the same depth that it did in the fresh water. What can be said about the buoyancy of water which contains substances in solution? Does a fish need to exert muscular force to float in water? Since water contains many substances in solution, it is possible for a water animal that does not move to be continually supplied with food.

Experiment 36. — (Teacher's experiment). Place a small handful of zinc scraps in a strong wide-mouthed bottle. Fit the bottle with a two-hole rubber stopper having a thistle tube extending through one hole and a bent delivery tube through the other. The thistle tube should reach nearly to the bottom of the bottle. Connect the delivery tube with the shelf of a pneumatic trough by a rubber tube. Have several inverted 8 oz. wide-mouthed bottles filled with water on the shelf of the trough. Pour enough water through the thistle tube to partly cover the zinc and then pour on commercial hydrochloric acid or sulphuric acid diluted 1 to 10.

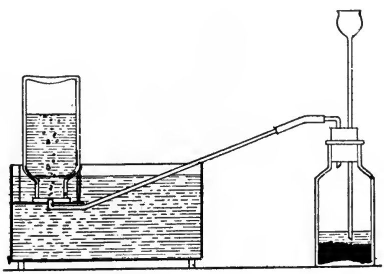


Fig. 42.

Chemical action will take place between the zinc and the acid and hydrogen will be freed. Allow the gas to escape for several minutes, as this is largely the air which was in the bottle. Collect several bottles full of the hydrogen. Keep the bottles inverted. Examine the hydrogen in one of the bottles. Has it color or odor? Holding the mouth downward thrust a lighted splinter into another bottle. The splinter does not continue to burn in this gas but the gas itself burns. Place another bottle mouth up on the table and allow it to stand for several minutes. Insert a lighted splinter. Why is not the hydrogen still present?

Draw out a glass tube so that the bore will be about as large as the point of a pencil and insert it in the rubber delivery tube. Pour more acid into the bottle and after this has been working for several minutes touch a lighted match to the glass tip of the rubber delivery tube. A jet of burning hydrogen will be formed. Hold a cold dry beaker over this burning jet. Water drops will collect in the beaker. The hydrogen is combining with the oxygen of the air and water is being formed.

Pure water is a chemical compound of two gases, hydrogen and oxygen. The oxygen we have always been familiar with, as it makes up about one fifth of the air by which we are surrounded. The hydrogen was prepared in the previous experiment. It is a colorless transparent gas, the lightest of all substances, and must be handled carefully. If it is mixed with oxygen or air and the mixture ignited, it explodes with much violence, forming water.

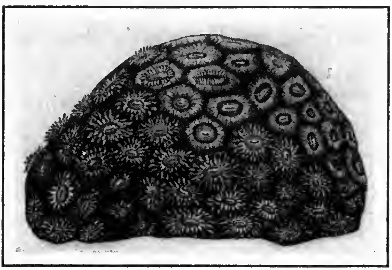
Experiment 37. — Fill a small beaker with fresh water. Heat it slowly. Bubbles collect on the bottom and sides. When the water becomes cold these bubbles do not disappear. If they were steam, they would change back to water. What are they? Where did they come from? Does water contain dissolved air? How can water animals that do not come to the surface obtain the air they need?

Experiment 38. — Put a piece of ice in water. What part of its volume sinks below the surface of the water? Is it heavier or lighter than water? From Experiment 24 do you conclude that cold water is heavier or lighter than warm water?

The water that we usually see has air and other substances dissolved in it, for water is the greatest solvent known. Another property of water which is very important is its practical *incompressibility*. No matter how much pressure may be put upon water its volume is little decreased and its density little changed. So it happens that substances which readily sink in the upper part of the sea sink to the bottom no matter how deep the water may be, as the bottom is so little denser than the top.

The substances that are dissolved in water mix thoroughly together. In isolated bodies of water there are often great differences in the amount and kinds of dissolved materials, but over the whole ocean from top to bottom the composition of the water is practically uniform.

From previous experiments we have learned some of the chief physical properties of water, so perhaps we can understand the different effects that water and land have had upon the development and activities of living things upon the globe. Some water animals move about easily to get their food, but others have it brought to them in solution and so obtain it without muscular effort. The air that they breathe is in solution and they cannot as easily obtain a large quantity of it as can the land animals. Since the energy of all animals depends upon the amount of oxygen they use in their bodies, the water animals are generally less energetic than the land animals. Since they also have such an easy time in moving or floating about to get the things they need they have not developed as high organisms as the land animals.



CORALS.

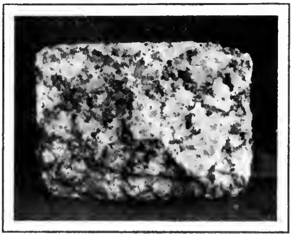
These are fixed animals whose food is brought to them in solution by the ocean currents.

Water is readily moved by the winds and becomes a means of cutting down the land and carrying away its material. When heated by the sun or any other source of heat it evaporates and, rising into the air, floats away to be condensed and to fall as rain or snow. It takes a great deal of heat to evaporate water and all this heat is given off when it condenses. Water seeks the lowest place it can find, giving out energy as it flows. In fact, the earth has been likened by some writers to a water engine, since water has played such an important part in its history.

Another property of water which is of great importance is its power to take up heat. This was shown in Experiment 27. When it cools, it gives out the heat it took up when its temperature was raised. It is for this reason that hot water bags are used to keep people warm, and that farmers sometimes in winter, when they fear that their cellars will freeze, carry down tubs of water to keep their cellars above the freezing point. This is why orange groves are often irrigated just before there is danger of a heavy frost.

A pound of water in cooling one degree gives out about as much heat as a pound of iron in cooling 9 degrees. This capacity for holding heat makes bodies of water warm up slowly in the summer and cool off slowly as winter approaches. As they cool they give back to the air the heat they have taken up. During the early part of the summer the air above them is kept cool and in the fall it is warmed. This property of water will be found later to be of great importance.

40. Materials Composing the Land. — **Experiment 39.** — Obtain specimens of the igneous rocks, lava, obsidian, basalt, granite; of the sedimentary rocks, sandstone, fossiliferous limestone, conglomerate, peat; of the metamorphic rocks, shale, schist, marble, anthracite coal. Examine these carefully with the eye and with the lens, noting whether they have a uniform composition or are made up of different particles. Are the particles composing the rocks crystalline? Are they scattered irregularly or arranged in layers? Test with a file or knife-blade the hardness of the rock as a whole and of its different constituents. Try a drop of hydrochloric acid on the different rocks to see whether they are affected by it. Describe in a general way the characteristics of each specimen.



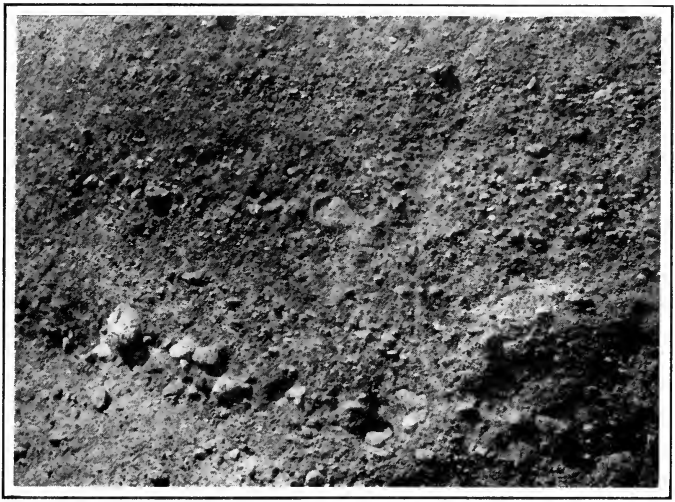
GRANITE.
Igneous rock formed deep below the surface of the earth.

The composition of different land areas varies greatly. Many different kinds of rocks are often found crowded together, or it may happen that the same kind of rock covers a large area. There is no uniformity. The soil on top of the rock is also variable. In some places it contains the minerals which are in the rock below and in other places its composition is not at all dependent upon the bed rock.

FOSSIL-BEARING LIMESTONE.
A sedimentary rock formed from sea shells.

The great variety of rocks of which the crust of the earth is composed has been divided into three great groups in accordance with the manner in which they were formed. These groups are *igneous*, *sedimentary* and *metamorphic*.

The *igneous* rocks are those which have solidified from a melted condition. They may have solidified deep down within the crust, or on the surface, or somewhere between the depths and the surface. If these rocks cooled slowly,

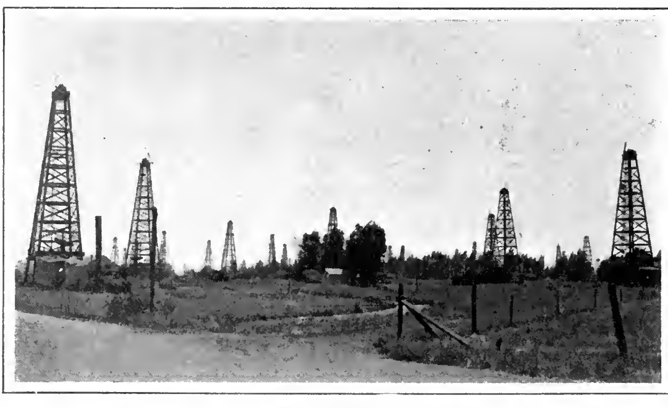


CONGLOMERATE.
A sedimentary rock formed from old gravel beds.

they will have a crystalline structure, as in granite, and if very rapidly, a glassy structure, as in obsidian. Their structure can vary anywhere between these two extremes. A common dark colored variety of this kind of rock is called basalt. There are many varieties of igneous rocks, but they need not be considered here.

The *sedimentary* rocks are those that are made by deposition in water. When rocks are worn away into fragments and these fragments are deposited in water they will, under certain conditions, harden into rocks. The shells and remains of sea animals also accumulate, and after a time consolidate into rock. The remains of plants may accumulate under such conditions that they will not rot but will solidify into rock which we call *bituminous* or soft coal. About four fifths of the land surface of the earth is composed of sedimentary rocks. They vary greatly in color, durability and usefulness to men.

The sandstones, which are composed of little grains of sand cemented together, are used for buildings and for many other purposes. The limestones, which are mostly made from the remains of sea animals, are the source of our lime and are also used for building and for other purposes. The shales are finely stratified mud deposits often having many layers in an inch of thickness. Bituminous coal, which is formed from plants of former ages, is the



Oil Wells.

Tapping the rock layers containing petroleum.

most useful and valuable of all mineral products. None of these rocks is crystalline. They are composed of fragments of other rocks or remains of plants or animals and usually occur in layers or strata.

Petroleum is probably a result of the accumulation in the sea of layers of animal and plant remains. These were covered by other layers and, during the ages since their formation, they have decomposed and changed into oil and gas.

The *metamorphic* rocks have a crystalline structure, often contain well-formed crystals imbedded in them and often bands of crystalline substances extending through them. These rocks are not in the condition in which they were originally laid down, but are modified forms of either the igneous or sedimentary rocks. The rocks originally laid down have been subjected to changes which have rearranged their mineral constituents and changed the structure.

GNEISS.
Probably metamorphosed granite.

These changes are generally due to heat and pressure. Marble is a crystallized limestone and gneiss generally a metamorphosed granite. Slate and mica-schist are greatly changed clay rocks and anthracite coal is a metamorphosed form of bituminous coal. The rocks of this group are often hard to distinguish from igneous rocks.

41. Structure of the Land Areas. — **Experiment 40.** — Take a copper ball having a ring just large enough to encircle it, the same apparatus as used in Experiment 19. (Fig. 22.) Place the ball within the ring and heat them both to a high temperature. Remove the ball from the ring and plunge it into a dish of water. Place the cooled ball again within the ring. The ring will be found too large to fit snugly upon it.

If the ring had been a cold hollow sphere fitting tightly to the surface of the hot ball and the ball had then been cooled until its temperature approached the temperature of the cold surrounding spherical surface, it would have shrunk away from this spherical surface. This would leave an unfilled space between the two into which the spherical shell must have shrunk if not strong enough to support itself. This shrinking would cause wrinkling in some parts of its surface.

Experiment 41. — When at home measure the greatest and least circumference of a large smooth apple by winding a string around it and then unwinding and measuring the length of the string. Bake the apple. Measure its circumferences again. Are they greater or less than before? Is the skin of the apple as smooth as it was before?

Not only do the land areas differ greatly in the kind of rocks of which they are composed, but also in the way in which these rocks are placed. Some of the rocks lie nearly

STRATIFIED ROCK.

These layers have remained horizontal as originally formed.

in the condition in which they were originally formed while others have been folded and warped and twisted.

Vast layers of rocks have been worn away by the forces which are continually wearing away and removing the rocks at the surface of the earth, and thus rocks which were once at great depths below the surface have been exposed. Even granite rocks which were originally formed at a depth of thousands of feet below the surface now appear at the surface and are being quarried in many places.

Folded Rocks.
Stratified rocks which have been folded since they were formed.

The folding and warping of the rock layers has brought some of the stratified beds which were originally horizontal into an almost vertical position so that we now find at the surface the worn-off edges of these beds. The different kinds of rocks and the different positions in which the rock layers are presented to the forces which are active in wearing them away cause great variety in the forms of the surface features.

It is not necessary to consider all the causes which may have disturbed the position of the rock layers, but the most important of them deserves attention. It has already been found that, although the exterior of the earth is cool, the interior is hot. Now it is known that almost all substances contract when cooled. If the interior of the earth is cooling, and there is every reason to believe that it is, then it must be contracting. As the crust is already cool it has ceased to contract and thus the interior shrinks away from it and it must fold up in order still to rest upon the shrinking interior. The cooling of the earth is so slow that the folding under ordinary conditions disturbs the surface but little.

42. Rock Weathering. — **Experiment 42.** — Weigh carefully a piece of dry coarse sandstone or coquina. Allow this to remain in water for several days. Wipe dry and weigh again. Why has there been a change in weight?

ROCKS WEATHERING AND FORMING DEEP SLOPES.

Experiment 43. — Fill a test tube or small glass dish about half full of limewater, made by putting about 2 ounces of quicklime into a pint of water. Blow from the mouth through a glass tube into the limewater. There is formed in the limewater a white substance which chemists tell us is of the same composition as limestone.

Experiment 44. — Continue to blow from the mouth for a considerable time through a tube into a dish of limewater. The white substance disappears. A gas in our breath called *carbon dioxide* dissolves in the water, forming a weak acid and causes the change. Now if we heat the water, thus decomposing the acid and driving out the gas, the white substance again appears. This gas is found everywhere in the air and is given out in the decay and burning of substances.

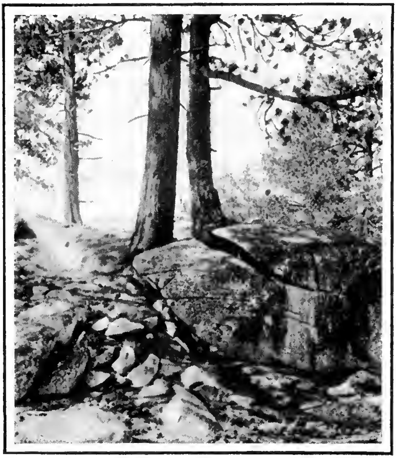
Rocks which are exposed to the atmosphere, especially in moist climates, undergo decomposition. If the climate is warm and dry, rocks may stand for hundreds of years without apparent change, whereas the same rock in another locality, where the weather conditions are different, will crumble rapidly. A striking example of this is found in the great stone obelisk, called Cleopatra's Needle, which was brought from Egypt to Central Park, New York, some time ago. Although it had stood for 3000 years in Egypt without losing the distinctness of the carving upon it, yet in the moist and changeable climate of New York it was found necessary within a year to cover its surface with a preservative substance.

Cleopatra's Needle, Central Park, New York.

Not only do different climates affect differently the wearing away of rocks, but different kinds of rocks themselves vary much in the rate at which they crumble. It has been found that while marble inscriptions, in a large town where there is much coal smoke and considerable rain, will become illegible in fifty years, that after a hundred years inscriptions cut in slate are sharp and distinct.

Experiment 45. — Allow a test tube filled with water and tightly corked to freeze. What happens? If the temperature of the air is not cold enough, place the test tube in a mixture of chopped ice and salt, or better, chopped ice and ammonium chloride (sal ammoniac), and allow it to remain for some time.

Water getting into the cracks of rocks and expanding when it freezes splits them apart and aids much in their destruction. Plant roots penetrate into the crevices of rocks and by their growth split off pieces of the rock. Water, especially when it has passed through decaying vegetable matter, has the power of dissolving some rock minerals. Certain minerals of which rocks are composed change when exposed to the air somewhat as iron does when it rusts.



ROCKS SPLIT BY ROOTS OF A TREE.

Where the temperature varies greatly during the day the expansion and contraction due to the heating and cooling sometimes cause a chipping off of the rock surfaces. In some localities, the winds, by blowing sand particles against the rocks, cut them away quite rapidly. All these agencies and others tend to break up and decompose the rocks, thus forming soil. The actions of some of these agencies were seen in the previous experiments.

WIND-CUT ROCKS.
These rocks have been fantastically cut by wind-blown sand.

43. Soil. — **Experiment 46.** — Into a 16 oz. bottle nearly full of water put a small handful of sand, and into another bottle about the same amount of pulverized clay. Shake each bottle thoroughly and allow the water to settle. Which settles the more rapidly? Which would settle first if washed by a stream whose current was gradually checked?

Wherever the inclination is not too steep, we find the surface of the bed rocks covered for varying depths with a loose material which we call *soil.* It is upon this that plants grow and in it lies the wealth of our agricultural communities. On examining this soil, it will be found that in some places it grows coarser and coarser the far-

LOCAL SOIL.

This soil is being weathered from the underlying rock.

ther down we dig. The coarser the pieces become, the more they resemble the bed rock, until finally they pass by imperceptible stages into it. This kind of soil is called *local* or *sedentary* soil.

In other localities the coarseness of the soil does not materially change as we dig into it, but suddenly we come upon the surface of the bed rock, which may contain few if any of the constituents which were in the soil. This soil, which in no way resembles the underlying rock, is called *transported* soil. We shall find out later how most of it reached its present position.

DIGGING PEAT IN IRELAND.

Peat is cut in small brick-like squares and dried, before being used as fuel.

The first kind of soil has evidently been made in some way from the rock below, since it gradually shades into this rock. This kind of soil changes with the change of the bed rock. A striking illustration occurs in Kentucky, where the rich and fertile "Blue Grass" region is bounded by the poor and sandy "Barrens." The one is underlaid by limestone and the other by sandstone.

The soil at the surface is usually finer than the soil a foot or so below the surface, and sometimes it has a great deal of decayed vegetable matter mixed with the decomposed rock, and to this its fertility is often largely due. Some soils are made up almost entirely of decayed vegetable matter, peat and muck. The underlying coarser and lighter colored soil, which contains little if any vegetable matter, is usually called the *subsoil.*

Experiment 47.—Examine under a strong magnifying glass samples of sand, loam, clay, peat and other kinds of soil. Notice the different kinds of particles composing the different soils and the shapes of these particles.

Experiment 48. — Put a handful of ordinary loamy soil into a fruit jar nearly full of water and allow it to stand for a day or two, shaking occasionally. At the end of this time shake very thoroughly and after allowing it to settle for a minute, pour off the muddy water into another jar. Allow this to stand for about an hour and then pour off the roily water and evaporate it slowly, being careful not to burn the material left. Examine with the eye, by rubbing between the thumb and fingers, and with a magnifying glass, the three substances thus separated. These three separates will be composed largely of sand, silt and clay.

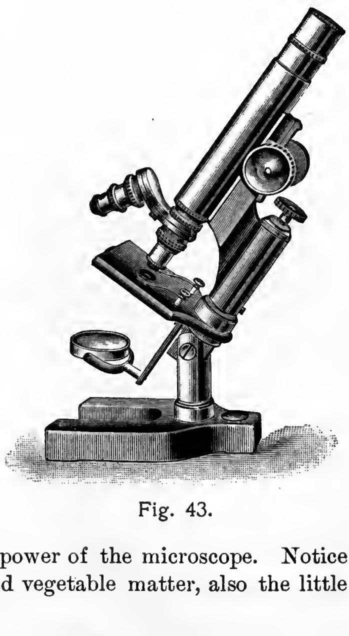


Fig. 43.

If a compound microscope is available, mix a bit of the silt and of the clay in a drop of water and put these drops on glass slides. Examine the drops under the low power of the microscope. Notice the little black particles of decayed vegetable matter, also the little bunches of particles that may still cling together. Why was it necessary to soak the soil so long? Draw the shapes of a few of the particles. Describe the composition of the soil you have examined.

If we examine most soils with a microscope, we shall find that they are composed, as was seen in Experiment 48, of many different kinds of material. Some of these materials dissolve slowly in water and thus furnish food for plants; others are insoluble.

In different soils the particles vary greatly in size as well as in composition. In gravel the particles are large and in a gram's weight there would be but few; in sands there are many more, dependent upon the fineness; and in a gram of clay there are several billion particles. Agricultural soils, intermediate between sand and clay, are usually called *loams*. There are sandy loams and clayey loams, with many intermediate varieties. As the mineral part of the soil is derived entirely from the rocks, only those minerals which were present in the underlying rock can be present in sedentary soils, whereas in transported soils the underlying rock has had no influence upon the soil.

The minerals composing the soil must furnish certain substances if the soils are to support plants. The substances needed in most abundance are nitrogen, phosphoric acid, potash and lime. Practically all soils except the quartz sands contain more or less of these substances.

The chemical make-up of the rock is, however, only one of the qualities necessary for it to support plant life. It must contain water. Plants require a very great deal of water. Yet few plants absorb the proper amount of water if they are submerged in it, or even if their roots are submerged. They must have the soil only partly saturated with water.

Experiment 49. — Take about a quart of soil from a few inches below the surface of the ground and after sifting out the large chunks, put it in a sheet iron pan and carefully weigh it to the fraction of a centigram. Place the pan containing the soil in a drying oven or ordinary oven, the temperature of which is but little above 100° C. The soil should be spread out as thin as possible. Allow it to remain in the oven for some time, until it is perfectly dry throughout. Weigh again. The loss of weight will be the weight of water contained in the soil. As there was no free water in the soil how was this water held? Dip your hand into water and notice how the water clings to it after it is withdrawn. Examine with the eye and the lens several particles of the original soil as taken from the ground and see if there is a water film on each of these as there was on the wet hand.

Experiment 50. — Take the soil after it was dried and weighed in the previous experiment and heat it throughout to a red heat over a Bunsen burner or in a very hot oven. Weigh again. If there is still a loss of weight this must be due to the burning of the organic matter, rotten twigs, roots, leaves, etc., which was in the soil. Soils differ greatly in the amount of water they contain and in the amount of organic substance present.

We have seen from Experiment 49 how the soil takes up water, and how each little particle has a film of water around it. Little hairs on the plant roots are prepared to take up these little films of water which surround the soil particles. These water films have probably dissolved a minute amount of material from the soil particles, and this material enters into the plant and can be used for food.

Experiment 51. — Fill an 8 oz. bottle with soil taken from a few inches below the surface. Fit the bottle with a two-hole rubber stopper having the long neck of a three or four inch funnel pushed as far as possible through one hole and a bent delivery tube just passing through the other hole. See that there is no air space between the soil and the stopper. The soil in the bottle should be as hard packed as it was originally in

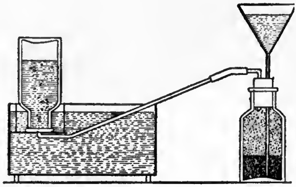


Fig. 44.

the ground. If necessary, push a wire down through the neck of the funnel so as to free all hard-packed particles of soil in it.

Connect the delivery tube with a bottle full of water standing inverted on the shelf of a pneumatic trough. Pour water into the funnel until it is full, and keep it full during the rest of the experiment. Allow the apparatus thus arranged to stand for some hours. Air will collect in the bottle over the pneumatic trough. Where did it come from? When the soil in the bottle has become entirely saturated with water, roughly compare the amount of air collected with the volume of the bottle containing the soil. What part of the soil's volume is the air?

The smaller the soil particles are, the more surface they present to water, the more they are dissolved, the more food the plant hairs can reach, and the more fertile is the soil, other things being equal. We have also seen by experiment that soil contains air as well as water. Air is needed if plants are to flourish, and it is necessary that it be changed frequently, just as it is necessary to change the air in a room if people are to flourish. The soil must be ventilated. Plant roots must have air to breathe.

MOLEHILLS.
Showing how animals dig up the soil and make it porous.

44. Fertile Soils. — Rock disintegration does not furnish all the complex materials needed for the growth of agricultural plants. Only the lower orders of plants, such as lichens, can grow on soil as at first formed. A fertile soil is the product of ages of plant and animal life, labor and decay.

Plants send their filaments and roots among the rock particles, prying open their crevices and pushing the pieces apart so that the agents of disintegration can more readily attack them. By their decay plants provide the *humus* so necessary for making soil fertility.

Animals like moles and gophers plow their holes through the soil, mixing up the particles and making the soil porous, so that the water can readily get in to aid in breaking up and decomposing the soil particles. These holes also provide openings through which plant roots and soil organisms can obtain the oxygen and dissolved food they need. Ants each year move vast quantities of fine material to the surface, and in some places change the surface soil in a few years.

ANTHILL.

This soil has been brought from below and piled up by the ants.

Angleworms, the most important animal soil builders, channel the soil with their burrows, thus providing ready-made openings for the growing roots and by increasing the porosity of the soil aid in its ventilation and drainage. They swallow the soil as they make their burrows, in order to get the decaying vegetable matter for food, and they grind it fine as it passes through their bodies. Every year they bring to the surface great quantities of this finely ground soil mixed with the undigested vegetable matter. Darwin estimated that the angleworms in English soil deposited one fifth of an inch of these castings each year over some parts of the surface. This is the finest kind of fertilizer. It is a common saying that the more angleworms the better the soil.

Besides harboring these visible plants and animals the soil teems with germ life. Some of these germs increase the fertility of the soil and some decrease it. It has been estimated that there are 50,000 germs of various kinds in a gram of fertile soil. It is these that cause the decay of the vegetable and animal matter in the soil. In the course of this decay various acids and gases are formed

MUD CRACKS.
Showing the way clay cracks when it dries.

which help to decompose the rock particles and other compounds which are needed for the food of the plants.

The most important of these germs to agriculture are the nitrogen-fixing bacteria. Plants must have nitrogen if they are to grow, but they are unable to take it from the air where it exists in greatest abundance. For the use of the plants it must be chemically combined with other substances and these compounds must be soluble in water. Saltpeter is a compound of this kind and is often used to fertilize plants. But soluble compounds of nitrogen are not abundant, and these would be soon removed from many soils unless in some way replaced.

This is most often done by adding manures to the soil. In these there are nitrogen compounds which the bacteria of the soil work over and get into shape so that the plants can use them. Some bacteria are even able to take the nitrogen from the soil-air and combine it so that it can be

LUMPY SOIL.

The result of cultivating at the wrong time.

used by the plants. If this varied and teeming life of the soil is to thrive, certain conditions must be maintained, and it is the skill of the agriculturist in maintaining and increasing these favorable conditions which determines his success or failure.

45. **Agricultural Soils.** — As has already been shown, soils differ greatly in fineness, mineral composition and water-holding capacity. They also differ greatly in the amount of decayed vegetable material or *humus* in them. The humus is a most important soil ingredient. It helps in

holding water, it furnishes plant food and it keeps the soil from getting too compact.

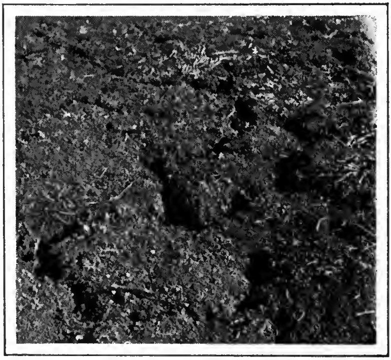
In sandy soils there is usually little humus, the water soon drains out of them and plants become parched. Such soils warm up quickly in the spring and dry out rapidly after long wet spells. When humus and plant food in the form of manure are added they are especially adapted for growing early crops and crops that do not require a great deal of moisture, such as grapes. The "Fresno Sand" of California and the sandy coast plains of the eastern United States are soils of this kind.

ADOBE SOIL.

A heavy clay soil, very fertile, but hard to cultivate.

In clay soil the particles are extremely small, as are also the spaces between the particles. Water is therefore taken up very slowly. It is, however, held tenaciously. When clays become wet, they are very sticky and cannot be worked. When they dry, they become very hard and crack. If cultivated at the wrong time they break into hard lumps and render further cultivation difficult. The adobe soil of the west is of this character. If the soil is nearly pure clay, it is useless for farming. If sufficient sand or humus can be added, it becomes valuable, since clays usually contain the elements needed by plants.

A soil having grains about midway in size between sand and clay is called a *silt*. This is usually a most fertile soil. It is the soil of the western prairies and the great grain-producing states of our country. It holds water well, contains an abundance of plant food, and is easily cultivated. Between these three types — sand, silt and clay — there are all grades of soils presenting problems of various degrees. The problem of the farmer, however, is to maintain a soil which holds water but is well drained, which contains the elements plants need, and which is mellow enough to be well aired and to let the plant roots grow.



THE CRACKING OF ADOBE SOIL WHEN DRY.

PRAIRIE SCENE.

Showing modern methods of harvesting the crops from the fertile silt soil.

46. Soil Water. — Although many soils contain everything needful for the production of agricultural plants, yet the rainfall is insufficient or so unevenly distributed that these plants are unable to grow. This is true over a large area of the United States, and the same conditions often prevail over the usually well watered part of the country in times of drought. The question of increasing the water-holding capacity and of preventing the loss of water by evaporation or in other ways is a very important one.

Experiment 52. — Weigh out equal amounts (about 100 g. each) of dried gravel, coarse sand and very fine sand. Put each of these into a four-inch funnel which has been fitted with a filter paper. Pour water upon each until all that can be absorbed has been absorbed. Allow each to stand until water ceases to drop from the funnel. Weigh again, balancing the weight of the wet filter paper retainer by a similar wet filter paper placed on the weight side of the scales. Which of these substances is capable of holding the most water? Since water does not penetrate into the grains composing these different substances the difference in water holding capacity must be due to the different sizes of the grains.

ALFALFA ROOT.
A long root which has gone deep to seek water.

If we dig deep enough into almost any soil we shall find water. Wells show this. Certain trees and plants have such long roots that they can reach the underlying water and flourish where other plants will die. When wet lands are so drained by tiling that the plants can send their long roots down to this constant water supply or *water table*, as it is called, they stand a drought much better than plants grown on undrained land where the water table has not so uniform a depth.

Experiment 53. — Place small glass tubes of several different bores in a dish of colored water. In which is the surface of the water higher, in the tubes or in the dish? In which tubes is it the higher, those of large or small bore?

Experiment 54. — Place two wide-mouth 4 oz. bottles side by side and fill one partly full of water. Put a coarse piece of cloth, or better, a lamp wick, into the water bottle and allow the other end to hang over into the empty bottle. Allow the bottles to stand thus for an hour. What happens? The force that causes the rising of water up small tubes, wicks and crevices is called *capillarity*.

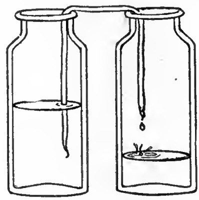


Fig. 45.

Experiment 55. — Tie pieces of cloth over the ends of four lamp chimneys. Fill one of the chimneys with coarse sand, another with fine sand, another with clay, and the fourth with a deep black loam. Stand each chimney in a shallow pan of water. Allow them to remain for a week, keeping water in the pan all the time. Note how high the water has risen in the different chimneys at the end of an hour; two days; a week.

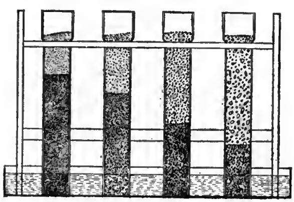
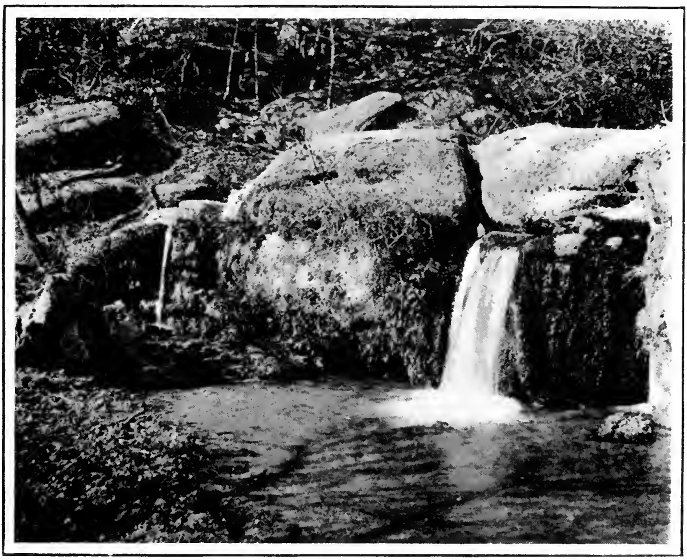


Fig. 46.

It was found in Experiment 49 that each little particle of soil was surrounded by a film of water, even though there was apparently no water in the soil. This film will be replaced if removed just as the water in the top of the wick (Experiment 54) was replaced by water flowing up the wick. Roots get a large part of their water by absorbing the water films of the soil particles.

If a region is well supplied with forests so that the rain as it falls is held by the moss, leaves and roots and protected from evaporation by the foliage, soil water will continue to be supplied to the surrounding open land long after it would have become dry had the forests been removed. Mountain soils have been found which hold back five times their own weight of water.



A NATURAL SPRING.
Coming to the surface between rock layers.

Gravity is continually pulling the soil water deeper and deeper into the ground. This deep soil water is frequently diverted to lower ground by impervious layers of soil or rock and comes to the surface as springs, or it may come gradually to the surface over a broad area a long distance away from where it fell and make a region, otherwise barren, fertile by subirrigating it.

It is often very essential to stop as far as possible this downward passage of water, or *seepage*, as it is called. The water in seeping through the soil dissolves plant food and if allowed to drain off would decrease the fertility of the soil. Whatever decreases the porosity of the soil will decrease the seepage and thus help to retain the plant food. This may be done by adding humus, and sometimes

AN ARTESIAN SPRING.

A deep water-layer has been pierced and the water diverted to the surface.

where the soil is very porous by rolling. At the time rain is likely to fall, however, the soil must be kept loose and mellow so that the water can sink into it.

Evaporation is, however, the cause of soil's losing the greatest amount of water. Soil water is constantly moving toward the surface on account of capillary action, and is being evaporated. This loss by evaporation must be counteracted, if in arid countries or during dry spells agricultural plants are to be provided with sufficient moisture.

Experiment 56. — Fill full of soil four tin cans having small holes punched in the sides and bottom. Water each with the same amount of water. Cover the first with about an inch of grass and the second with about an inch of sawdust, and weigh carefully. Weigh the third and fourth. Record the weight of each. Thoroughly stir the surface of the third, as soon as it is dry enough, about an inch deep. Keep this stirred. Let the fourth stand undisturbed. Weigh all four every school day for two weeks. Keep a record of the loss of weight of each. Why have they lost weight? How do the grass, the sawdust, and stirring of the earth affect the loss? Suggest ways to keep soils from losing their moisture.

In Experiment 56, it was seen that if a layer of grass or sawdust was put on the top of the soil, the moisture did

"Dry Farming" in Egypt.

not evaporate as rapidly as it did when the soil was not covered. The grass could have been replaced by shavings, manure, or any substance which would protect the ground from the sun and wind. Protections of this kind are called *mulches*. They are most frequently used around trees, vines and shrubs. It is impracticable to use them extensively on growing crops.

It was also found that soil water was not readily evaporated where the top of the soil was kept stirred, so that the little capillary tubes by which the soil water reaches the surface were broken and the sunshine and air were kept from the under part of the soil by a layer of finely divided soil mulch. When the surface of the soil is thoroughly stirred or cultivated the particles are separated so far apart that the water cannot pass from one grain to another, and so is retained in the under layer ready for the plant roots. Thorough tillage of agricultural crops is perhaps the best way to assure the plants sufficient moisture in regions subject to droughts.

KAFFIR CORN.
A plant suitable for dry farming.

In some parts of the arid region of the United States *dry farming* is practiced. The soil is deeply plowed and the plow often followed by a bevel wheel roller called a *soil packer*, in order to pack the under soil or subsoil so that the air cannot circulate through it and dry out the upper soil. The surface soil is then most thoroughly cultivated so as to make as perfect a soil mulch as possible. Thus, whatever moisture falls is kept from seeping below the reach of the plant roots and from evaporating from the surface. In this kind of farming the aim is to use more than one year's moisture in growing a crop.

Crops are usually planted only every other year, two years' moisture being retained for one crop. The soil is, however, kept thoroughly cultivated all the time. Of course plants requiring the least amount of moisture are best adapted to dry farming.

Irrigation is the most efficient means of raising crops in regions of insufficient rainfall or of droughts. Water is

IRRIGATION IN SQUARES.

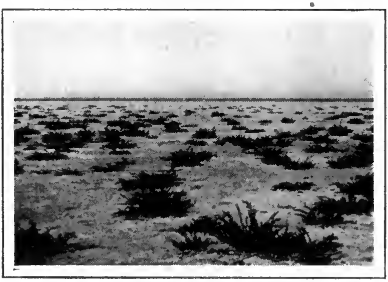
brought to the land from distant sources, or from flowing artesian wells, or is pumped from wells which have been sunk to an available water table. In this way water can be supplied to plants whenever needed. Where the ground is quite level it is often flooded, sometimes in larger or smaller squares, with little ridges separating the squares. A great deal of water is lost in this way by evaporation.

Another way is to plow furrows eight to ten inches deep in the direction of the surface slope and run the water into these from the irrigation ditch. In either case the water is allowed to soak in until the soil is thoroughly wet. The surface is then cultivated so as to check surface evaporation. In the last few years the government and many private companies have spent millions of dollars in putting in irrigation plants. By this

IRRIGATION IN FURROWS.

means thousands of acres of land which would otherwise have been valueless for agriculture has been made exceedingly productive.

47. Alkali Soils. — In dry regions where the rainfall all sinks into the ground and after remaining for a time rises to the surface and is evaporated, large areas are found upon which almost nothing can be made to grow even when sufficient water is provided. Often in the dry season white or brown crusts appear scattered over the surface in large patches. The white crust usually tastes like Epsom salts and the brown like salsoda. The salts forming these patches have been dissolved out of the soil by the soil water and left on the surface when it evaporated.



ALKALI SOIL.

Few plants can grow here because of the excess of alkaline salts.

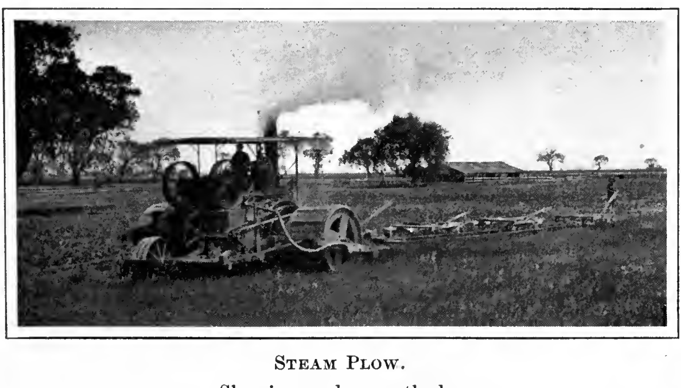
Such substances are not found in wet regions because they are carried away by the water which runs into the streams. About the only way soil of this kind can be treated to make it productive is to irrigate and drain it, thus washing the salts out of the

RECLAIMING ALKALI SOIL IN THE SAHARA.

soil. This is just what is done by nature in well-watered regions. Sometimes if there is not much alkali deep plowing or the planting and removal of certain plants such as sugar beets, which are capable of growing in such soils, will sweeten it.

Roman Plowing.
Showing primitive methods.

48. **Soil and Man.** — Although nature through countless ages has been preparing the soil, and generation after generation of plants and animals has been contributing to its fertility, yet it will not continue profitably to produce



Steam Plow.
Showing modern methods.

agricultural crops unless carefully handled by man. The materials taken from it must be replaced by manures. It must also be thoroughly tilled in order (1) to keep in the moisture, (2) to prepare a mellow place where the roots of the plants may spread, (3) to provide air and water and humus needed by the germs which build up the soluble nitrogen compounds, and (4) to kill the weeds which would use the space and plant foods needed by the growing crops and would choke them out. Proper tillage probably has more to do with thrifty and productive farming than any other one thing. By careful tillage much expense for fertilizers can be saved and the value of the crop produced greatly increased.

Good Soil.
A truck farm.

49. Value of Soils. — Many different factors enter into the determination of the value of a soil. Soils which in one locality would be of great value are almost valueless in other localities. Light sandy soil far from a market, unless transportation facilities are exceptionally good, is almost worthless, while the same soil near a city where fertilizers can be easily procured and where early vegetables find a ready market is of great value.

Different soils are adapted to different crops, and where a soil, although not good for many crops, is adapted for raising a crop which in its locality is valuable, the soil is called good. Thus the soil in many parts of Florida, although unsuited for raising most crops, is suited for orange trees and early vegetables, and so is a good soil. The stony soil in certain of the orange regions of California would be an exceedingly poor soil for most crops, but it is good for oranges and therefore it is most valuable.

Summary. — Only a little more than a quarter of the earth's surface is land, and only a little over a twentieth of this land belongs to the United States. Though there are depths in the ocean greater than our highest mountains, most sea animals live near the surface, while land animals are distributed over hills and valleys. This gives greater variety to life on land.

Water is simply a compound of oxygen and hydrogen. It has many valuable and interesting properties: it is practically incompressible; it is the greatest dissolver of substances that there is; it evaporates readily, giving us rain, and, when put under pressure, our steam power; it has great power of taking up heat, thus regulating the climate of the land near which large bodies of it lie.

The land is made up of various animal, mineral and vegetable substances. But four fifths of it consists of *sedimentary* rocks, that is, those that were deposited by water, as distinguished from *igneous* or rocks formed from melted materials within the earth, and *metamorphic* or rocks that have been changed from sedimentary or igneous rocks.

The soil comes chiefly from the decaying and weathering of rocks. It is divided into local or *sedentary* soil, that which is formed from the rocks directly beneath it, and *transported* soil, that which is generally brought down and deposited by water, ice and wind. Soils are classed roughly as *gravel*, *sand*, *clay*, and *loam*.

The fertility of the soil depends largely upon composition, air and water, ventilation and drainage. Fertile soil must contain *nitrogen*, *potash* and *lime*. The roots of plants must have air to breathe, and water must dissolve the nourishing substances in the soil and bring them to the roots to be absorbed. For this reason the soil should not be packed hard like clay, nor should it be loose like coarse gravel, as clay does not let the water soak through readily, while gravel lets it seep down too fast.

To *maintain its fertility*, the soil must be frequently cultivated to decrease seepage and evaporation. It must be supplied with fresh nourishment by manures or other fertilizers. In some districts where the rain supply is inadequate, irrigation and dry farming are practiced. Different soils are suited to different crops. Without the fertility of the soil, life on the earth would cease.

Questions

For what would you look if trying to determine whether a land surface had ever been under the sea?

What are the characteristic differences between land and water surfaces and between the conditions to which the animals and plants of each are subjected?

What reasons can you suggest for likening the earth to a water engine?

To what great classes do the rocks in your neighborhood belong?

What examples of rock weathering have you ever seen? Describe.

Is the soil in your neighborhood local or transported? Does its character vary much in different places? Does the fertility vary?

What would you suggest as the causes of these variations?

What is necessary to produce a fertile soil?

How can the fertility of a soil be maintained?

How can the supply of soil water be maintained in dry regions and at times of drought?

What determines the value of a soil?

CHAPTER V

THE ATMOSPHERE OF THE EARTH

50. The Origin of the Atmosphere. — As the earth cooled down from the intensely hot condition which it is supposed to have had at first, the substances which had not chemically combined and formed liquids and solids, or which required a low temperature for their consolidation were left still in the gaseous state around the solid core. This gaseous envelope composed of these substances surrounding the earth we call the *atmosphere*. Some of

BLUE HILL OBSERVATORY, MILTON, MASS.
One of the first places in America where conditions of the upper atmosphere were studied.

these gases are inert and do not readily combine with other substances. Others have formed extensive combinations, but they exist in such large quantities that they were not thereby exhausted.

51. The Composition of the Air. — **Experiment 57.** — (To be performed only by the teacher.) Having rounded out a cavity in a small flat cork, cover the cavity and surface around it with a thin layer of plaster of Paris. After the plaster has set and become thoroughly dry float the cork on a dish of water with the cavity side up. Place a piece of phosphorus as large as a pea in the cavity and carefully light it. (Great care must be taken in handling phosphorus as it ignites at a low temperature and burns with great fierceness. It must always be cut and handled under water.)

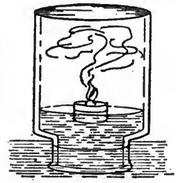


Fig. 47.

As soon as the phosphorus is lighted, cover it with a wide-mouthed bottle. Be sure that the mouth of the bottle is kept slightly under water. The water will be found to rise in the bottle. The phosphorus soon ceases to burn. White fumes are formed, but these soon clear up. A clear gas is left in the bottle, but this cannot be air, for if it were, the phosphorus would have continued to burn in it, since it burns in air. If it were not for this property of not permitting phosphorus to burn, the gas left in the bottle could not be distinguished by ordinary means from air.

The gas fills more than three fourths of the bottle, so that more than three fourths of the air is composed of a gas which does not support combustion. This gas is called *nitrogen*. The other constituents of the air must also be transparent colorless gases, since the air is transparent and colorless. The most important of these is called *oxygen*. The phosphorus united with this and formed the white fumes. These fumes dissolved in the water, leaving the nitrogen.

Be careful to put the cork on which the phosphorus was burned in a place where it cannot cause a fire.

Although the air appears like a simple gas and was so considered until the end of the eighteenth century it has been shown to be composed of several different colorless gases. One of these, *oxygen*, supports combustion; another, *nitrogen*, neither burns nor supports combustion. Chemists have found that these two gases are mixed in the air in the proportion of about one part of oxygen to four parts of nitrogen.

Another heavy colorless gas called *carbon dioxide* is found in the air in the proportion of about 3 parts to 10,000. There are in addition very small quantities of several other gases, but these are not of sufficient importance to be studied here. Besides the gases, the air contains other matter, such as water vapor, dust particles and microbes.

Experiment 58. — Obtain four bottles of oxygen from the chemical laboratory. If not obtainable, place a piece of sodium peroxide (oxone) about as large as the end of a finger in a side necked test tube provided with a medicine dropper filled with water, as shown in Fig. 48. Put the end of the delivery tube under the mouth of an inverted bottle filled with water arranged on the shelf of a pneumatic trough. Drop water slowly on to the sodium peroxide and collect the gas generated. Fill several bottles. Oxygen can also be prepared by heating a mixture of about one part manganese dioxide and two parts potassium chlorate in a test tube and collecting the gas over water (Fig. 49). Does the

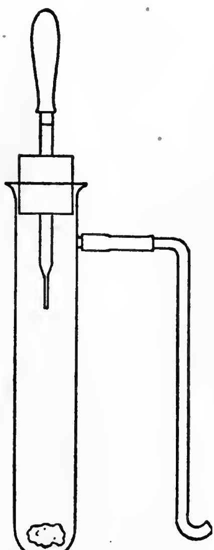


Fig. 48.

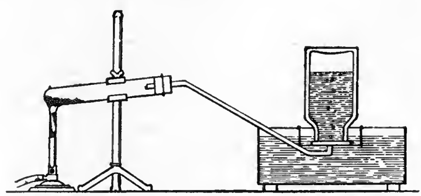


Fig. 49.

appearance of this gas differ in any way from air? Smell of it. Has it any odor? Into one of the bottles of oxygen insert a splinter of wood having a spark at the end. It bursts into flame. Does the same thing take place when the stick with the spark upon it is held in a bottle of air?

Hold a lighted match at the mouth of another of the bottles containing oxygen. Does the gas itself burn as illuminating gas does when a match is applied to it? If the oxygen in the air were increased or decreased, it would have a great effect upon combustion. Attach a piece of sulphur to a short piece of picture wire. Ignite it and place the wire in a bottle of oxygen (Fig. 50). Does the sulphur burn strongly? How about the wire? Does it burn too?

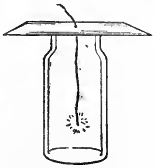


Fig. 50.

The oxygen is the most important part of the air to animals, for without it they could not live. They breathe in oxygen and breathe out carbon dioxide. All their heat and energy is due to the power they have of combining oxygen with carbon and forming carbon dioxide. Plants also need it.

Plants need carbon dioxide as much as animals need oxygen. By far the greater part of plants is made from the carbon which they get from this gas. The growth of a plant is due to the power it has of tearing apart the carbon dioxide by the help of the sun and building the carbon into its structure. It returns the oxygen to the air to be used again by the animals and plants.

Experiment 59. — Get two or three bottles of carbon dioxide from the chemical laboratory, or prepare it by pouring dilute hydrochloric acid upon pieces of limestone in a bottle and collecting the gas over water. Does the appearance of this gas differ in any way from that of air? Smell of one of the bottles that has stood over water for some time. The gas has no odor. Plunge a lighted match into one of the bottles containing the carbon dioxide. What happens? Does the gas burn or support combustion? Slowly overturn a bottle of the gas above a lighted candle. The candle is extinguished. The gas falls out when the bottle is overturned, thus showing that it is heavier than air. If the amount of carbon dioxide in the air were largely increased, what effect would it have upon combustion?

Animals smother in carbon dioxide. It is known to coal miners as *choke damp*, because frequently after they have escaped from an explosion they are smothered by it. It occurs at a few localities, as at the Dog Grotto near Naples and in Death Gulch, Yellowstone National Park, in sufficient quantities to be fatal to animals passing through these places.

As a rule, however, the proportion of oxygen, nitrogen and carbon dioxide is the same for all places on the surface of the earth and it is only where for some peculiar cause carbon dioxide is emitted from the ground in a place sheltered from the wind, that it can accumulate. As animals and men breathe it out, rooms where they stay must have proper ventilation.

The nitrogen is needed to dilute the oxygen. If oxygen were undiluted, animals could not live, and a fire once started would burn up iron as readily as it now does wood. As has already been stated, certain bacteria take nitrogen from the air and prepare it so that plants can use it.

Plants and animals both need water vapor. Were it not for this form of moisture there would be no rain, and without rain life could not exist. Thus the air which contains oxygen and water vapor for both plants and animals, carbon dioxide for the plants, and nitrogen to dilute the oxygen, is one of the greatest factors in the life history of the earth.


Fig. 51.

52. Weight of Air. — **Experiment 60.** — Into a five-pint bottle insert a tightly fitting rubber stopper through which a glass tube extends. To the outer end of the glass tube tightly fit a thick-walled rubber tube of sufficient length for the attachment of an air pump. Put a Hoffman's screw upon the rubber tube. See that all connections are air-tight. Weigh carefully the apparatus as thus arranged. Now attach the rubber tube to the air-pump and extract the air from the bottle. When all the air that can be exhausted has been removed, close the rubber tube tightly with the Hoffman's screw and weigh again. Unclamp the Hoffman's screw and allow the air to enter the bottle. The weight should be now the same as at first. Or, instead of weighing a bottle of air, weigh an incandescent light bulb. Make a hole in it with a blowpipe and weigh again. Is the weight now the same as before?

We have found by the previous experiment that air has weight. With the apparatus used it was impossible to tell exactly the weight of the air extracted or to determine the weight of a definite volume of the air. If we had been able to do this, we should have found that on an average day, at sea level, the weight of a liter, a little more than a quart, of air, is about 1.2 grams. 12 cu. ft. weigh about 1 lb. The air extends to so great a height that although very light, the weight of so great a mass of it is considerable.

BALLOON.
The gas in the balloon is lighter than air, so the balloon floats in air as a piece of wood does in water.

Now that air has been found to have weight, it can be seen why a light body like a balloon will float in it in the same way that a stick will float in water. The weight of the air varies with the pressure and temperature, as we shall find later.

53. Expansion of Air when Heated. — Air expands very much when heated, as was seen in Experiment 17. It is found that if air at freezing is heated to the temperature of boiling water, it will expand about $\frac{4}{11}$ of its volume. The force with which air expands is so great that sometimes when buildings are on fire and there is no opening for the confined air to escape, the walls are blown out or the roof blown off by the expansion of the hot air, and great injury done to those fighting the fire. That air expands upon being heated is readily seen when a toy balloon is brought from the cold outer air into a hot room, — the covering begins at once to tighten and the balloon to swell.

54. Weight of Air as Affected by Heat and Cold. — **Experiment 61.** — Take two open flasks of nearly the same weight and capacity and balance in as nearly a vertical position as possible at the ends of the arms of a beam balance. Bring the flame of a Bunsen burner to the upper side of the bulb of one of the flasks so that the hot air currents that are generated will have no upward push on the flask. Do not allow the hot air to get under the flask. What is the effect?

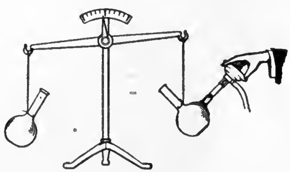
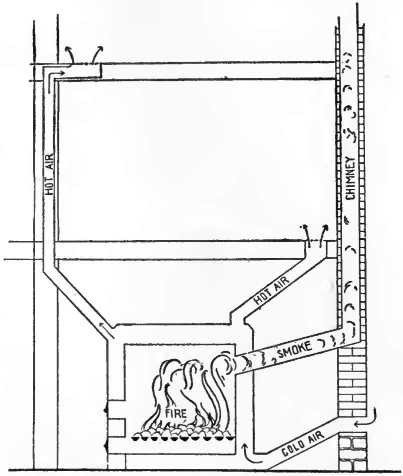


Fig. 52.

As the previous experiment shows, and as we should expect from the fact that air has been found to expand when heated, it follows that hot air is lighter than cold air. A liter of air at freezing under ordinary pressure weighs about 1.293 grams, but at the temperature of boiling water it weighs only about .946 grams. So a mass of cold air, being heavier, will exert more pressure at the surface of the earth than a mass of hot air.

As air is a gas whose particles can move freely among themselves we should expect that a heavier column of cold air would sink down and distribute itself along the surface under surrounding lighter air just as a column of water falls when its supports are withdrawn and forces up the lighter air which surrounds it.

A similar action is seen when water is poured upon oil; the water sinks to the bottom and forces the oil to rise. Thus if air is heated at any place, we should expect that there would be a rising current of hot air and a current of colder air creeping in to take its place. The winds of the earth are due to this property of air. It is this tendency of heated air to rise that makes hot air furnaces useful for heating houses. Valleys are generally colder than the surrounding hillsides, so that delicate crops can be grown successfully on the hillsides although those in the valley are frost bitten.



HOT AIR FURNACE.

The hot air rises through the pipes and registers, and cold air presses in from outside.

55. **Pressure of Air.** — **Experiment 62.** — Use a convection apparatus or take a tight chalk box and in two places on the top punch holes in a circle not quite as large as the bottom of a lamp chimney. Place a small lighted candle at the center of one of the circles of holes and a lamp chimney, tightly sealed to the box, about each circle. Hold a smoking piece of paper above the chimney which does not inclose the candle. (If a pane of glass is put into one of the vertical sides of the box, better observations can be made.) What happens? Put out the candle and carefully heat the chimney with a Bunsen burner. Is there the same action as before? Why is it that sparks rise from a fire? What is meant by the *draft* of a stove? Why in order to ventilate a room is it best to open a window at the top and bottom?

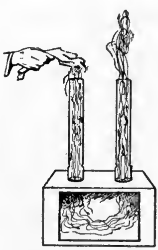


Fig. 53.

Experiment 63. — If a tin can with a tightly fitting screw cap can be easily procured, boil a little water in it, having the screw cap open so that the steam can readily escape. While the water is still strongly boiling, quickly remove from the heat and tightly cork. Be sure not to cork before removing entirely from the heat. Set the tin thus corked upon the desk and observe. What happens as the steam condenses? Why?

Experiment 64. — By means of an air pump exhaust the air from a pair of Magdeburg hemispheres. Now try to pull the hemispheres apart. It cannot be done as easily as before the air was exhausted. Why?

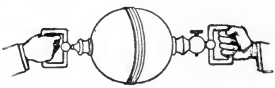


Fig. 54.

Experiment 65. — Fill a glass tumbler even full of water and press upon it a piece of writing paper. Be sure that the paper fits smoothly to the rim of the tumbler. Take the tumbler by its base and carefully invert it over a pan. Does the water fall out? If not, why not? While the tumbler is in the inverted position, insert the point of a pencil between the paper and the rim of the tumbler. What happens?

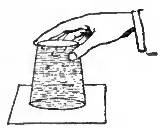


Fig. 55.

Anything that has weight must exert pressure upon the surface upon which it rests. The air has been found to have weight, therefore it must exert pressure at the surface of the earth. Air is a gas and its particles easily move over each other, therefore this pressure is exerted equally in all directions. No one feels the pressure, however, because the air is within us as well as about us. Those that have measured this pressure find that it is about fifteen pounds to the square inch at sea level. If two egg shells from which the insides had been removed, one of them with the holes left in it and the other completely sealed, were sunk to a considerable depth in water, which one would be crushed and which one would not? This illustrates why we are not crushed by the pressure of the air upon us.

56. Decrease of Volume due to Pressure. — **Experiment 66.** — In a Mariotte's tube cause about a centimeter of mercury in the short arm to balance the same amount in the long arm. The pressure inside the short tube will then be equal to that outside the long tube and will be that of the air upon the day of the experiment. The short arm will now be sealed with mercury so that no air can get in or out. Pour mercury into the long arm. The air in the short arm will be gradually compressed and will occupy less and less space. If we remember that the pressure upon the air in the short arm is the air pressure of the day plus the height that the mercury column in the long arm exceeds that in the short arm, we can show by careful measurement that the volume of the air decreases just as the pressure increases.

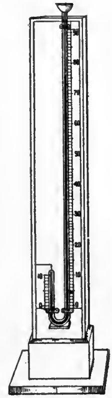


Fig. 56.

As was seen in Experiment 1, the volume of the air can be very much decreased by pressure, but when the pressure is removed, it regains its original volume. It cannot be told from this experiment whether the volume of the gas decreases as the pressure increases or whether it decreases much more rapidly when first pressed upon than afterward. This can be best shown by the use of the Mariotte's tube as in Experiment 66. But if the bicycle pump is a good one, it will answer the question of the rate of decrease quite accurately. It is found that *the volume decreases directly as the pressure increases.*

57. Barometers. — As the measurement of the atmospheric pressure is of great importance in the study of atmospheric conditions, it is necessary to have an instrument by which these measurements can be readily made. An instrument designed for this purpose is called a *barometer*. There are two kinds of barometers in common use, called the *mercurial* and the *aneroid*.

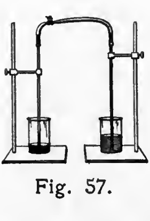


Fig. 57.

Experiment 67. — (Teacher's Exp.) Take a thick-walled glass tube of about ½ cm. bore and about 90 cm. long and slip tightly over the end of it about 10 cm. of a thick-walled flexible rubber tube 30 cm. in length. Firmly secure the rubber tube to the glass tube by winding tightly around them many turns of string, making it impossible for the rubber tube to slip or admit air. Completely close the rubber tube with a Hoffman's screw just beyond the place where it leaves the glass tube. Placing this closed end in a large dish so as not to waste any mercury, fill the glass tube with mercury. Place the thumb over the open end of the tube and invert it in a cup of mercury. If the connections were made tight, the mercury will not fall far below the end of the glass tube. The air pressure keeps the mercury up. This is a simple form of barometer.

Fig. 59.

While the tube is still standing in the mercury cup take another glass tube similar to the first and attach it to the open end of the rubber tube in the same way as the first was attached. Place the free end of this tube in a dish of colored water and gradually open the Hoffman's screw. The water rises in the tube. Why? What is meant by sucking water up a tube?

Experiment 68. — Fill a bottle with clean water and fit it tightly with a rubber stopper having two holes in it. Plug one of the holes tightly with a glass tube one end of which has been closed by heating in a Bunsen burner. Through the other hole put an open glass tube 10 to 15 cm. long. See that both tubes fit tightly in the stopper and that the stopper fits tightly in the bottle. Now attempt to "suck" the water out of the bottle through the open tube. Does it come out freely? Pull out the glass plug. Does it come out any better? If so, why?

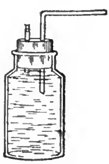


Fig. 58.

The mercurial barometer we have already made in a rough form. The best form of these instruments consists of a glass tube of uniform bore about eighty centimeters long and closed at one end. After being carefully filled with pure mercury, it is inverted in a cistern of mercury. The cistern of mercury has a sliding bottom easily moved up and down by means of a set screw. At the top of the cistern there is a short ivory peg. The lower end of the ivory peg is at an exactly measured distance from the bottom of a scale. The scale is placed beside a slit near the top of a metallic tube which is firmly fastened to the cistern and surrounds and protects the glass tube.

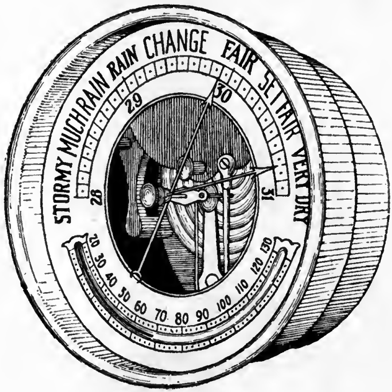
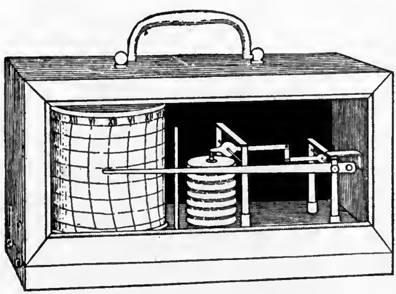


Fig. 60.

When it is desired to read the barometer, the sliding bottom of the cistern is raised or lowered until the top of the mercury in the cistern just touches the bottom of the ivory peg. The height of the top of the mercury column is then read from the scale. In order to determine the height with great precision there is generally attached to the metallic tube a sliding vernier which moves in the slit.


BAROGRAPH.

This is arranged so as to record the air pressure automatically for a week at a time.

The aneroid barometer consists in general of a corrugated metallic box from which the air has been partially exhausted. Within the box is a stiff spring so that the pressure of the air will not cause it to collapse. Attached to the box are levers by which any change in the volume of the box will be multiplied and indicated by a pointer arranged to move over a dial. The dial has a scale upon it and thus the air pressure is registered.

Instruments called *barographs* are constructed in which a long lever provided with a pen point is attached to the aneroid and made to record on a cylinder revolved by clockwork. Thus a continual record is made of barometric readings.

58. Determination of Height by a Barometer.—**Experiment 69.**—Carry an aneroid barometer from the bottom of a high building to the top. Note the reading of the barometer at the bottom and again at the top. Why is the barometer lower at the top of the building?

As the pressure of air at any surface is due to the weight of the air above that surface, it happens that as we go up the pressure decreases, since there is a continually decreasing weight of air above. If the rate of this decrease is determined, then it is possible to determine the elevation by ascertaining the pressure.

Although the height of the barometer is continually varying with the changing air conditions, yet if these conditions remain about the same, it may roughly be estimated that the fall of $\frac{1}{16}$ of an inch in the height of the mercury column indicates a rise of about 57 feet, and that the fall of a millimeter indicates a rise of about 11 meters. These values are fairly reliable for elevations less than a thousand feet, under ordinary temperatures and pressures.

At the height of 25 miles the barometric column would probably not be more than $\frac{1}{25}$ of an inch high. Several measurements made in different ways indicate that the air is at least 100 miles in depth, probably more. Nearly three fourths of the atmosphere however is below the top of the highest mountain. The highest altitude ever reached by man was about 7 miles.

To study air conditions small balloons to which meteorological instruments are attached have been sent to a height of 21 miles. It is found that the minimum temperatures occur at a height of from 6 to 10 miles. Conditions affecting weather, however, seem to extend to a height of not much over 3 miles.

59. Adiabatic Heating and Cooling of Air. — **Experiment 70.** — Have a five-pint glass bottle fitted with a two-hole rubber stopper. Pass through the holes in the stopper a chemical or air thermometer and a short glass tube the lower end of which extends into the bottle not near the bulb of the thermometer, so that when the air is exhausted or allowed to enter the bottle there will be no movement of the air near the bulb of the thermometer. The end of the column of the thermometer must be visible above the stopper.

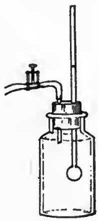


Fig. 61.

Attach the glass tube to an air pump by means of a thick-walled rubber tube. Note the temperature of the thermometer within the bottle and also of the air outside. Quickly exhaust the air from the bottle, carefully noting the action of the thermometer. See that the temperature of the air in the room does not change during the experiment. Allow the air quickly to enter the bottle and note the action of the thermometer. The temperature inside the bottle changes as the air is quickly exhausted, or as it is allowed to enter the bottle again and thus to increase the density of the air in the bottle.

It has been found that when air expands its temperature falls and when it is compressed its temperature rises. This heating and cooling of the air without the application of external heat or cold, but simply by a change in the density of the gas itself, is called *adiabatic* heating or cooling. It is taken advantage of in the manufacture of liquid air and is the same principle which is utilized in cold storage plants. This property of air has much to do in developing our wind circulation and storms.

The heating effect of compressing air can be well seen when a pneumatic tire is filled. No matter how well the piston of the pump may be oiled, as the density of the air in the tire begins to increase, the pump will grow warm rapidly. This rapid heating cannot be due to friction, as the pump is not being worked any more swiftly than at first. It is due to the greater compression of the air. As this compression increases, the heating increases, the effect of friction in a well-oiled pump being of small value.

60. Effect of Temperature on the Capacity of the Air to hold Moisture. — **Experiment 71.** — Take a liter flask and put into it just sufficient water to make a thin film on the inside of the flask when shaken around. Now warm the flask gently, never bringing its temperature near to the boiling point, until the water disappears from the inside and the flask appears to be perfectly dry. Having tightly corked the flask, allow it to cool. The flask appeared dry when warm and on account of having been corked tightly no moisture could have entered it. The air in the flask was perfectly transparent both before and after heating. The film of water around the inside of the flask was taken up by the air when it was warmed but the moisture reappeared when the flask was cooled.

Experiment 72. — Fill a bright tin dish or glass beaker with ice water and after carefully wiping the outside allow it to stand for some time in a warm room. Can water go through the sides of the dish? Does the outside of the dish remain dry? If water collects upon it, from where does the water come? See if the same results will happen if the water within the dish is as warm as or warmer than the air in the room.

Experiment 73. — Partially fill a dish or beaker like that in the previous experiment with water having a temperature a little warmer than that of the room. Gradually add pieces of ice, continually stirring with a chemical thermometer. Note the temperature at which a mist begins to appear upon the outside of the dish. When the mist has appeared, add no more ice but stir until the mist begins to disappear. Note this temperature. Take the average of these two temperatures. This average is probably the temperature at which the mist really began to form. This temperature is called the *dew point.*

When we wish to dry clothes, we place them in a warm room or in the sunshine. Soon we find that the water has left the clothes. It must have gone into the air. It would thus appear that when the temperature of the air is raised, it has the capacity of taking up more moisture than when it is cold. The previous experiment has shown this, and the one in which the dew point was determined showed that when heated air was cooled it deposited moisture.

This property that air has of taking up a large amount of water when heated and giving it out when cooled is the cause of our clouds and rain. If it were not for this there would be no circulation of moisture over the land, no rain, and without rain there could be no vegetation and no animal life. Thus this simple property of the air furnishes the means for the support of practically all the animate life on the earth.

61. Moisture in the Atmosphere. — **Experiment 74.** — Carefully weigh a dish of water and place it in a convenient place where there is a free access of air. After some hours weigh it again. What causes the change of weight? Try this experiment with a test tube, watch-glass and a wide-mouthed beaker under various conditions and in various places.

The atmosphere at all times and under all conditions contains some moisture. When its temperature has been raised, its capacity to hold moisture is increased, but at no place is it so cold that it cannot contain a certain amount of moisture. When water in the solid or liquid condition is exposed to the air, it gradually disappears and is taken up into the air.

If the water surface is large and the temperature high, there is a large amount of evaporation and the water rapidly rises into the air. In the tropics the evaporation from the water surface amounts to perhaps eight feet per year. This means that the energy of the sun lifts about five hundred pounds of water from every square foot of the surface every year. In the polar latitudes the amount of evaporation is perhaps a tenth of that in the tropics.

From every water surface on the globe, however, a large amount of water is evaporated each year. In many places much of the water evaporated falls upon the same surface from which it came, but a considerable part of it is carried by the winds to other places and falls upon the land surface, furnishing the moisture needed for the land life of the world.

62. **Humidity.** — The condition of the air as regards the moisture it holds is called its *humidity*. If the air contains all the moisture it can hold, it is said to be *saturated* or to

CUMULUS CLOUDS.
Typical low level clouds, indicating showers.

have reached its dew point. The amount of vapor present in the air is called its *absolute humidity*. The amount of vapor in the air divided by the amount that it would contain if it were saturated is called the *relative humidity*. If the air contains much moisture, its humidity is said to be high. When air which has a high humidity is cooled, it can no longer hold all the moisture which it previously held, and this moisture will be deposited.

The moisture in the air may form into little droplets high above the earth's surface, making *clouds*, or these droplets may be near the surface of the earth. In this case we name the moisture *fog*. If it collects on objects attached to the surface we call it *dew*.

FOG.

A low cloud formed near the surface of the earth.

By determining the dew point as was done in Experiment 73 and comparing this with tables which have been prepared by meteorologists from many observations the relative humidity can be readily determined. An instrument for determining the humidity of the air is called a *hygrometer* (Fig. 62).

63. **Effect of Atmospheric Conditions on Light.** — **Experiment 75.** — Allow sunlight to pass through a glass prism and fall upon a white wall or piece of paper. How has the white sunlight been affected? Where did the colors come from? In what order are the colors arranged? This group of colors into which a prism separates white light is called the *spectrum*.

If the light that comes from the sun is passed through a glass prism, as in Experiment 75, it will be seen to be composed of many different colors. In fact it is the absorption of some of these colors and the reflection of others which make objects appear of different color.

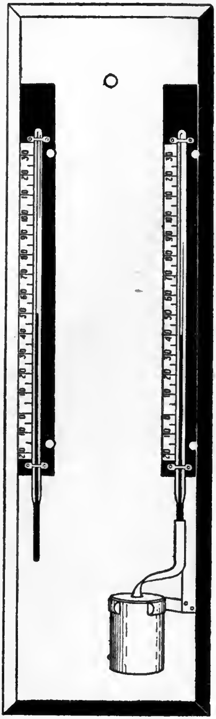


Fig. 62.

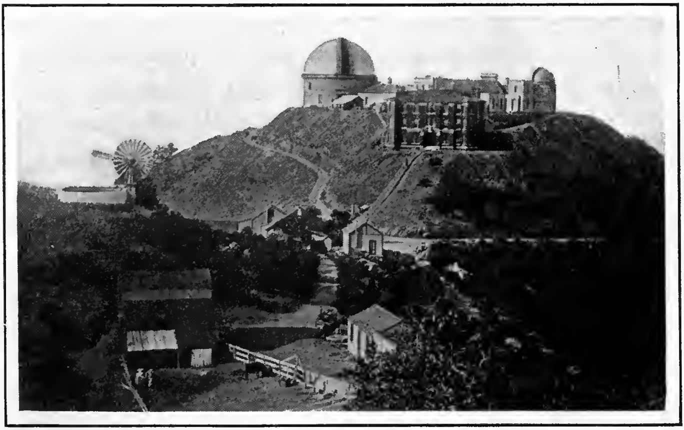
Light itself is a vibration which has the power of affecting the optic nerve, and the different colors are vibrations of different lengths. Now the sunlight is affected by the air through which it comes. If there is smoke or dust in the air, the sun will appear to be red. When the sun sets at night and the rays come to us through a considerable thickness of air which is near the surface of the earth and contains dust, the light often appears red. On the top of a high mountain or on a clear day or when the sun is high overhead the sky appears blue. Both these colors are due to the effect of the atmosphere on transmitted light.

Sometimes after a shower an arch appears in the heavens composed of beautiful colors; we call this a *rainbow.* In this case the sunlight is broken into its different colors by the drops of water or little ice crystals in the air, just as it is when passing through a prism.

Sometimes the sun or moon is surrounded by bright rings called, when of small diameter, *coronas*, and when of great diameter, *halos.* These rings are due to the effect of water or ice particles on the light coming from the sun or the moon.

Under certain conditions it may happen that light coming from objects at a distance is so refracted and reflected by the layers of air of different density, through which it comes to the eye of the observer, that objects appear to be where they are not, like the image of a person seen in a mirror. This phenomenon is called *mirage* or *looming.* It occurs most frequently on deserts and over the sea near the coast.

Sometimes in high latitudes arches and streamers of colored light are seen illuminating the northern sky. The



LICK OBSERVATORY.

As light is affected by the atmosphere, observatories must be placed where atmospheric conditions are the best. This famous observatory is on a mountain in the clear air of California.

brilliancy and colors of the illumination vary. Sometimes it is bright enough to be seen even in the daytime. This display is called the *aurora borealis* or "northern lights" and is believed to be an electrical phenomenon in thin air. The heights of the streamers have been calculated to be more than a hundred, perhaps several hundred miles, so that it is probable that air in a rare condition extends to this elevation.

64. The Warming of the Atmosphere. — The sun transmits both light and heat to the surface of the earth through the atmosphere. On the top of a high mountain the temperature is found to be colder than on the lower levels. The amount of sun radiation, technically called *insolation*, that falls upon a given surface on the mountain is about the same as that which falls upon an equal surface in the valley. If the heating effect is less, it must be due to something besides the number of heat rays intercepted.

In the spring when gardeners wish to hurry the growth of their plants, they cover them with boxes, the tops of which are made of glass (Fig. 63). It is found that the temperature within the boxes is higher than that outside. The heat rays coming from the sun are in some way affected by the reflection of the ground so that they are not able to get out through the glass as readily as they get in.

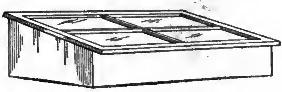


Fig. 63.

Now the atmosphere affects the heat rays reflected from the earth in the same way that the glass does, and keeps them from flying back into space and leaving the surface cold. Where the atmosphere is thin, as on the mountains, this effect is not so great, and therefore the surface is colder and often covered with snow. When there are clouds in the air, they help to hold in the heat. That is why in the fall, when it is getting cold enough for frosts, the farmers say that the frosts are likely to come on clear nights but not on cloudy ones.

For the same reason plants are covered by pieces of paper and smoky fires are built around cranberry bogs to cover them with an artificial cloud of smoke on nights when there is likely to be a frost. Thus the atmosphere acts as a blanket to the earth and keeps in the heat of the sun just as blankets on a bed keep in the heat of the body. If there were no atmosphere on the earth, its surface would become intensely hot during the day, when the sun shines directly upon it, and intensely cold at night, so that it would not be possible for life to exist.

It has been estimated that, if there were no atmosphere, the mean temperature of the earth's surface during the day would be 350° F. and during the night – 123° F. Thus the atmosphere is not only needed for the breathing of plants and animals and for carrying moisture, but also for keeping in the heat of the sun. On the moon, where there is no atmosphere, there can be no life as we know it.

65. Cause of the Variation in Atmospheric Temperatures. — **Experiment 76.** — Cut a hole 4 in. square in the center of a board 12 in. square. Fit tightly into this hole one end of a wooden tube 4 in.

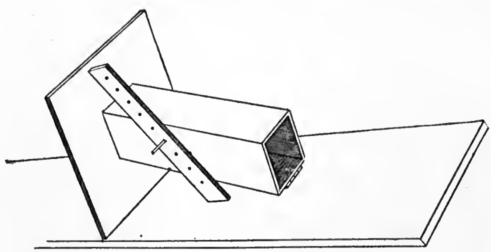


Fig. 64.

square and 1 ft. long. Paint the inside and outside of the tube a dull black. Hinge the opposite end of this tube 10 in. from the end of a baseboard 2 ft. long and 16 in. wide, having 6 in. of the board on either side of the tube.

On a clear day place this apparatus out of doors on a table freely exposed to the sun with a piece of paper on the baseboard under the end of the tube. Point the tube directly at the sun in the early morning, in the middle of the forenoon, at noon, in the middle of the afternoon and about sunset. Mark on the paper the amount of surface illuminated by the sunlight passing through the tube at each of these different times. Why are different amounts of surface covered at these different times?

Place a thermometer in the centers of the surfaces covered by the sunlight passing through the tube at these different times. Note the different readings of the thermometer. Can you suggest a reason why they are not alike? The opening exposed to the rays has been the same throughout the experiment. Draw diagrams illustrating the action of the sun's rays in the different positions.

The number of rays of the sun which fall upon a given area depends upon the angle at which they strike the surface. Figure 65 shows that the same number of rays fall

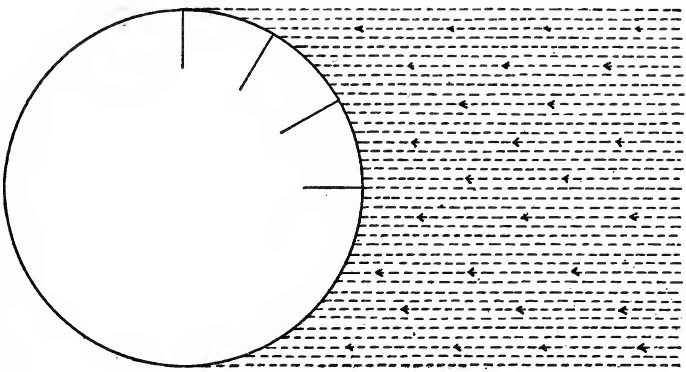


Fig. 65.

upon a much smaller surface when the direction of the sun is vertical than when it is nearly horizontal. In the 30-degree arcs there are $2\frac{1}{2}$, 7, and $9\frac{1}{2}$ ray spaces respectively. The sun is here considered to be vertical at the equator, as it is on March 20 and September 23. Thus on these days, other conditions being the same, about one fourth as much heat from the sun falls upon the 30° about the pole as upon the 30° north of the equator.

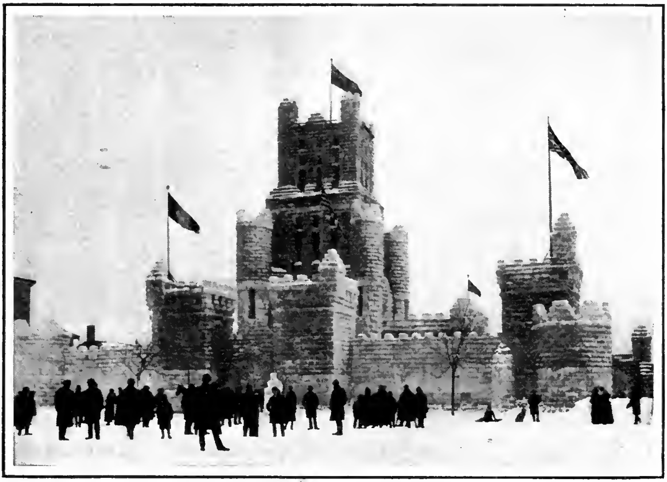
The latitude of a place has much to do with the amount of heat that it receives. As the sun becomes vertical to places north of the equator, the length of the day in the northern hemisphere increases and the time that a place is in the sunshine is greater, so that it receives more heat from the sun. On the 21st of June all points within $23\frac{1}{2}°$ of the north pole, as at North Cape, have 24 hours of sunshine, and the amount of heat received at the pole during these 24 hours is greater than that received at the equator where the day is only about half as long.

A Winter Scene in Venice.

Although the latitude of a place has much to do with the amount of heat received, there are also many other things which affect its temperature. This will appear when we consider that Venice, Italy, with its mild and equable climate is in almost the same latitude as Montreal, Canada.

As has been seen, the height above the sea makes a difference with the temperature, since there is less thickness of air above and therefore a thinner blanket to hold the heat. Then, too, the kind of soil affects the temperature. If the soil is sandy and there is little or no vegetation, it becomes rapidly heated in the daytime and radiates back the heat into the air very rapidly, thus making the temperature of the air near the surface very hot during the day; while at night, when the sun is not adding heat, it rapidly loses the heat acquired during the day, and so the temperature of the air becomes low. In the daytime on great sandy deserts the heat is almost unbearable, but at night it is so cold that heavy blankets are needed to keep the traveler warm.

The nearness to the sea and the direction of the wind also greatly affect the temperature of a place. In some parts of the earth these are the principal causes in determining the temperature. Thus the temperature of the



A WINTER SCENE IN MONTREAL.

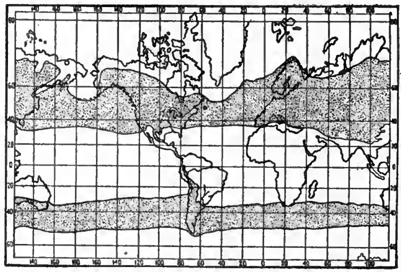
The famous Ice Palace, built entirely of blocks of ice.

atmosphere at any place is not due to a single cause, but is the result of many and complex causes, such as latitude, height, direction of prevailing winds, ocean currents, nearness to the sea, and kind of soil.

Maps are sometimes constructed showing heat belts where tropical, temperate and frigid conditions are found. These belts do not correspond very closely to the torrid, temperate and frigid latitude zones.

66. **Graphic Method of Showing the Temperature of a Region.** — It is often quite essential that the temperature

over a considerable region should be known and a record of it made and preserved. This might be done by taking a map and writing their temperatures above the different places marked on the map. This would make a map full of small figures and very difficult to read.



HEAT BELTS.

Notice how these heat belts vary from the latitude zones shown on Figure 10, page 25.

A much better method has been developed and is now almost universally used. In making this map the temperatures are first written on the map and then lines are drawn through places which have the same temperature. These lines are called *isotherms* and the map is called an *isothermal map.* By the use of such a map it is possible at a glance to determine the temperature prevailing at any place and to see the relation which this has to the temperature of other places on the map. As a rule the isotherms are not drawn for each degree, but only for each ten degrees.

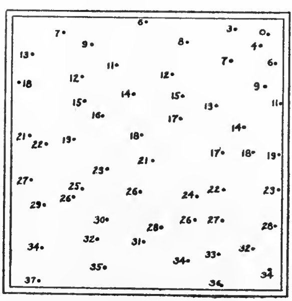
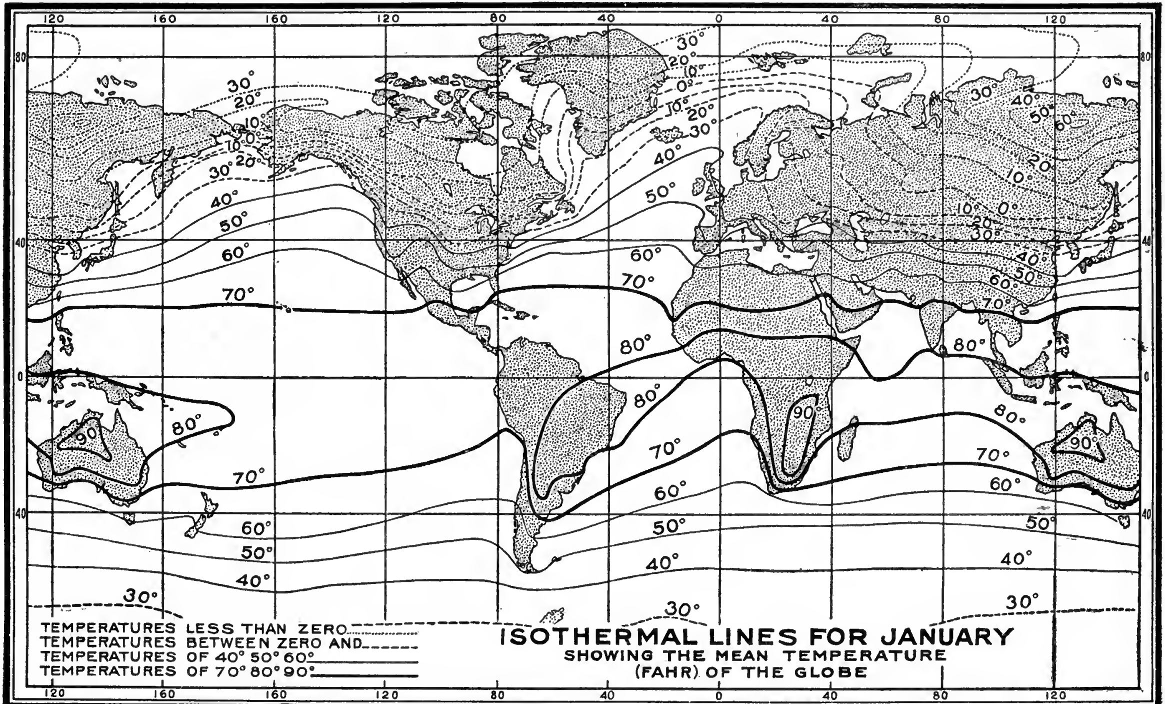
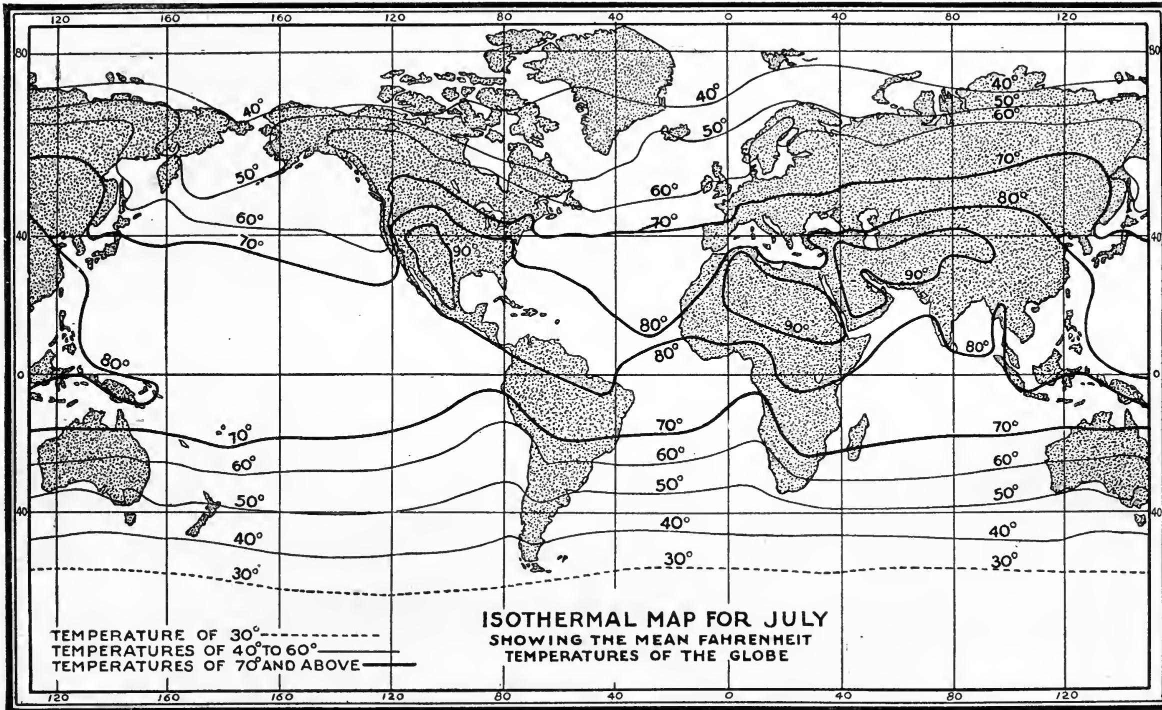


Fig. 66.

When the map has been constructed, copies are made in which the figures are left off and only the isotherms are preserved. In Figure 66 we have a plan before the isotherms are drawn, and in Figure 67 after the isotherms are drawn. Figure 68 is a typical isothermal diagram. If the map itself were sketched, it would be an isothermal map.



ISOTHERMAL LINES FOR JANUARY
SHOWING THE MEAN TEMPERATURE
(FAHR) OF THE GLOBE



ISOTHERMAL MAP FOR JULY
SHOWING THE MEAN FAHRENHEIT
TEMPERATURES OF THE GLOBE

Maps recording barometric conditions are made in the same way as the isothermal maps, only their lines pass through places of equal barometric pressure instead of places of equal temperature. These lines are called *isobars*.

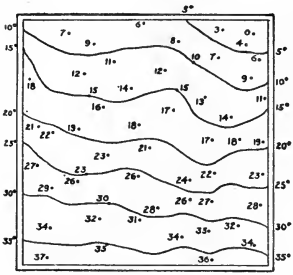


Fig. 67.

Weather maps are prepared by the United States Weather Bureau every day, on which are both the isotherms and isobars for that day. The data for these maps are telegraphed each morning from stations scattered all over the settled part of North America.

67. Weather Maps. — Expensive weather bureaus are maintained not only by the United States, but by all the other highly civilized countries of the world. Records are kept also by sea captains and by other observers throughout the world, and these are gathered together by scientific men and from them are made charts of the weather conditions over the entire surface of the earth. Every year more and more data are being collected and these charts are becoming more and more reliable.

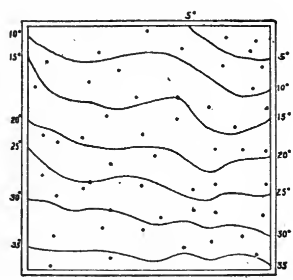


Fig. 68.

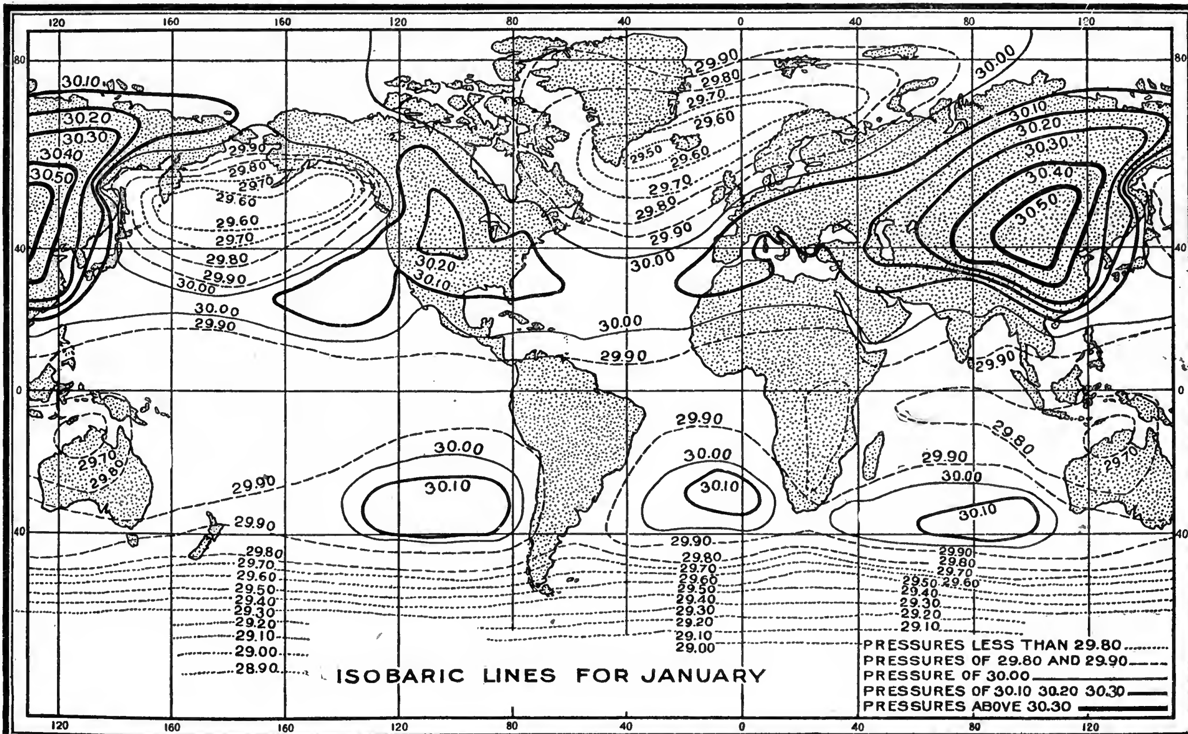
These charts are of great value, since they aid in the explanation of climatic conditions in different parts of the world. The results of the data thus gathered together have been of untold service to commerce and each year have saved many lives and a vast amount of wealth. On pages 136 and 137 are isothermal maps of the world for the months of January and July.

68. Land and Water Temperatures. — As was seen in Experiment 27, water has the power to hold a great amount of heat. During the summer, water is heated less rapidly than the air above it, so it continually extracts heat from the air, making the air cooler than it otherwise would be. In the winter, water loses its heat less rapidly, so, being warmer than the air above it, it constantly gives heat to the air. Consequently the air over large bodies of water changes its temperature less rapidly than does the air over the land.

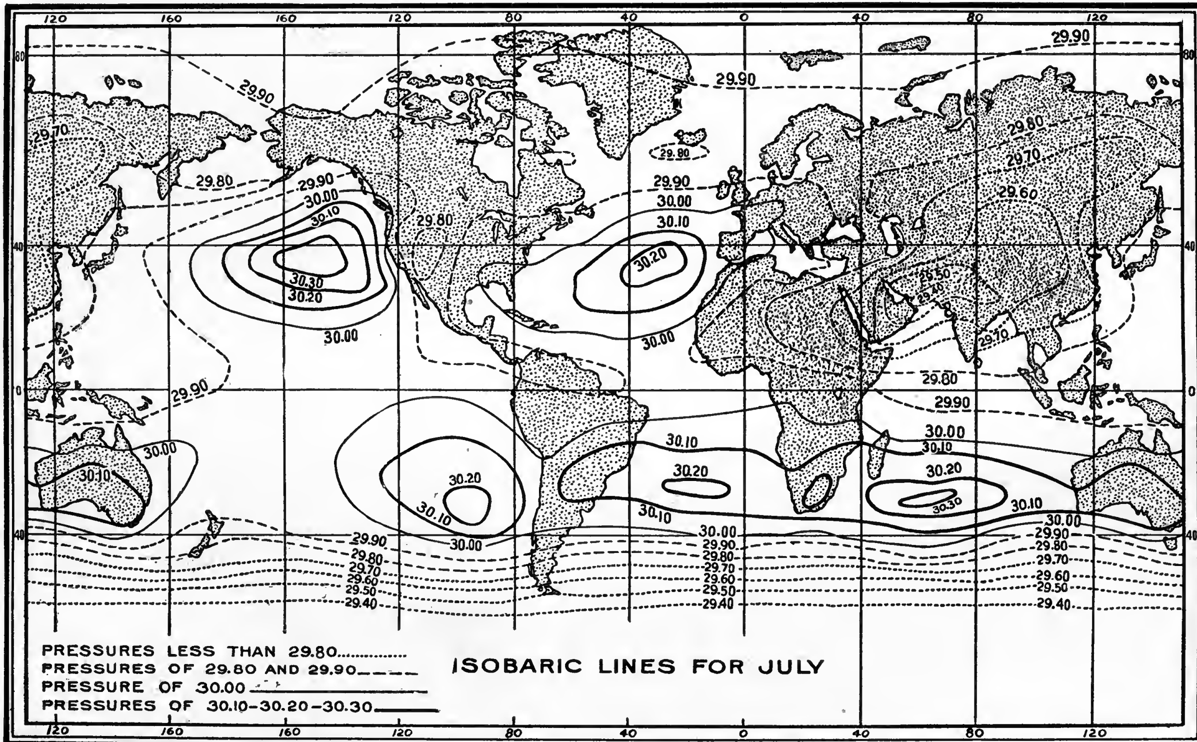
When air moves in wind from the ocean to the land, it cools the land in summer and warms it in winter. It is found therefore that lands which border on the ocean usually have a smaller range of temperature than those which are far from the sea. On some islands the range of temperature throughout the year is almost imperceptible, whereas in the interiors of continents the average temperature of some of the summer months is more than a hundred degrees higher than that of some of the winter months.

69. Distribution of Air Pressure over the Earth. — An examination of the isobar maps for January and July (pages 140 and 141) shows that atmospheric pressure, like temperature, is greatly affected by land masses. In the southern hemisphere, south of 40° latitude where there is little land, the isobars are very regular in their directions and nearly parallel to the parallels of latitude. North of this in the same hemisphere they are somewhat affected by the land, but the sea is still the predominant influence.

In the northern hemisphere, however, the land and water are much more equally divided and here the effect of the land masses is at once apparent. In the winter the high-pressure areas and the low-temperature areas are found over the land, but in the summer, the low-pressure



ISOBARIC LINES FOR JANUARY


ISOBARIC LINES FOR JULY
PRESSURES LESS THAN 29.80
PRESSURES OF 29.80 AND 29.90
PRESSURE OF 30.00
PRESSURES OF 30.10–30.20–30.30

areas and the high-temperature areas are over the land. This illustrates what we have already learned; that land heats and cools much more rapidly than water and that hot air is lighter than cold air.

In both summer and winter there is an area of comparatively high pressure on either side of the equator, but this area is not fixed; it moves north and south. In summer it is farthest north in the northern hemisphere.

The winds are simply a transfer of air from a place where the pressure is high to a place where it is low, or a transfer of air along what are called *barometric gradients* from a high barometer to a low barometer. So the above-mentioned changes in the relation between the pressure on the land and on the sea must have an effect upon the directions of the winds. As a rule the wind blows out from the land interiors in the winter and into these interiors in the summer. It is thus seen that isotherms and isobars are closely related to each other, and that the wind is but a result of the atmospheric conditions which they represent.

70. Wind. — **Experiment 77.** — On a day when the temperature in the room is considerably higher than that outside, open a window at the top and bottom and hold a strip of tissue paper in front of the opening. Is there an air current, and if so, in what direction does it move at the top and at the bottom of the window? What causes "drafts" in a room?

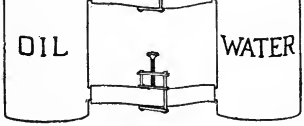


Fig. 69.

Experiment 78. — Procure two similar dishes about 15 cm. high and 5 or 6 cm. in diameter with short tubes of about 1 cm. in diameter opening out from near the top and bottom. Connect the bottom tubes of the two dishes with a tightly fitting rubber tube. Do the same with the top tubes. Place a Hoffman's screw upon each of the rubber tubes and screw it tight so that no liquid can flow through either tube. Fill one of the dishes with colored water and the other with kerosene or some light oil.

Although the two liquid columns are similar, yet the pressure at the bottom of the dish of water will be greater than that at the bottom of the dish of oil since the water is heavier than the oil. These are the conditions that exist on the surface of the earth at two places one of which has a high and the other a low barometer. Release the Hoffman's screw upon the top tube and then the one at the bottom. Notice carefully what happens as the lower tube is allowed to open. The dishes are not now filled with oil and water respectively. In the transfer of the liquids, through which tube did each pass? (If part of each rubber tube is replaced by a glass tube, the action in the experiment can be seen to better advantage.)

Experiment 79. — Fill a convection apparatus with water, putting in a little sawdust and mixing it well with the water. Heat one side of the tube and observe the convection currents set up.

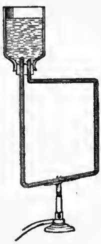


Fig. 70.

In Experiment 78 the interflow from one dish to the other is due to the fact that the water is heavier than the oil and runs under it and pushes it up so that the oil overflows into the dish that the water has left. The same thing happens in the atmosphere when from any cause the column of air above one place becomes heavier than that above another place. There will be under these conditions a transfer of air, along the surface, from the place where the pressure is greater to that where it is less great, and this movement of the air we call *wind*.

The wind on the surface of the earth is not usually in the same direction as that high up. The strength of the wind depends upon differences in air pressures. As the air pressure is measured by the barometer, the wind is commonly spoken of as due to a difference in *barometric pressure* or to the *barometric gradient*. Winds are named from the direction from which they come. A west wind is a wind that blows *from* the west.

If there were no other forces that affected the movement of the air, except the high and low pressures, the transfer would be in a straight line from one place to the other, and it could always be told in what direction the high and low pressures were, by direction of the wind. But obstacles like mountains and hills deflect the air currents. There are also other causes which influence the direction of the movement; chief among these is the rotation of the earth on its axis.

71. Velocity and Effect of Wind Action.—The velocity of air movement varies from a gentle breeze which has not force enough to stir the leaves, to the terrific and almost irresistible blast of the tornado, which sometimes attains a velocity of a hundred miles an hour and sweeps everything before it. The velocity of ordinary wind is measured by an instrument called an *anemometer*, which usually consists of four aluminum cups attached by horizontal arms to a vertical spindle, the number of revolutions of which is recorded on a dial by a train of cogwheels geared to the spindle (Fig. 71).

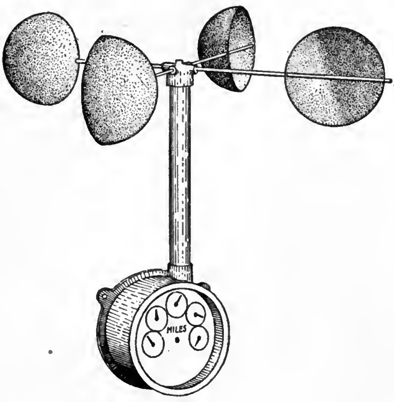


Fig. 71.

When the wind has great velocity, it can be estimated only by the pressure which it exerts. A measure for the velocity of wind which needs no apparatus is given by Professor Hazen and is as follows:

0. Calm.
1. Light; just moving the leaves of trees.
2. Moderate; moving branches.

3. Brisk ; swaying branches ; blowing up dust.

4. High ; blowing up twigs from the ground, swaying whole trees.

5. Gale ; breaking small branches, loosening bricks on chimneys.

6. Hurricane, or tornado ; destroying everything in its path.

Although the wind in its great paroxysms of rage is sometimes very destructive, it is ordinarily a most benefi-

A Dutch Windmill.

Windmills are widely used to pump water.

cent force. It is the circulatory medium for the earth ; as the blood is for the animal and the sap for the plant. Without it the activities of the earth would stagnate. It spreads over the land the water evaporated from the sea. It cools the hot regions with the invigorating breath from the mountains and the uniformly tempered sea. It warms the cold places by bearing to them the heat taken from the warm ocean waters and the parched places of the earth.

It bears man's commerce across the seas and by the power of the water which it has borne over the land, furnishes him the means for his manufacturing. It scatters the seeds over the fields and sweeps the smoke and foul air away from his cities.

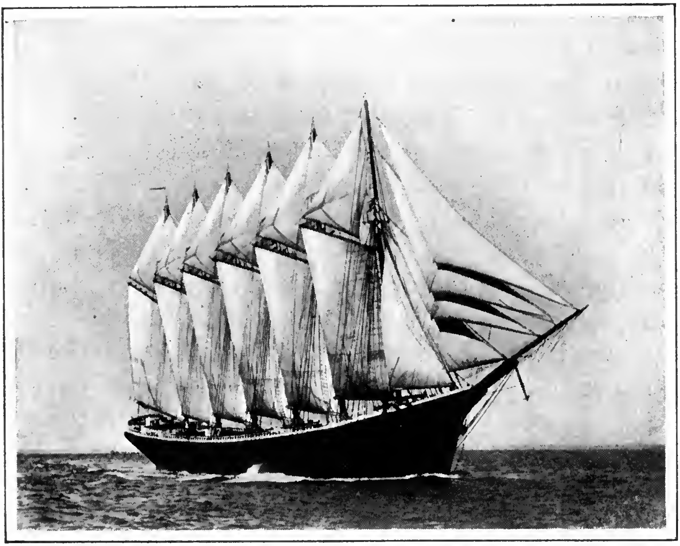
EFFECT OF WIND ON THE GROWTH OF TREES.

The trees have grown in the direction in which the prevailing wind blows.

72. The Effect of the Earth's Rotation on Winds. — **Experiment 80.** — Revolve a globe from left to right and while it is revolving draw a piece of chalk from the pole toward the equator. Does the line as marked on the globe follow a meridian? What is its general direction in lower latitudes?

The rotation of the earth affects the direction of movement of all bodies free to move over its surface. Thus if a current of air starts from the north pole to flow south, it will, as it goes along, tend to move toward the right, and so when it reaches middle latitude it is no longer moving south but southwest. Why this is so can be fairly well understood if the conditions of this moving body of air are considered.

As the earth is about 25,000 miles in circumference and turns on its axis once in 24 hours, a body situated at the equator is carried from west to east at the rate of about 1000 miles per hour, whereas a body at the poles simply



A SAILING VESSEL.
Showing how the wind is used in commerce.

turns around during a revolution. Thus as we go on the surface from the poles toward the equator, each point has an increasing west to east velocity.

A body of air, not being attached to the surface, will have this west to east velocity imparted to it very slowly by friction. Thus as it goes from higher to lower latitudes, it will lag behind particles on the surface which have this west to east velocity, and so will appear to have an east to west motion, just as a person sitting in a train that is just starting appears to be sitting still and the objects outside seem to move in the opposite direction. The combination of the north to south movement with the apparent east to west movement gives a northeast southwest direction to the air current.

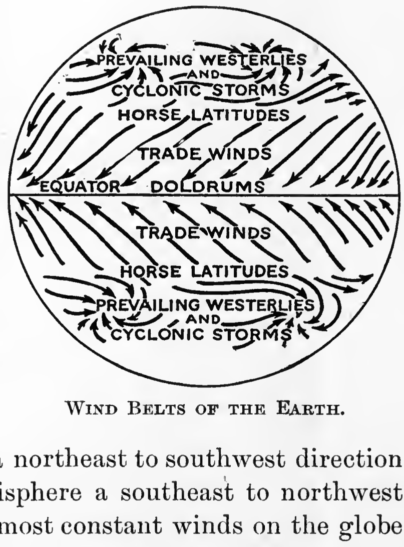
It can be proved mathematically that all freely moving bodies on the earth's surface are deflected toward the right in the northern hemisphere and toward the left in the southern hemisphere. This statement is called Ferrel's law.

73. **Planetary Wind Belts.** — As the air at the equator receives a large amount of heat, it becomes warm and light, while that near the poles is cold and heavy. The air would thus have a constant tendency to move along the surface of the earth toward the equator and in an upper current from the equator toward the poles, just as in the dishes where water and oil were connected. But this direct movement is affected by the rotation of the earth and by certain atmospheric conditions so that between 25° and 35° both north and south of the equator there is an area of high pressure. These high-pressure areas can be seen on the isobar maps of January and July.

From these areas of high pressure the surface currents move both toward the equator and toward the poles. On account of the earth's rotation the directions of these movements are not north and south but in the northern hemisphere northeast and southwest. Winds of this kind must occur on every revolving planet having an atmosphere; hence these winds are called *planetary winds*.

As the rotation of the earth and the heating of the air near the equator are conditions that do not change, among the most permanent things about our planet are the belts into which the wind circulation is divided. The change in the position of the *heat equator*, — the belt of highest temperature, — due to the apparent movement of the sun north and south, modifies the conditions in these wind belts during the year. The planetary winds thus modified are sometimes called *terrestrial winds.*

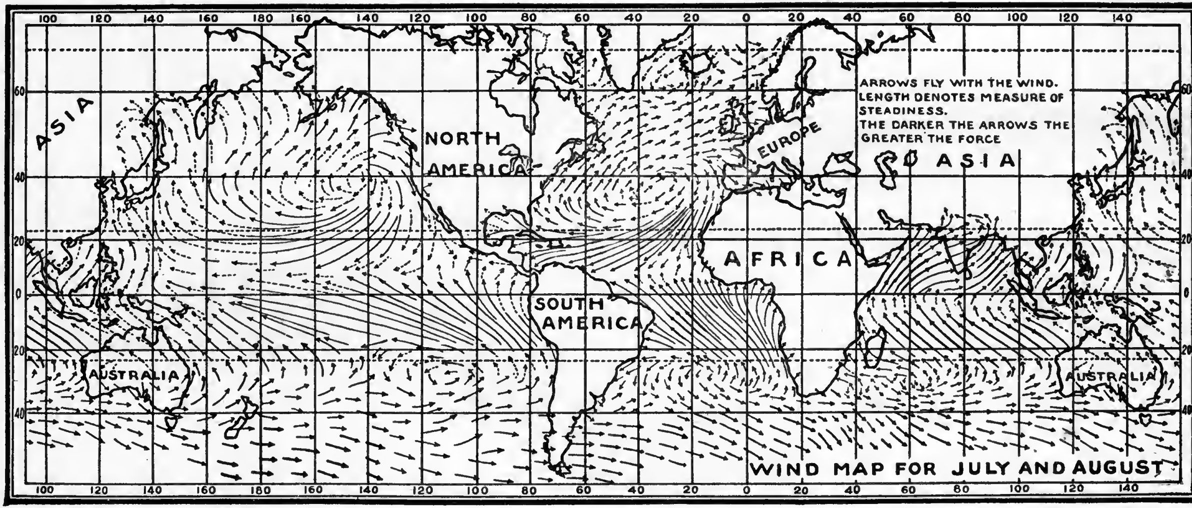
74. Wind Belts of the Earth. — Near the heat equator where the air is rising there is a belt of calms and light breezes called the *doldrums.* As the air here is rising and cooling, thus having its capacity to hold moisture decreased, this is a cloudy rainy belt of high temperature in which much of the land is marshy and the vegetation so rank and luxuriant that agriculture is exceedingly difficult.

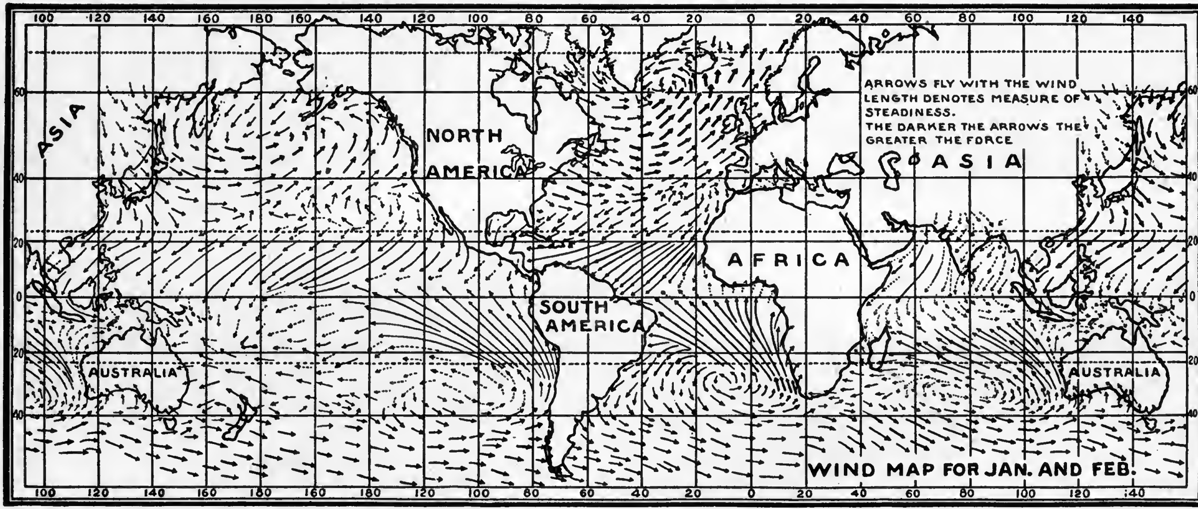


WIND BELTS OF THE EARTH.

Extending north and south of the doldrums to about 28° of latitude are belts in which constant winds blow toward the doldrum belt and supply the air for the upward current there. In the northern hemisphere these winds have a northeast to southwest direction and in the southern hemisphere a southeast to northwest direction. They are the most constant winds on the globe in their intensity and direction, and are called *trade winds.* Since they blow from a cold region to a warmer region, their power to hold moisture is constantly increasing and clouds and rains are not usual. The places where they blow are dry belts and in them are found the great dry deserts of the world.

On the poleward sides of the trade-wind belts lie the areas of high pressure already referred to. These are


ASIA
NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
AUSTRALIA
AUSTRALIA
ARROWS FLY WITH THE WIND.
LENGTH DENOTES MEASURE OF STEADINESS.
THE DARKER THE ARROWS THE GREATER THE FORCE
WIND MAP FOR JULY AND AUGUST



WIND MAP FOR JAN. AND FEB.

called the *horse latitudes* or *belts of tropical calms* and are rather ill-defined. The air is here descending and the surface movements are light and irregular. These, like the doldrums, are regions of calms. But unlike the doldrums, they are dry belts, since the temperature of the descending air is increasing, owing to adiabatic heating (§ 59), and thus its power to hold moisture is increasing. Therefore the tendency in these belts is to take up moisture rather than to deposit it.

In the middle latitudes there is a belt of irregular winds which have a prevailing tendency to move from west to east or northeast. This general eastward drift of the air is constantly being interrupted by great rotary air movements having a diameter of from 500 to 1000 miles. These are called *cyclones* and *anti-cyclones*. In this region of the "westerlies," since the air tends to move from lower to higher latitudes, an abundance of moisture is usually supplied.

In the anti-cyclone the air movement is slowly downward and outward from the center and in the cyclone it is inward toward the center, and upward. The center of the anti-cyclone is a place of clear sky and high pressure, while that of the cyclone is a place of cloudy sky and low pressure. The anti-cyclones, or high-pressure areas, have dry, cold, light winds, while those of the cyclones, or low-pressure areas, are usually strong and wet.

75. Land and Water Winds. — As the land is much more rapidly heated by the rays of the sun than is the water, the land during the daytime becomes hotter than the water near it. On this account the cool air over the water flows in over the land and displaces the lighter warm air. Therefore near large bodies of water when the temperature is high there is often in the daytime a wind blowing from the water to the land. At night, as the land loses its heat more rapidly than the water, the wind blows in the opposite direction. These water winds temper the climate of the tropics near the coasts and also render seaside resorts popular in summer.

76. Monsoons. — Over the interior of the great continent of Asia the temperature becomes so high in the summer months that the air above it is greatly expanded and decreases in weight. This causes a strong indraft from the colder ocean. The high temperature also brings the heat equator far north of the earth's equator and causes the

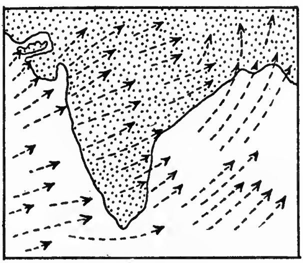


Fig. 72.

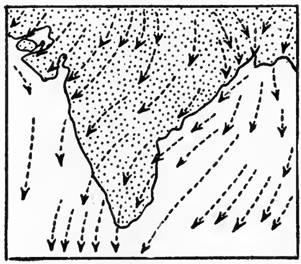


Fig. 73.

southeast trade winds to cross the earth's equator. These swing to the right on the north side of the equator and proceed as southwest winds (Fig. 72), thus greatly strengthening the air movement toward the heated continental interior.

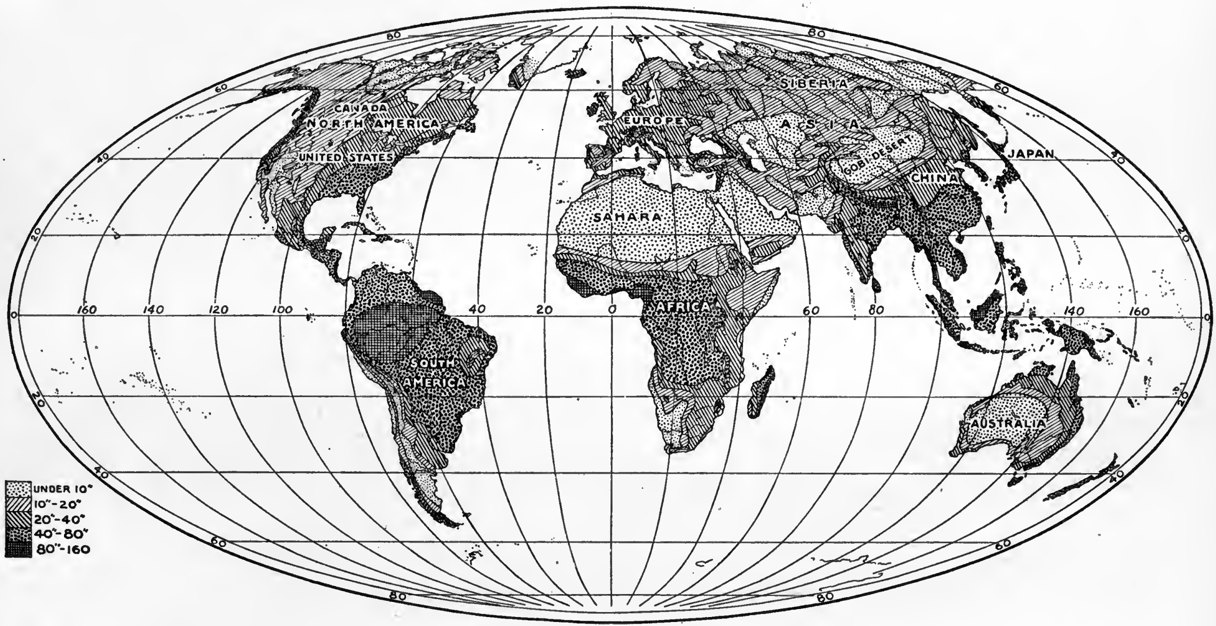
The winds, being heavily loaded with moisture from their passage over the tropical seas, are forced to rise when they come upon the high lands of India near the coast. There they become cooled and deposit a great amount of rain, making this southern part of Asia the place of greatest rainfall on the earth.

In the winter, when the heat equator has moved south and when the continental interior has become exceedingly cold, there is a strong movement of air out from it toward the warmer ocean (Fig. 73). This strengthens the northeast trade winds over the Indian Ocean. It thus happens that near the southern coast of Asia there are strong seasonal winds that blow toward the northeast in summer and toward the southwest in winter. These winds are called *monsoons*. In the early sailing voyages to India they were very important, the trip to India being made so as to utilize the summer monsoons and that from India so as to utilize the winter monsoons. On this account these winds had much to do with the conquest of India by the nations of Europe.

77. Rainfall and its Measurement. — **Experiment 81.** — Place a dish with vertical sides in a large open space so that the rim is horizontal and at a height of about one foot above the ground. Fasten the dish so that it cannot be overturned by the wind. After a rain, measure the water that has collected in the dish to the smallest fraction of an inch possible. This will be the amount of rainfall for this storm.

The amount of rainfall during the year varies greatly in different places. It amounts to nothing or only a few inches over some regions, as in parts of Peru where rain falls only on an average of once in five years. But in the Khasi Hills region of India it has been known to be over 600 inches; and over 40 inches, or about the average yearly rainfall for the eastern United States, has been known to fall in 24 hours. This was in the season of the southwestern monsoons.

The rainfall in different parts of the earth has been carefully measured and maps showing its average amount prepared. As agriculture is largely dependent upon the amount of rain and the season of the year in which it falls, these maps tell much about the relative productivity of different regions of the earth. An annual total of eighteen or more inches is necessary for agriculture; and this must be properly distributed throughout the year.



RAINFALL MAP OF THE WORLD.

On examining the map of the mean annual rainfall, we see that there are large areas where it is not sufficient for agriculture without irrigation. Such areas are within the belts of dry winds or in continental interiors far from large bodies of water. The rain-bearing winds coming from the water are forced to rise and cool so that their moisture is deposited before reaching these interior regions.

The rainfall of a place depends largely: (1) upon its elevation, since most of the rain-bearing clouds lie at low altitudes; (2) upon the direction and kind of winds that blow over it; and (3) upon the elevation of the land about it. The sides of mountains toward the direction from which the rain-bearing winds approach will be well watered, while the opposite side may be a dry desert. Explain the cause of the dryness of five of the great dry regions as found on the map on page 155.

A cylindrical vessel having vertical sides, called a *rain gauge* (Fig. 74), is used to determine the amount of rain. It is placed in an open space away from all trees and buildings and after each rain the amount collected is measured. Snow is melted before it is measured. As a rule eight or ten inches of snow make an inch of rain.

Fig. 74.

If the temperature is below the freezing point, 32° F., when condensation takes place, the moisture of the air will form into a wonderful variety of beautiful six-rayed snowflakes. These float downward through the air and often cover the ground with thick layers of *snow*. Although snow is itself cold, yet it keeps in the heat of the ground which it covers, so that in cold regions soil which is snow-covered does not freeze as deeply as that without snow. Therefore, to keep water pipes from freezing, it is not necessary to bury them as deeply in localities where snow is abundant as in places equally cold where snow seldom falls.

If raindrops become frozen into little balls in their passage through the air, they fall as *hail*. Hail usually occurs in summer and is probably caused by ascending currents of air carrying the raindrops to such a height that they are frozen and often mixed with snow before they fall. Sometimes hailstones are more than a half inch in diameter. They occasionally do great damage to crops and to the glass in buildings.

Sleet is a mixture of snow and rain.

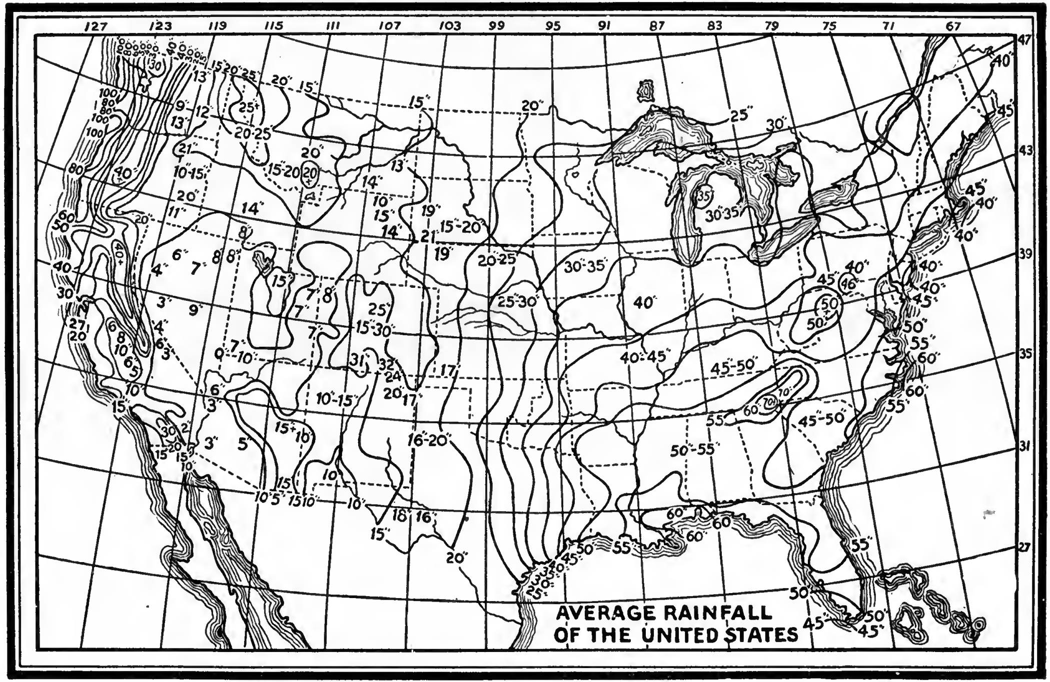
78. Rainfall of the United States. — An examination of a rainfall map of the United States (page 158) will show that the distribution of rainfall can readily be divided into four belts which, although gradually shading the one into the other, are yet quite distinct. These belts may be called the north Pacific slope, the south Pacific slope, the western interior region, and the eastern region.

SALMON RIVER DAM, IDAHO.

A typical irrigation dam in the United States.

In the north Pacific coast region the storms of the "westerlies" are common, particularly in winter, when the westerly winds are strong and stormy. The yearly rainfall here amounts to about seventy inches.

From central California south the rainfall of the Pacific



AVERAGE RAINFALL OF THE UNITED STATES

slope decreases until, in southern California, there is almost no rain in summer and the entire rainfall for the year averages about 15 inches. By reference to the isobar map of the world (page 141) it will be seen that the high-pressure area of the dry tropical calm belt moves sufficiently far north in summer to take this region out of the influence of the wet westerlies and into that of the drier belt.

The western interior region, extending from the Cascade and Sierra Nevada mountains to about the 100th

EAST END OF THE ASSUAN DAM ACROSS THE NILE.
The greatest irrigation dam in the world.

meridian, is dry over the larger part of its surface, since the winds have deposited most of their moisture in passing over the mountains to the west. On the mountains and high plateaus, however, there is a considerable fall of rain, as the winds are cooled sufficiently in passing over these to deposit their remaining moisture. In most of this region, as in southern California, irrigation must be resorted to if agriculture is to succeed. The fall of rain on the mountains and high plateaus supplies rivers of sufficient size to furnish water for extensive irrigation, and so a considerable part of the area which is now practically a desert will in the future be reclaimed for the use of man. The government is at present engaged in extensive irrigation work in this territory.

From about the 100th meridian to the Atlantic Ocean there is a varying rainfall, but it is as a rule sufficient for the needs of agriculture. It gradually increases toward the east, moisture being supplied plentifully from the Gulf of Mexico and the Atlantic Ocean by the southerly and easterly winds. The rainfall is well distributed throughout the year and averages from thirty to sixty inches.

79. Electricity. — **Experiment 82.** — Place some small pieces of paper or pith balls on a table and after rubbing a glass rod with silk bring it near the pieces. Do the same with a stick of sealing wax or a hard-rubber rod rubbed with flannel or a cat's skin. Note the action of the pieces.

Experiment 83. — Rub a glass rod briskly with silk and place in a wire sling such as was used in Experiment 12. Bring toward one end of the glass rod another glass rod which has been rubbed with silk. Do the rods attract or repel each other? Bring toward the suspended rod a piece of sealing wax or a vulcanite rod which has been rubbed with flannel or a cat's skin. Does this repel or attract the glass rod?

Experiment 84. — Suspend a pith ball by a silk thread from the ring of a ring stand. Rub a glass rod with a piece of silk and bring it near the pith ball but do not allow the two to touch. Note the action of the ball. Touch the pith ball with the rod. Does it behave now as it did before? Rub a vulcanite rod with a piece of flannel or cat's skin and bring it near a suspended pith ball. Does the pith ball act as it did with the glass rod? Touch the pith ball with the rod. How does it act? Bring a glass rod rubbed with silk near a pith ball which has been in contact with a vulcanite rod after it was rubbed with flannel or a cat's skin. Does the glass rod repel or attract the ball?

Experiment 85. — Suspend a pith ball from the ring of a ring stand by a very fine piece of copper wire no larger than a thread. Wrap the wire around the pith ball in several directions. Bring a rubbed glass rod toward the pith ball. Does it act as it did when suspended by silk? Allow the ball to touch the rod. Does the ball now act as it did when suspended by silk? Try these same experiments, using the vulcanite rod.

It was known by the ancient Greeks that when certain substances, one of which was amber, were rubbed, they had the power of attracting light objects. This property was afterward called *electricity*, from the Greek word for *amber*. From the previous experiments it has been seen that when glass is rubbed with silk, and vulcanite with flannel or a cat's skin, they seem to have two different kinds of electrical charges. The like kinds repel each other and the opposite kinds attract. These two kinds are called *positive* and *negative* respectively.

Whether there are really two kinds of electricity has not yet been fully determined, but electricity acts exactly as it would if there were two kinds, and it has become customary to speak as if there were. In Experiment 84 it was found that pith balls suspended by a silk thread could be charged with electricity if brought in contact with a charged body. Experiment 85 showed that this was not possible when they were suspended by a copper wire. The wire conducted the electricity away. Substances like copper that conduct electricity are called *conductors*, and those substances like silk which will not conduct it, *nonconductors*.

Experiment 86. — Having started the electrical action in a static electrical machine (Fig. 75), pull the knobs as far apart as the spark will jump and notice the course taken by the spark. Does it travel in a straight line? Hold a piece of cardboard between the knobs so that its edge is just within the line joining them. What effect does the cardboard have upon the direction taken by the spark? Place the cardboard so that it entirely covers one of the knobs. Is the spark able to pass through the card? Attach a wire with a sharp point to each of the knobs and extend it vertically two or three inches above the knob. Start the machine. Do sparks now jump across between the knobs? Why are houses provided with lightning rods?

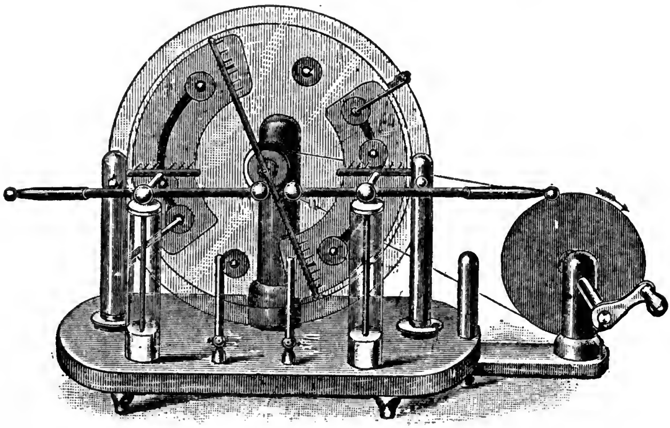
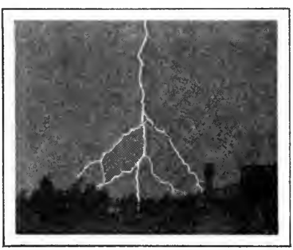


Fig. 75.

About the middle of the eighteenth century, Benjamin Franklin proved by his notable kite experiment that lightning was simply an electrical discharge between the clouds and the earth, or between different clouds. This discharge is similar to that which takes place on an electrical machine. The electricity in the clouds attracts as near as possible the opposite kind of electricity on the earth's surface and tends to hold it accumulated on high objects. If the attraction is sufficient, the electricity discharges between the cloud and the object, and we say the object was *struck by lightning.*



A FLASH OF LIGHTNING.
Showing it takes different paths of least resistance.

If a sharp point, such as a lightning rod, is present on the object where the electricity tends to accumulate, it allows the electricity to pass off gradually before enough accumulates to cause damage. Lightning rods, however, must be continuous conductors and properly terminated in the ground.

Tree Completely Shattered by a Stroke of Lightning.

80. Thunder-storms. — Often on a hot, sultry summer afternoon large cumulus clouds are seen to rise and spread out till they cover the sky. The wind soon begins to blow quite strongly toward the cloud-covered area, the clouds moving in a direction opposite to the surface wind. As the storm clouds approach, a violent blast of wind, often called the *thunder squall*, blows out from the front of the storm. Soon flashes of lightning appear and thunder is heard. As the storm comes nearer, the rain begins to descend and for a short time, usually about half an hour, it rains heavily. Then the clouds roll away and the sky becomes clear with perhaps a rainbow to heighten the beauty of the clearing landscape.

Thunder-storms are caused by hot moist air rising over certain areas and causing an updraft, which is increased by the inflow and upward movement of air from the surrounding regions. The condensation of the moisture in the rising air quickly forms clouds, and these become charged with electricity. As the electrical charge increases, discharges take place which cause lightning flashes. These discharges occur along the lines of least resistance and are often very irregular and forked. As tall objects are likely to offer good paths for the discharge, it is safest to keep away from trees and walls during a thunder-storm.

The air becomes greatly agitated by the lightning discharges and makes us aware of this by the noise of the thunder, just as the agitation of the air caused by the

THUNDER-STORM CLOUDS.

discharge of a gun is made apparent to us by what we call the noise of the report. Since sound travels at about the rate of a mile in five seconds and the lightning discharge is practically instantaneous, the noise from different parts of the discharge will reach us at different times and to this and the echoing from clouds or hills is due the roll of the thunder. The distance of the flash can be told approximately by dividing the number of seconds between seeing the flash and hearing the thunder by five.

Frequently in the evening flashes called *heat lightning* are seen near the horizon. These are due to the reflection on clouds of flashes of lightning in a storm which is below the horizon. Thunder-storms occur sometimes in winter. They are very prevalent in the tropics.

81. Electrical Communication. — **Experiment 87.** — Attach one end of a wire to a pole of a dry cell and the other end to one of the binding posts of a telegraphic sounder. From the other binding post of the sounder lead a wire to the binding post of a telegraphic key. Connect the free binding post of the key with the free pole of the battery (Fig. 76). When the key is pushed down, the circuit is closed and the sounder clicks. If a relay can be procured, remove the sounder and connect two of the binding posts of the relay in the same way that the sounder was connected.

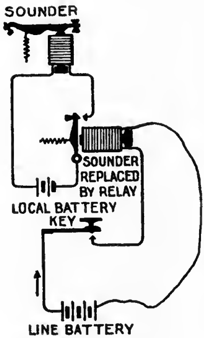


Fig. 76.

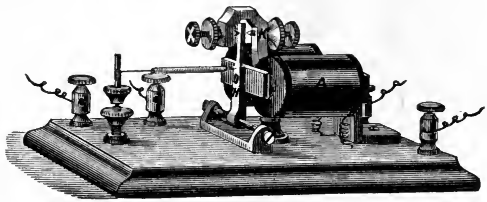


Fig. 77.

Connect one of the free binding posts of the relay with a binding post of the sounder and the other binding post with the pole of a dry cell. Connect the other pole of the dry cell with the free binding post of the sounder. When the key closes the circuit through the relay, the circuit through the sounder and its dry cell is closed by the relay (Fig. 77) and the sounder clicks. This is the usual arrangement in a simple telegraph office. The sounder in the first part of the above experiment can be replaced by an electric bell (Fig. 78) and the key by a push button, thus showing the arrangement of the ordinary doorbell.

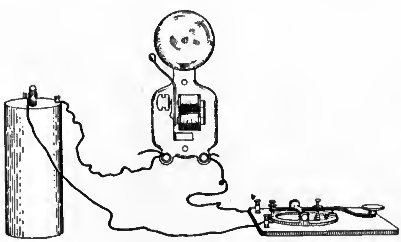


Fig. 78.

Electricity can be developed by chemical action as well as by friction, and many different kinds of *electrical cells* have been invented. The most simple of these is a sheet of copper and a sheet of zinc placed so that they do not touch and put in a dish containing dilute sulphuric acid (Fig. 79). The current developed by this cell is very weak. At the present time dry cells are used for almost all ordinary purposes in which electric batteries are needed.

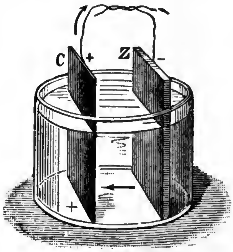


Fig. 79.

The history of the development of our knowledge of primary cells and current electricity is exceedingly interesting and important, but it cannot be dwelt upon here. In 1832 an American, Samuel F. B. Morse, invented the commercial telegraph. This was the first step in the wonderful progress that has been made during the last century in communicating rapidly between distant points. The necessary instruments used in this form of communication are a *sounder* (Fig. 80) and a *key* (Fig. 81).

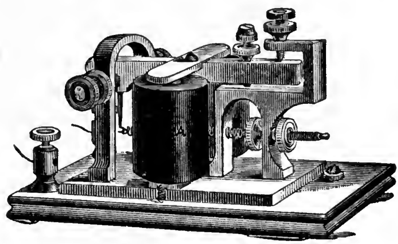


Fig. 80.

The sounder is simply an electro-magnet such as was made in Experiment 14, arranged to attract a piece of soft iron held at a short distance from it by a spring. When this piece of iron is attracted toward the magnet, it strikes on another piece of iron, making a click, and so remains drawn to the magnet as long as the circuit is kept closed.

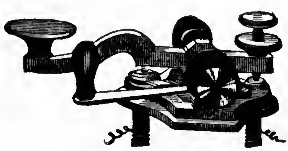
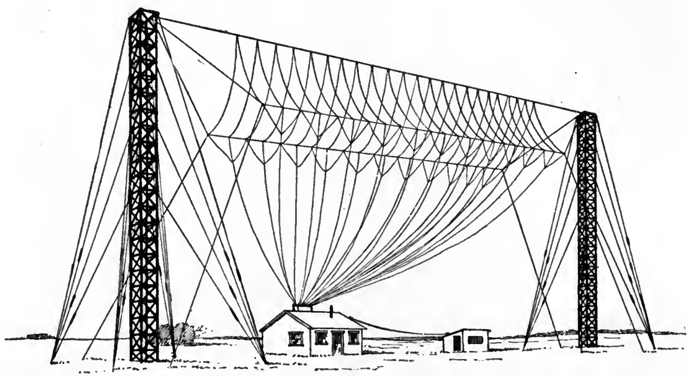


Fig. 81.

Thus long and short clicks can be made. Morse arranged a combination of these long and short clicks to represent the alphabet. Thus he was able to send words from one station to another. Experiment 87 illustrates how a simple telegraph can be arranged.

Many improvements have been made since Morse first sent a dispatch between Washington and Baltimore, but his dot-and-dash alphabet and the electro-magnet sounder and the key are still in use. Since 1832, the land has



WIRELESS TELEGRAPH STATION, LOS ANGELES.

been strung with telegraph wires and the ocean girdled with cables, and now an important event occurring in any part of the earth is known almost instantly in all other parts. The telephone, the wireless telegraph and the wireless telephone, all electrical devices, have added to the ease of communication so that the whole earth is brought into such close relation that every part knows what all the other parts are doing. No other form of energy which man has discovered is of such diversified usefulness as electricity.

82. Tornadoes and Waterspouts. — Sometimes causes like those which produce a thunder-storm are so strongly developed that the indraft is exceedingly violent and a furious whirling motion is produced. Such storms are called *tornadoes*. The warm moist air rises rapidly and spreads out into a funnel-shaped cloud with the vertex hanging toward the earth. In the center of the whirl the air pressure is much diminished and the velocity of the inrushing whirling wind is tremendous, being often sufficient to demolish all obstacles in its path.

A TORNADO.
Notice the funnel-shaped cloud.

The length of the path swept over by a tornado is rarely over thirty or forty miles and the width generally less than a quarter of a mile. The rate of progress in the Mississippi valley is from 20 to 50 miles an hour, usually in a northeasterly direction. These storms are often wrongly called *cyclones*. When storms of this kind occur at sea, a water column is formed in the funnel-shaped part of the storm and they then receive the name of *waterspouts*.

83. **Cyclones.** — In the belt of westerly winds are found, as has already been noted, large storm areas called *cyclones*. As the barometric pressure in the center of these areas is lower than that of the surrounding region, they are marked "Low" on the weather maps. Into these low-pressure areas the air from all directions is moving, but on account of the deflection due to the rotation of the earth, the wind

does not blow directly into them, but produces great whirls in which the air moves spirally inward and upward.

The rate at which the wind blows varies in different parts of the whirl, but is never very great. In the northern hemisphere the rotary movement is in the direction opposite to that in which the hands of a watch move,

THE EFFECTS OF A TORNADO.

The iron windmill was blown across the cellar and protected the people who had fled there for safety.

while in the southern hemisphere it is with the hands of a watch. As these are areas of ascending air, they are storm areas. The extent of the precipitation varies in different parts of an area according to the direction from which the ascending air has come. Note the direction of the wind and the rainfall area as shown on the map (page 172).

Air which comes from the continental interiors is dry, while that from the oceans contains much moisture, some of which it deposits when made to ascend. These whirls move in a general eastward direction with varying velocities, but averaging about 20 or 30 miles per hour. To these is due the larger part of the rain which falls in middle latitudes. Areas of high pressure in which the air moves spirally downward and outward from the center

REMAINS OF FARM BUILDINGS DESTROYED BY A TORNADO.

as has already been stated (§ 74) are called *anti-cyclones.* These are areas of dry, cold weather.

84. Paths of Cyclonic Storms across the United States. — The map on page 172 shows the paths of a large number of cyclonic storms across the United States. It will be seen from this that although these paths vary considerably, yet the general direction is a little north of east. The movement of the cyclone is in the direction of the prevailing winds of the middle latitudes.

In summer time the average rate of motion of the cyclone across the continent is about 500 miles per day, while in winter it is 800. The velocity of the wind in the cyclone is also much less in summer than in winter, as the difference in pressure between the low and high areas is much less. The changes in temperature as the storms pass are greater in winter than in summer since the regions from which the northerly and southerly winds flow in toward the center of low pressure vary more in their temperatures.

WATERSPOUT SEEN OFF THE COAST OF NEW ENGLAND.

85. Sudden Weather Changes. — In middle latitudes there often occur, particularly in winter, sudden changes in the temperature of 20° or more in a few hours. In our own country, if the temperature falls 20° or more in 24 hours, reaching a point lower than 32° F. in the north or lower than 40° in the south it is known technically as a *cold wave*, and there is a special flag (Fig. 82) displayed by the Weather Bureau to indicate the approach of such a change.

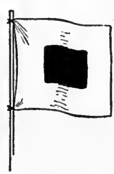
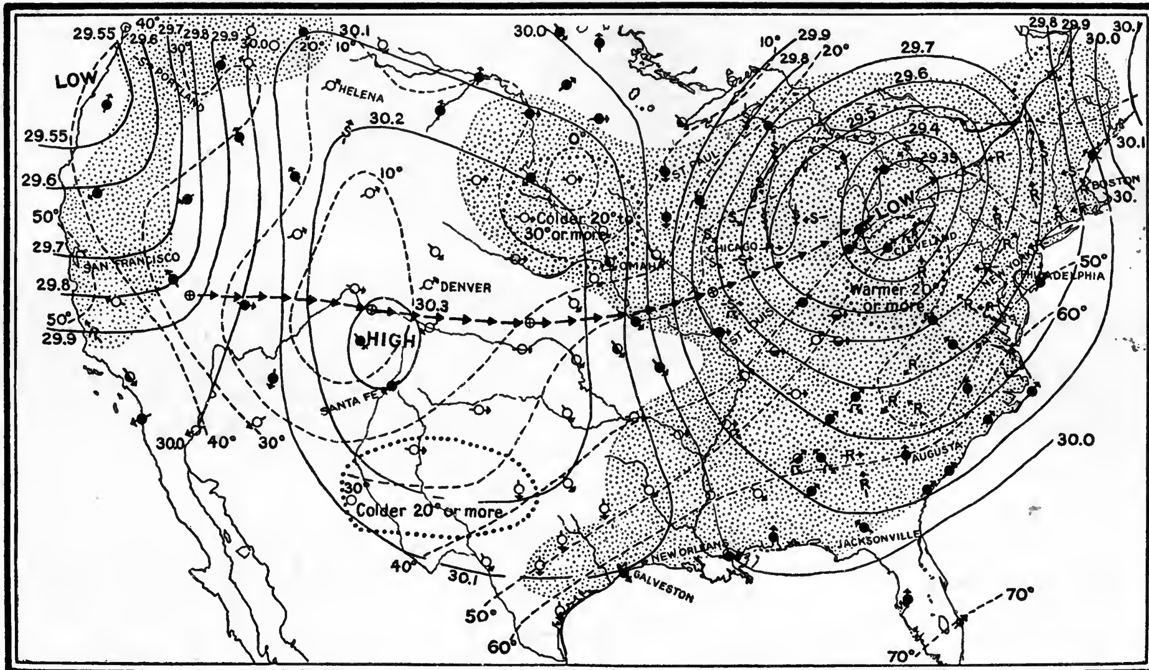


Fig. 82.

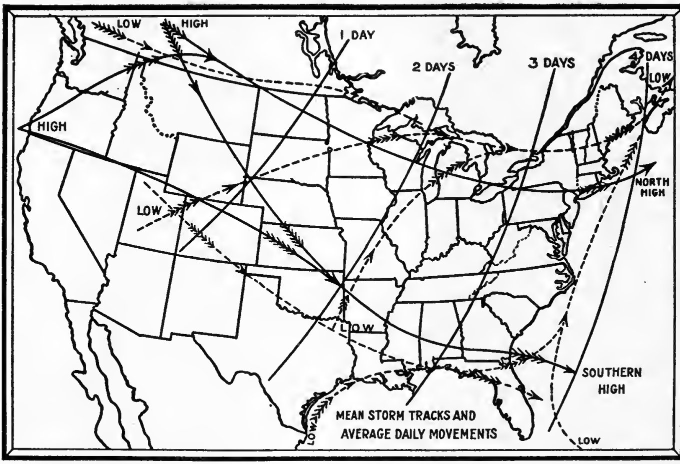
When these waves extend over the southern part of the country, they are very destructive to the orange groves and delicate crops and are known as "freezes." A notable freeze of this kind occurred in 1886 and did tremendous damage to the orange groves of Florida. So great was the effect upon this important industry throughout the orange belt that for years afterward the "freeze" was the date from which events were reckoned.

If the northwesterly wind which brings on the cold



Cyclones and Anti-cyclones.

wave is accompanied by snow, it is called a *blizzard*, and on the plains and prairies, where the wind has a clear sweep, it is much dreaded. Cattle and men, when caught in it, frequently perish. In southern Europe the coldest winds



are from the Siberian plains and are therefore northeasters. In the United States the cold area is at the southwest and rear of the cyclone, whereas in Europe it is at the north and front.

When, instead of the strong, cold northwest winds which blow into the rear of a cyclonic area and in the colder seasons may produce a cold wave, there is a prolonged movement of highly heated air from the south into the front of the low pressure, as sometimes occurs during the warm months, the "hot spells of summer" are caused. The air is sultry, exceedingly hot and oppressive. Sunstrokes and prostrations from heat are common. The "hot winds" of Texas and Kansas, the Santa Ana of lower California and the siroccos of southern Italy are intensified examples of these winds. All sudden weather changes of this kind are due to atmospheric conditions related to areas of low pressure.

86. Weather Forecasting. — The data necessary for forecasting the weather are telegraphed to the Weather Bureau Stations every day, and a record of them placed on the weather map. The observations recorded on these maps furnish the forecasters with all the information obtainable as to what the weather of the future is to be. It has already been stated that the dominant cause of our weather conditions is the eastward movement of cyclones and anti-cyclones.

If the direction and rate of motion of these can be determined the weather of those places which are likely to come under their influence can be foretold with a good deal of accuracy. If a cyclone were central over the lower Mississippi valley with an anti-cyclone to the west of it, we should expect that the southerly and southeasterly winds and rains to the east and southeast of the Mississippi would gradually change to fair weather and westerly winds with increasing cold, as the cyclonic area was replaced by the anti-cyclonic.

The rate at which the change would take place would depend upon the rapidity of the movements of the two areas of high and low pressure, and the order of change in the direction of the winds would depend, for any place, upon the directions taken by the centers of these areas. The direction of movement and the rapidity of movement of the cyclonic areas are, therefore, two of the chief factors which enter into the prediction of the weather. There is usually an increase in the intensity of the storm as the Atlantic coast is approached.

87. Climate. — The average succession of weather changes throughout the year, considered for a long period of years, constitutes the *climate*. Thus, if the average temperature of a place throughout the year has for a long period been found to be high, and the rainfall large and uniformly distributed, the place is said to have a hot and humid climate. The climate is a generalized statement of the weather. Two places may have the same average temperature throughout the year without having the same climate, as in one the temperature may be quite uniform and in the other very high at one season and very low at another. Many factors enter into the making up of a comprehensive statement of climate.

88. **Effect of Climate upon Animals and Plants.** — Plants are greatly affected by climate. The ornamental palm

A SOUTHERN COTTON FIELD.

and orange trees, which are sometimes cultivated in the north, have to be protected from the winter cold with great care, whereas in southern climates they grow and flourish as the apples and pears do in the north. Corn and wheat are the staple agricultural products of the northern part of the United States, while cotton, rice and oranges are of the southern part.

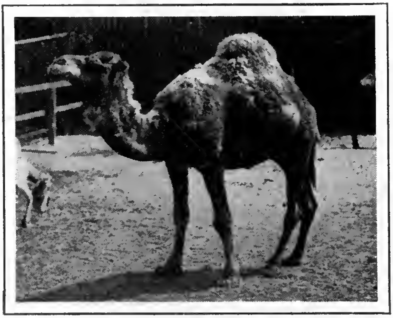
If plants are to flourish, the heat and cold and amount of moisture must be such that the seeds can ripen and find suitable conditions for preservation and growth in succeeding years. Plants like the cactus and the Yucca Palm which

YUCCA PALM.

thrive in the dry and desert regions of New Mexico and Arizona would soon die in the moist climate of Louisiana.

As animals live upon plants or upon other animals, the plants must supply the food of the plant-eating animals and through these of the animal eaters. Thus, the distribution of plants has a great effect upon the animal life. Animals that eat grass will not live in a desert, neither will animals that eat nuts live in a prairie, where there are no nut-bearing plants.

Temperature and moisture also affect animals as well as plants, although animals can hide away from the scorching sun and move about for water as plants cannot. An animal like the polar bear, whose coat has become thick to protect him from great cold, would soon pine away and die, if transferred to the jungles of Africa, where his fellow flesh-eater, the lion, revels in joyful existence. To the camel of the desert the damp, grassy savannas would be, indeed, a dreary waste and verdant cemetery. Thus, when once plants and animals have become adapted to certain climatic conditions, they cannot flourish if placed under very different conditions.



CAMEL.

89. **Effect of Climate upon Man.** — Since man can change his outer covering of clothes whenever he desires and is able to carry with him and store for long periods his necessary food, and by artificial means raise or even lower the temperature of the space in which he lives, he is not nearly so dependent upon climate as are either plants or animals.

The same man can, for a time, live in arctic regions or in the tropics. Men can, moreover, by centuries of effort become accustomed to the climate of almost any part of the globe. The Laplander and the South Sea Islander both flourish in their adopted homes. Neither of these, however, has attained to the highest development of which man is capable. The rigorous severity of the climate saps the energies of one and its uniform geniality lulls the ambition of the other.

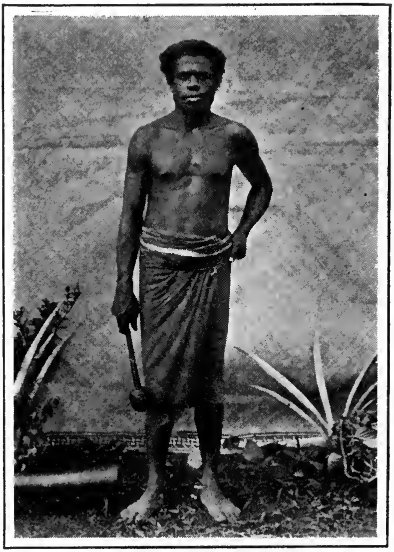
In temperate latitudes, where there is need of providing for the winter when plants do not grow and when food is hard to find, where the blood is stirred by the invigorating cold, and where nature in her ever changing mood gives zest to living, is the place where man has attained his highest achievements. Here the fight for existence does not require all man's energy, and the bounty of nature does not free him from strenuous effort. Thus it is seen that even upon man the influence of climate is great. How great, it is impossible fully to realize, so complex are his relations.

A LAPLANDER.

Summary. — The *atmosphere* is just as important to life upon the earth as are energy, light, heat, water and land. Air contains *oxygen* from which we get heat and energy, *carbon dioxide*, from which plants build up their tissues, and *nitrogen* which dilutes these two.

The *weight of air* is not usually realized because it presses uniformly in all directions. Air expands when heated; so a cubic foot of warm air weighs less than a cubic foot of cold air. Warm air will also hold more moisture than cold air.

The *pressure of air*, due to its weight, may be measured by a *barometer*. The heights of mountains may also be measured by this instrument, as there is less air above a high mountain than above a low one. The winds are caused by changes in atmospheric pressure; their prevailing direction is affected by the earth's rotation. Certain winds common to all planets are called *planetary winds;* when modified by certain peculiarities of the earth they are called *terrestrial winds.* Because of their constancy and their aid to traffic, some of these winds are called *trade winds.* South of Asia there are winds called *monsoons.*



A South Sea Islander.

When very moist air cools, it cannot hold as much moisture as when it is warm, so this falls as rain, hail, sleet or snow. The *rainfall* varies from nothing at all in some places to over fifty feet a year in others. In the United States the north Pacific slope has a rainfall of about seventy inches a year; the south Pacific slope about fifteen inches; the eastern slope of the Rockies is very dry; and the Mississippi valley and the country to the east of it have a rainfall of from thirty to sixty inches.

Rainstorms when accompanied by thunder and lightning are called *thunder-storms.* Thunder and lightning are caused by certain clouds having a *higher charge* of electricity than others. The higher charge bursts across to the lower charge, making a flash of lightning and a roll of thunder.

When the wind blows spirally and with great violence, sweeping everything before it, it is called a *tornado*. This is popularly known as a *cyclone*, but a cyclone is really a very large circular storm area. Real cyclones do no damage.

All these storms have a marked effect upon the *weather*, the changes of which are forecast by the *weather bureau*. The general weather conditions of a place determine its *climate*. The climate of any place has a great effect upon plants, animals and man.

Questions

What are the characteristics and principal uses of the three most abundant gases in the atmosphere?

How can it be shown that air has weight and exerts pressure?

What effect has heat upon the weight and volume of air?

What effect has pressure upon the weight and volume of air?

How do the two kinds of barometer ordinarily used differ in construction?

Where have you ever observed the effects of adiabatic heating?

What experiences have you ever had which show that hot air will hold more moisture than cold air?

How are the light and heat rays from the sun affected by the atmosphere?

Name and explain the chief causes that affect the temperature of a place.

What is the cause of wind and how is its velocity measured?

How are the winds influenced by the earth's rotation?

In going from Boston to Cape Horn through what wind belts would a sailing vessel pass and how would her progress be affected by the winds in these belts? What weather conditions would she probably encounter?

At what season of the year would a steam vessel equipped with sails make the best time to India by way of the Suez canal? Why?

Upon what does the rainfall of a place largely depend?

How is the rainfall of the United States distributed?

What is the relation between lightning and electricity? What is thunder?

With what electrical devices are you familiar?

What are the principal differences between a tornado and a cyclone?

What are the chief effects of climate upon plants and animals?

State the climatic conditions which are best for man's development.

CHAPTER VI

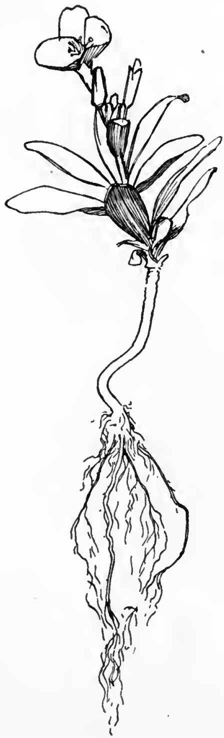
THE LIVE PART OF THE EARTH

90. Plants and Animals. — Plants and animals are combinations of the earth's elements endowed with life. By means of the sun's energy they are able, the plants directly and the animals indirectly, to do both internal and external work which results in growth, reproduction and other activities. Since plants and animals are entirely dependent upon the earth and sun for their existence, they, like other earth and sun phenomena, should be studied in this course.

THE ROCKY MOUNTAIN GIANT.

The monarch of all plants, 93 feet around at the base. Notice the cavalry at the foot.

91. Plants. — Although in their lower microscopical forms it is very difficult to distinguish between plants and animals, yet the forms ordinarily seen differ greatly. Most plants are fixed and consist of root, stem and leaves, while most animals are movable and possess a variety of different parts. But some plants, like the seaweeds, appear to have no roots; some, like the dandelion, no plant stem, and some, like the cactus, no leaves.



A TYPICAL PLANT.
Showing root, stem, leaf and flower.

If we dig around the base of a tree, we find in the soil a network of roots holding firmly erect a pillar-like stem with branches bearing a profusion of leaves. If we examine these divisions carefully, we shall find that each has a distinct part to play in the life work of the tree. We shall also find (1) that plants as well as animals need air, water and other kinds of food, (2) that plants, like animals, take in, digest and assimilate food, and (3) that each in the higher forms has parts which are particularly adapted for doing these different kinds of work.

92. **Plant Roots.** — Plant roots not only usually secure the plant to the ground so that the stem may be supported, but they take up food from the soil and pass it on to the rest of the plant. In most plants all the foods except carbon and oxygen are taken in by the roots. The soil elements that the plants must have are nitrogen, potassium, calcium, magnesium, phosphorus, sulphur and iron. Water is composed of hydrogen and oxygen, while carbon, the other necessary element, is taken from the air. The soil elements must be in soluble chemical combinations, such as nitrates, phosphates, sulphates and so on.

Experiment 88. — Fill three 2-quart fruit jars each about half full of distilled water. Add to the water in the first of these $\frac{1}{2}$ gram of potassium nitrate, $\frac{1}{4}$ gram iron phosphate, $\frac{12}{100}$ gram calcium sulphate and $\frac{12}{100}$ gram magnesium sulphate. Add to the water in the second jar the same ingredients with the exception of the potassium nitrate. Replace this by potassium chloride. Put the three jars where they will receive plenty of sunlight and warmth and place in each a slip of Wandering Jew about 10 inches long. Note which slip grows the most thriftily. In the third jar there is no mineral food, in the first all of this food which is necessary and in the second all the necessary food except nitrogen.

In Experiment 88, it was found that in the distilled water the plant made but little growth. It did not thrive when the nitrogen was lacking, but grew very well when all the necessary elements were present. All plant foods must be in dilute solution before plants can appropriate them.

Experiment 89. — In another fruit jar make a strong solution of potassium nitrate or, as it is commonly called, saltpeter. Place in this a slip of Wandering Jew as was done in the previous experiment. Does the slip grow well? It has a great abundance of nitrogen, which was found so important. Place in a similar strong solution a growing beet or radish freshly removed from the ground. Notice how it shrivels up. Place a similar beet or radish in water. It is not similarly affected. What is the effect of strong solutions on plants?

If the solution is too strong, as seen in Experiment 89, the plant cannot use it. This is the reason many alkali soils will not support plants. The alkali salts are so readily soluble that the soil water becomes a solution stronger than the plants can use.

Experiment 90. — Place three or four thicknesses of colored blotting paper on the bottom of a beaker. Thoroughly wet the paper and scatter upon it several radish or other seeds. Cover the beaker with a piece of window glass and put in a warm place. Allow it to stand for several days, being sure to keep the blotting paper moist all the time. When the seeds have sprouted, examine the rootlets, with a magnifying glass or low power microscope, for the root hairs which look like fuzzy white threads. Touch the root hairs with the point of a pencil. They cannot, like the rest of the root, stand being disturbed. On what part of the root do the root hairs grow? As the blotting paper dries, what happens to the root hairs?

Plant roots are prepared particularly by the little root hairs, which were examined in Experiment 90, to take the film of water which surrounds the soil particles and carry this water to the stem and, through it, to the leaves. The water which the roots take from the soil is a dilute solution containing the plant food substances. Not only do roots absorb the water from the soil, but they secrete weak acids which aid in dissolving the mineral substances which the plants need. This can be seen where plant roots have grown in contact with polished surfaces, such as marble. These surfaces are found to be etched.

Experiment 91. — Cut a potato in two. Dig out one of the halves into the shape of a cup and scrape off the outside skin. Fill the potato cup about $\frac{2}{3}$ full of a strong solution of sugar. Mark the height of the sugar solution by sticking a pin into the inside of the cup. Place the cup in a dish of water. The water should stand a bit lower than the sugar solution in the potato cup. After the cup has stood in the water for some time, notice the change in the height of the denser sugar solution.

Fig. 83.

Experiment 92. — Bore a $\frac{3}{4}$-inch hole 3 or 4 inches deep in the top of a carrot. Scrape off the outside skin and bind several strips of cloth around to keep the carrot from splitting open. Fit the hole with a one-hole rubber stopper having a glass tube about 1 meter long extending through it. Fill the hole in the carrot with a strong sugar solution colored with a little eosin and strongly press and tie in the stopper. The sugar solution will be forced a short distance up the tube by the insertion of the stopper. Mark with a rubber band the height at which it stands. Submerge the carrot in water and allow it to stand for a few hours. Mark occasionally the height of the column in the tube. Taste the water in which the carrot was submerged. There has been an interchange of liquids within and without the carrot.

The plant root takes up its water in the same way the water was taken into the sugar solution of the potato cup or of the carrot. The water or *sap* within the substance of the root is denser than the soil water, just as the sugar solution was denser than the water outside. It has been found that whenever two liquids or gases are separated by an animal or plant membrane, there is an interchange of the liquids or gases, the less dense liquid or gas passing through more rapidly. This is called *osmosis* and is of the greatest importance to both plants and animals.

All animals and plants are made up of exceedingly minute parts, called *cells*. Fig. 84 shows the cells in a leaf and the leaf hairs greatly magnified. The higher plants and animals are composed of vast numbers of these cells. The cell usually has a thin cell wall, which in living and growing cells incloses a colorless semifluid substance called *protoplasm*. This protoplasm is the living part of the plant. It is found in all the cells where growth is taking place, where plant substances are being made, or where energy is being transformed. It has the power of dividing and forming new cells, and it is in this way that the plants grow.

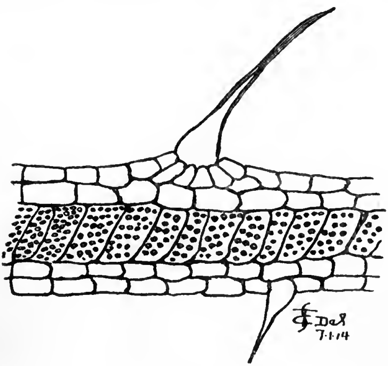


Fig. 84.

The little root hairs are one kind of plant cells. They consist of a thin cell wall within which is protoplasm and cell sap, a solution of different plant foods. Since the protoplasm and cell sap are denser than the soil water, more liquid moves into the cell than from it. A little of the cell solution does move out, however, and it is this which helps to dissolve the soil particles. The protoplasm in the cell regulates to some extent the interchange of liquids.

Experiment 93. — Cut off the stem of a thrifty geranium, begonia, or other plant an inch or two above the soil. Join the plant stem by a rubber tube to a glass tube a meter long, of about the same diameter as the stem. See that the rubber tube clings strongly to both glass tube and stem. It may be best to tie it tightly to these. Support the glass tube in a vertical position above the stem and pour into it sufficient water to rise above the rubber tube. Note the position of the water column. Thoroughly water the soil about the plant. Watch the height of the water column, marking it every few hours.

Fig. 85.

The water taken in by the roots passes on from cell to cell by osmotic action and rises in the stem in the same way that the water rose in the tube attached to the stem of the growing plant in Experiment 93. The root pressure, together with *capillarity*, as seen in Experiment 54, will account for the rise of the sap in lowly plants, but the cause of the rise of the sap to the top of lofty trees is difficult to understand.

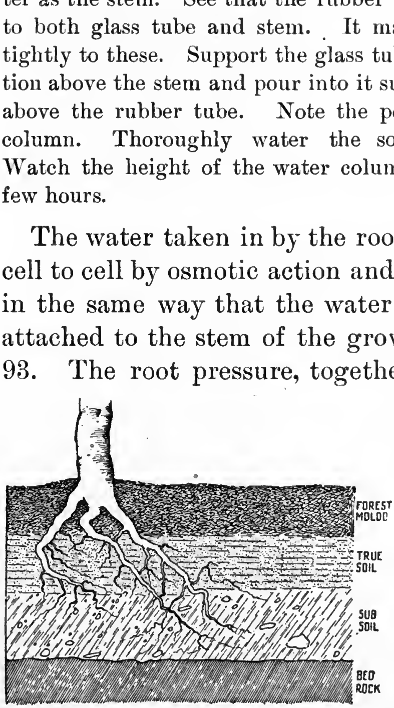


Fig. 86.

Roots extend themselves through the soil by growing at the tips. Here the cells are rapidly dividing, forming new cells and building root tissue. As water is so essential, they are always seeking it and extending themselves in the direction where it is to be found. This causes them to extend broadly and to sink deeply (Fig. 86). A single oat plant has been found to have an entire root extension of over 150 feet. This seeking of the roots for water sometimes causes the roots of trees to grow into drain pipes and stop them up. For this reason the planting of certain trees near sewer pipes is often prohibited.

Experiment 94. —Boil some water so as to drive out the air and after it has become cool fill a 2-quart fruit jar half full. Dissolve in this all the necessary plant food as was done in Experiment 88, making the solution the same strength. Place in this a slip of Wandering Jew. Pour over the surface of the water a layer of castor oil or sweet oil. Place this jar alongside the slip in the other complete food solution, Experiment 88. Both slips have the same conditions except that the oil keeps out the air from the roots of one of them. Does the absence of air affect the growth of the slip?

As the tips of the roots are delicate, it can be readily seen that if they are to grow readily the soil around them must be mellow. It was also seen in Experiment 94, that if roots are to grow they must have air, another reason for keeping the soil mellow.

Roots are, however, not simply absorbers of water and dissolved food. Some of them act as storehouses for the food that the plant has prepared for future use. Beets, carrots, parsnips, turnips and sweet potatoes are examples of roots which store food ready for the rapid growth of the next year's plant.

93. **Stems.** — **Experiment 95.** — Examine a corn stalk. Notice how and where the leaves are attached to the stem. Do the alternate leaves come from the same side of the stem? Cut a cross section of the stalk. Notice the outside hard rind, the soft pithy material and the small firmer points scattered about in the pith. Cut a section lengthwise of the stalk and notice how these small firmer points are related to the lengthwise structure of the stem.

Cut off a young growing corn stalk and place the cut end in water colored by eosin or red ink. Allow it to stand for some time and then cut the stalk off an inch or two above the surface of the water. How have "the firmer points" been affected? If possible, make the same observations and experiments on the stem of a small seedling palm tree.

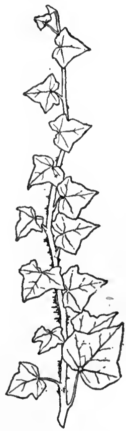
Experiment 96. — Examine a piece of the growing young stem of a willow, apple tree or other woody stem that shows several leaf scars. Is the arrangement of the leaves the same as in the corn stalk? Cut a cross section of this stem and examine it. Does it resemble the cross section of the corn stalk? Strip off a piece of the bark and compare it with the rind of the corn stalk. Examine carefully the smooth, slippery surface of the wood just beneath the bark. This is the *cambium layer.*

Examine the firm wood beneath this layer. Where is the pith in this stem? With a lens you may be able to see lines radiating from the pith to the circumference of the stem. These are called the *pith rays.* Cut a lengthwise section of the stem and examine it. Are there any fiber-like bundles as in the corn stalk? Cut off a piece of the stem already examined having the bark on it, or a piece of sunflower stem, and place the end of it in colored water. Allow it to remain for some time and then cut a cross section above the point where it was in the water. Has the water risen and colored this cross section as it did the cross section of the corn stalk?

A Pine Tree.

Notice the erect position of the stem.

Stems vary greatly in the positions they assume. Some rise firmly erect from the root, like the oak and the pine; some cling to supports, like the grape and the ivy; some twine around supports, like the bean; some creep upon the ground, like the strawberry; some grow in the form of a thickened bulb like the onion (Fig. 87); some, like the cacti, assume a fleshy leaflike, though leafless form; some, like the nut grass, Johnson grass and witch grass, grow underground and send up shoots, and some stems store up food underground in tubers, like the potato (Fig. 87), from which the next year's plant may grow.



AN IVY BRANCH.

Notice the tiny root-like appendages by which it clings to its support.

Notwithstanding all the diversity shown by the stem, its principal functions are to support the leaves, so that they will best be exposed to the light, and to conduct the food solutions from the root to the leaves. The part of the stem through which the cell sap flows was seen in Experiments 95 and 96.

There are two great types of stems, one represented by the corn stalk and palm and the other by the willow, sunflower and bean. On account of the structure of the seeds these are called, respectively, *monocotyledonous* (one seed leaf) and *dicotyledonous* (two seed leaves). That these differ greatly in their appearance was seen in Experiments 95 and 96, where the two kinds of stems were compared. It was also found in these experiments that, in the first, the red colored water that

Fig. 87.

Fig. 88.

took the place of the sap rose in the fibrous bundles scattered through the pith, while in the second it rose through the woody tissue within the bark.

Experiment 97. — Examine a cross section of a hardwood tree several years old, and if possible of a palm. Notice the ring-like arrangement of the layers in one and the absence of all such arrangement in the other.

In Experiment 97, when the cross section of a dicotyledonous tree was examined, it was found to be composed of circular rings, but no such rings are found in the cross section of the monocotyledonous tree. When later we

A Banyan Tree.

Some of its branches descend, and take root in the ground, and so appear like stems.

examine the seeds of corn and bean, we shall find that they also differ very much.

When the bark is removed from a stem, like the willow or apple, the soft smooth layer underneath is found to be composed of living cells. This is called the *cambium layer.* During the season of growth, these cells are continually subdividing and forming new cells, thus adding to the thickness of the stem. The age of a tree can be determined by counting these rings. No such layer is found in the monocotyledonous stems. *Grafting* (Fig. 89) and *budding* (Figs. 90 and 91) are processes of bringing the cambium layers of two trees of similar kinds in contact and keeping them protected so that they will grow together. In this way, many of our finest species of fruit are propagated.

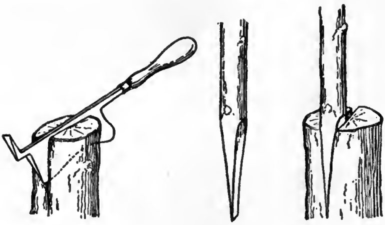


Fig. 89.

Experiment 98. — Examine several growing stems or twigs which have buds upon them and notice how the buds are arranged. Is the arrangement the same in all? If these buds grew into twigs or leaves, would they shade each other? Is there a bud at the end of the twig or stem?

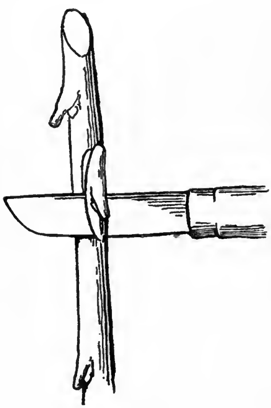


Fig. 90.

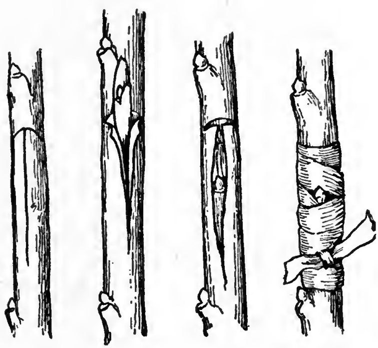
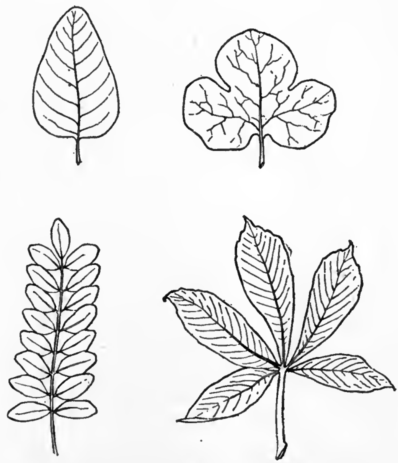


Fig. 91.

If we examine the tip of a growing stem or twig, we shall find a *bud*. In most of the trees and shrubs of temperate regions a terminal bud is formed at the close of the growing season, and from this the shoot continues to grow the following season. Buds are also found along the length of the stem and branches, as was seen in Experiment 98. These are lateral buds and, since they are usually found in the axis of the leaf, at the angle formed by the leaf and stem, they are called *axillary*. In some trees the terminal buds die at the end of the growing season, and the next year's growth is due to one of the axillary buds.

94. **Leaves.** — If we examine the arrangement of the leaves on a plant or tree, we shall see that they do not lie one directly above the other, but that they are so arranged as not to shade each other. Their position generally is such that the broad upper surface of the leaf receives the strong light rays perpendicularly upon it. To accomplish this, the leaves in many trees are arranged spirally around the stem.



DIFFERENT FORMS WHICH LEAVES ASSUME

The stem of the leaf itself, in some parts of the tree, often grows long and twists about, in order to push the leaf out to the light and yet not let it be wrenched away by the wind. The horse-chestnut is such a leaf. In some plants, like the sunflower, the younger leaves follow the sun all day. In other plants the rays of the sun seem to be too bright in the middle of the day and the leaves are then held edgewise to the light.

A striking example of this is the compass plant, the leaves of which arrange themselves so that the sun's rays strike the broad surface of the leaves at night and morning when the rays are not very strong, but at noon the edge of the leaf is toward the sun, the leaf thus maintaining a nearly vertical position all day, with its greatest length extending in a nearly north and south line. It is the effort to regulate the amount of light falling on the leaf, and not any magnetic influence, which causes the leaf to point in the direction of the compass needle.


Fig. 92.

The shapes of the leaves vary greatly in different plants. Sometimes they assume very singular forms, as in the pitcher plant (Fig. 92) and Jack-in-the-pulpit. Sometimes they even become carnivorous, as in the sundew and Venus flytrap.


Fig. 93.

Around the margin of the sundew leaf and on the inner surface are a number of short bristles each having at the end a knob which secretes a sticky liquid. As soon as an insect touches one of these knobs, it sticks to the knob and the other bristles begin to close in upon the insect and hold it fast. Soon the insect dies and the leaf secretes a juice which digests its soluble parts.

In the Venus flytrap (Fig. 93) the leaf terminates in a portion which is hinged at the middle and has on the inside of each half three short hairs, while the outside is fringed by stiff bristles. As soon as an insect touches the hairs, the trap closes rapidly upon it and stays closed until it is digested, when the trap again opens. Carnivorous plants of this kind usually grow in places where it is difficult to get nitrogenous foods, and they have adopted this way to supply the need.


Fig. 94.

Some leaves extend themselves into spiny points, like the thistle (Fig. 94), in order to keep animals from destroying the plant, or they may develop a sharp cutting edge, like some grasses, or emit a bad odor, or have a repugnant bitter taste.


Fig. 95.

The veins or little ridges extending through the leaf from the leaf stem vary (Fig. 95.) Sometimes these veins extend parallel to each other through the leaf, as in the corn and palm. This is generally characteristic of monocotyledonous leaves. In other leaves, the veins form a network, as in the maple and apple. This is characteristic of dicotyledonous plants.

Experiment 99. — Place the freshly cut stem of a white rose, white carnation, variegated geranium leaf, or any thrifty leaf which is somewhat transparent, in a beaker containing slightly warmed water strongly colored with eosin. Allow it to remain for some time. The coloring matter can be seen to have passed up the stem and spread through the leaf or flower.

The great function of the leaf is to manufacture plant foods. The leaf is so constructed that air can enter it and come in contact with its living cells, as does the water coming up from its roots. The circulation of water in the leaf was seen in Experiment 99. There is in the living cell of the leaf a green substance called *chlorophyll.* This has the power to utilize the energy of sunlight and to combine carbon dioxide, a gas which makes up a small part of the air, with water from the roots, forming a substance which probably at first is grape sugar, but which in many leaves is changed at once into starch.

Experiment 100. — Boil a few fresh bean or geranium leaves for a few minutes in a beaker of water. Pour off the water and pour on enough alcohol to cover the leaves. Warm the alcohol by putting the beaker in a dish of hot water. When the leaves have become colorless, remove from the alcohol and wash. Place the leaves in another beaker and pour on a solution of iodine. (This solution can be made by dissolving in 500 cc. of water, 2 grams of potassium iodide and $\frac{1}{2}$ gram of iodine. The solution should be bottled and kept.) If the leaves turn dark blue or blackish, starch is present.

Experiment 101. — Place a thrifty geranium or other green plant in darkness for two or three days and then treat the leaves as was done in Experiment 100. Do they show the presence of starch? The direct presence of the sun's energy in the form of light is necessary for the formation of starch in the leaves.

It was found in Experiment 100 that leaves exposed to the sun contained starch, and in Experiment 101 that leaves which had been deprived of sunlight did not have starch. The starch disappeared while the plant was in darkness. Carbon dioxide is composed of carbon and oxygen; and water of hydrogen and oxygen. In the manufacture of starch by the chlorophyll some of the oxygen is not used and becomes a waste product which the leaves throw off. This is seen in Experiment 102.

Experiment 102. — Under an inverted funnel in a battery jar, place some pond scum or hornwort. Fill the jar with fresh water and over the neck of the funnel place an inverted test tube filled with water. When placed in the sunlight, bubbles of oxygen will rise into the test tube and collect. The oxygen can be tested by turning the test tube right side up and quickly inserting a glowing splinter. If the splinter bursts into a flame, oxygen is present. (A freshly picked leaf covered with water and put in the sunlight will be seen to give off these bubbles.) After a small amount of gas has been collected in the test tube, mark the height of the water column and place the battery jar in the dark, allowing it to remain there for ten or twelve hours. No oxygen is given off in the dark. Place the jar in the light again. Oxygen is given off. Is the sun's energy needed to enable the plant to give off oxygen?

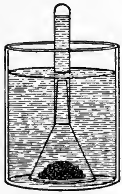
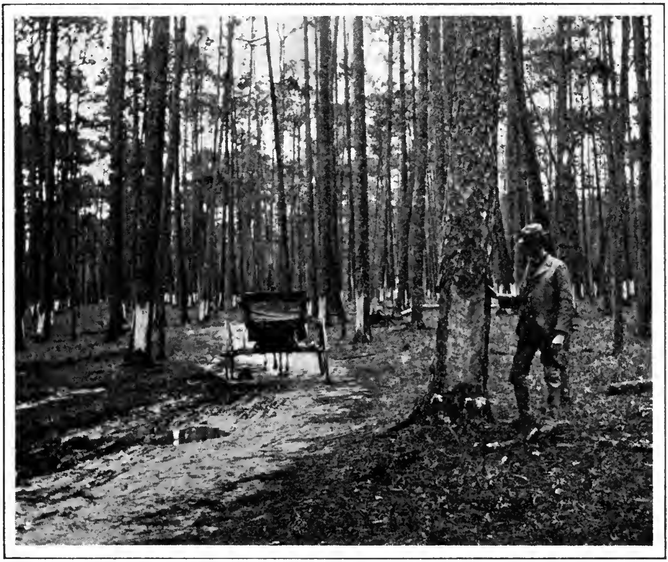


Fig. 96.

The starch manufactured is insoluble in water and is stored in the leaf during the day. But at night, when the leaf is not manufacturing starch, it is able to digest the starch by means of a special substance, *leaf diastase*, which it forms. This changes it into sugar, which is soluble and which flows to other parts of the plant. Compounds such as starch and sugar, in which there is only carbon, hydrogen and oxygen, are called *carbohydrates*.

The cells in the leaf and in other parts of the plant have the power to change the sugar and combine it with other substances contained in the sap, thus forming more complex chemical compounds. These contain nitrogen and sulphur, besides the elements of the sugar. Such compounds are called *proteins*. They are essential to the formation of plant protoplasm and are very important as animal foods.

The digested and soluble substances which are prepared by the leaves are transported to other parts of the plant, where they are combined by the protoplasm of the living cell with other substances contained in the cell sap. Thus the protoplasm itself is able to increase and form new cells as well as other substances, such as woody tissue and oils and resins. In forming these substances the plant uses oxygen just as animals do. If air is kept from the roots of certain plants, as was seen in Experiment 94, the plants cannot live.



A Forest of Pines.

From the sap of these, turpentine and resin are made.

These food substances which plants make by using the energy supplied by the sun are the bases of all plant and animal life. The sun's energy stored up in the green leaf is the source of all plant and animal energy. If it were not for the leaf manufactory run by the sun's power, life, as we know it, would cease. Even white plants, like the mushroom, must live on the food manufactured by the chlorophyll of the green plants.

Experiment 103. — Procure a small thrifty plant growing in a flower pot. Take two straight-edged pieces of cardboard sufficiently large to cover the top of the flower pot and notch the centers of the edges so that they can be slipped over the stem of the plant and thus entirely cover the top of the flower pot. Fasten the edges of the cardboard together by pasting on a strip of paper. The top of the pot will now be entirely covered by the cardboard but the stem of the plant will extend up through the notches of the edges. Cover the plant with a bell jar. No moisture can get into the bell jar from the soil in the pot as it is entirely covered. Set the plant thus arranged in a warm sunny place. Moisture will collect on the inside of the bell jar. This must have been given out by the plant leaves.

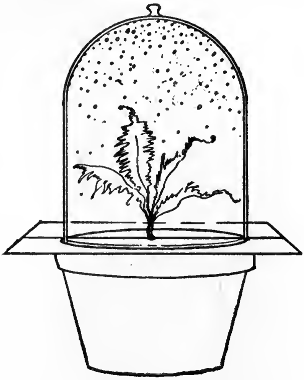


Fig. 97.

Since all the processes of forming new material by the plant require large amounts of water, it can readily be seen why water is so essential to plant development. The water from which the food materials have been taken is thrown off by the leaves, as seen in Experiment 103. The amount of water thus thrown off by plants is very great. A single sunflower plant about six feet tall gives from its leaves about a quart of water in a day, and an acre of lawn in dry hot weather gives off probably six tons of water every twenty-four hours.

A Sunflower Plant.

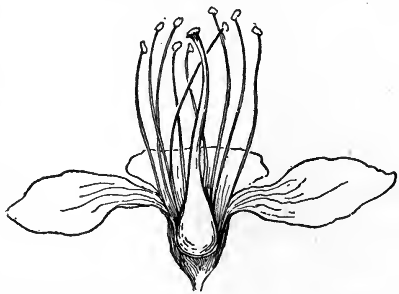
If the water passes out of a plant too rapidly so that there is not enough left to provide for the making and transporting of the food, the work of the plant cannot be carried on, and the plant dies. It is on account of this that many plants are especially prepared to retain their water supply. In almost all plants the *stomata*, or little pores in the leaf through which the water passes out, close up when too much water is being lost.

In some plants, like the corn, when the root cannot supply sufficient moisture, the leaves curl up and thus present less surface for evaporation. In trees like the eucalyptus the leaves hang vertically when the sun gets too bright and present their edges to the sun's rays. Some leaves, like the sage, are especially prepared to conserve their moisture by having their surfaces covered with hairs. Others have a waxy covering, as the cabbage and the rubber tree. In some plants the leaves are very small and have few pores, as the greasewood of the desert, and some have done away with leaves altogether, as the cactus. It is because the roots cannot supply sufficient moisture where the ground freezes in the winter that trees having large leaves shed them, and only trees like the pine whose needle-like, waxy leaves give off almost no moisture can retain theirs.

EUCALYPTUS LEAVES.

95. Flowers. — The stem not only bears leaves but, in the higher kinds of plants, it bears flowers. The function of the flower is to produce seeds and provide for the continued existence of its kind. If the flower of a buttercup, quince, cassia, or geranium is examined, it will be found to be made up of four distinct kinds of structures.

Around the outside is a cluster of greenish leaves. This is called the *calyx*. Within the calyx is the *corolla*, a cluster of leaves which in many plants are colored. Within the corolla are a number of parts consisting of a rather slender stalk with an enlarged tip. This tip is called the *anther*, and the stalk and anther together, the *stamen*.



FLOWER, SHOWING COROLLA, STAMEN AND PISTIL.

In the center of the flower are the *pistils*. At the top of a pistil is generally a somewhat enlarged portion, the *stigma*, which is sticky or rough; and at the bottom there is an enlarged hollow portion, the seed-bearing part, called the *ovary*. These two parts are connected by the stalk-like *style*. The stamens and pistils are the essential parts of the flower, the calyx and corolla being simply for protection or assistance. All flowers do not have these four parts, but every flower has either stamen or pistils or both.

PINK GENTIAN.

Showing the anthers which are covered with pollen.

The anther produces a large number of little granular bodies, called *pollen grains*, each of which consists of a free cell containing protoplasm. When the pollen grains are ripe, the anther opens and exposes them. If a pollen grain of the right kind falls upon a stigma, it grows and sends down a tiny tube through the style into the ovary, where a little protoplasmic cell, called the *egg cell*, has been produced. The essential parts of these two different kinds of protoplasms unite and a new cell is formed.

This new cell grows and divides into more cells, thus forming the young embryo of a new plant. This embryo is the living part of the seed and around it usually a great deal of plant food is stored, so that when it begins to grow it will have plenty of nourishment until it is able to develop the roots and leaves necessary to prepare its own food.

Embryos cannot be produced unless pollen grains and egg cells unite, so it is absolutely essential that the right kind of pollen grains be brought to the stigma. Some stigmas are able to use the pollen grains produced by the anthers of their own flowers, but others can only use pollen from other flowers and other plants. It is therefore necessary that these pollen grains be carried about from flower to flower if fertile seeds are to be produced.

MINT FLOWER.

In some cases the pollen is borne about by the wind, as in the case of corn. In this way an exceedingly large number of pollen grains are wasted, as can be seen by the great amount of yellow pollen scattered over the ground of a cornfield when the corn is in bloom. In the corn each one of the corn silks is a pistil and a seed is produced at its base if a pollen grain lights upon the stigma at its upper extremity. The flowers of walnut and apple trees are fertilized by wind-blown pollen.

The pollen of very many plants, however, is carried about by humming birds, bees and other insects. As the bee crawls into the flower to get the nectar at the bottom, it brushes against the anther and some of the pollen grains become attached to it. These, later, are rubbed off by the rough or sticky stigma of another flower which the bee has entered and thus the flower is fertilized. The humming bird, by reaching its long slender beak down into the long narrow tube formed by the corolla of the "wild honeysuckle" (Fig. 98), brushes upon the stigma the pollen grains it has obtained from another flower and thus distributes pollen from flower to flower. In no other way could these plants be fertilized.

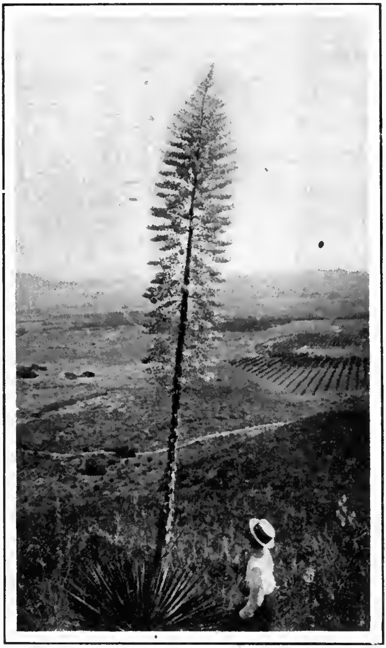
Fig. 98.

The beautiful colors of flowers and the sweet nectars that many of them secrete are the adaptations of the plant for enticing insects to enter them and bring to their stigma the pollen from other flowers, or take from their anthers pollen needed to fertilize another similar plant.

Some flowers are so constructed that only certain insects can fertilize them, the wild honeysuckle requires the humming bird, the red clover the bumble-bee (Fig. 99) and other plants, other kinds of insects. Flowers of some varieties of plants cannot be fertilized by flowers of a like variety. Certain varieties of strawberries, for example, need to have other varieties planted near them, if they are to prosper. Some plants need not only to have other varieties planted near, but they also require the presence of special insects.

Fig. 99.

One of the most striking examples of this is the Smyrna fig. For many years attempts were made to introduce this fig into California. The trees grew all right but the fruit did not mature. It was then observed that in the regions where this fig was successfully grown a species of wild fig was abundant and that the natives were accustomed to hang branches of the wild fig in the Smyrna fig trees at the time they were in flower. These wild fig trees were brought to California and grown near the Smyrna fig trees, but still figs did not mature. Upon further examination it was observed that at the time of flowering a small insect issued from the wild figs and visited the flowers of the Smyrna figs. This insect was brought to California and now it is possible to grow figs. The flower of the Smyrna fig has no stamen and it is necessary for the wild fig to furnish the pollen which is only successfully carried to the stigmas of the edible fig by the small fig-fertilizing insect.



YUCCA OR SPANISH BAYONET.

A somewhat similar case is that of the yucca found in the dry region of southwestern United States. This flower can only be fertilized by the aid of a small moth which flies about at night from flower to flower. It enters the flower, descends to the bottom, stings one of the ovaries, deposits an egg, then ascends and crowds some pollen on the stigma. The grub, when it hatches from the egg, feeds on the seeds in the ovary, but as there are many seeds in the flower which have been fertilized and the grubs eat only a few of these, the moth has made it possible for the yucca to produce seeds sufficient for its continued propagation, which would be impossible if it were not for the moth.

These are only a few of the vast number of cases which show the close relationship existing between plants and animals and the dependence of the one upon the other.

96. **Seed Dispersal.** — Not only must flowers produce fertile seeds, if the plants are to continue to exist, but these seeds must be scattered. To do this the seed pods of some plants suddenly snap open and spread their seeds. The touch-me-not and pea are examples of this. In some plants, like the maple, the seeds are winged (Fig. 100) and float for some distance in the air.

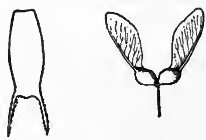


Fig. 100.

Fig. 101.

Others, like the thistle and the dandelion, have light hairlike appendages which enable them to float away. In the case of the tumble-weed (Fig. 101) the plant itself is blown about, scattering the seeds over the fields as it bumps along from place to place.

Some seeds are provided with hooks or barbs, like the beggar's ticks (Fig. 100), which attach the seeds to animals so that they are carried to a distance. Seeds having an edible fruit cover, such as the cherry, blackberry and plum, are eaten by birds and animals and the undigested seed deposited far away from the place where the seed grew. Seeds like the acorn are carried about by squirrels and other animals. Many seeds are able to float in water for a considerable time without being injured and are borne about by currents. Shores of streams and islands receive many of their plant seeds in this way. The cocoanut palm is a notable seed of this kind and is found widely scattered over tropical islands.

SCRUB OAK BRANCH.
Showing the acorns.

97. Seeds and their Germination. — **Experiment 104.** — Take two common dinner plates and place in the bottom of one of them two or three layers of blotting paper and thoroughly wet it. Place some wheat or other kinds of seeds upon this. Now invert the other plate over the first, being careful to have the edges touch evenly. This makes a moist chamber and gives the most favorable conditions for germination. Do all the seeds germinate at the same time? Does the position of the seed make any difference? What takes place first in the process of germination? What appears first, the leaf or the root? Why does the seed shrivel up?

Experiment 105. — Cut open several seeds, such as pumpkin, squash, bean, corn, and drop on to the inside of each a few drops of the iodine solution made in Experiment 100. Do the seeds show the presence of starch?

Experiment 106. — Soak some beans for about twenty-four hours. Rub off the skin from two or three and examine their different parts carefully. Plant the beans in a box of damp sawdust. Put the box in a warm place. Plant some corn that has been soaked for two or three days in the same box. After the seeds have been planted several days, carefully remove a bean and a grain of corn and examine. Make a sketch of each of the seeds.

After a few days more remove another seed of each and examine and sketch. Continue to do this until the little plants have become quite well grown. Do the two seeds develop alike? Which of the seeds has two similar parts? These two parts are called *cotyledons.* What appears to be the use of these parts to the sprout? Consult the results of Experiment 104. Note the root development in each seed and the stem development. The sprouts get their food from the seed.

When we examined the different seeds in Experiment 105, we found that they each contained starch. When the seeds were soaked and planted, we found that a part of the seeds began to grow, forming a *sprout.* This part is the embryo already described. We also saw that the bean seed divided into two like parts which gradually withered and shrank, as the sprout grew, while the corn had only one such part.

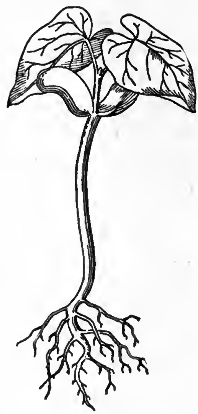


Fig. 102.

These parts are called *cotyledons*, or seed leaves (Fig. 102). The bean seed is a *dicotyledon* (two seed leaves) and the corn a *monocotyledon* (one seed leaf). These cotyledons are the food storehouses for the germinating seed. As the sprout grew, the root, with its root hairs, developed, and the stem with its leaves. When these had grown strong enough, the cotyledons, having performed their part, dropped off. The plant was now ready to prepare its own food by the aid of the sunlight.

Experiment 107. — Place several beans in a tumbler of damp sawdust and put it in a warm, light place. Keep the sawdust moistened. After the beans are well sprouted, with a sharp knife cut one of the half beans or cotyledons off from a sprout. Cut both cotyledons off another sprout. Put the sprouts back on the sawdust. Do the sprouts grow as well as those of the other beans?

Experiment 108. — Fill a 16-ounce wide-mouth bottle about one third full of peas or beans. Pour in water enough to more than cover them. Tightly cork the bottle and put in a warm sunny place. Put another similar corked empty bottle beside it. Allow the bottles to stand for several days until the peas have sprouted. Remove the cork from the bottle containing the peas and insert a burning splinter. Do the same to the empty bottle. Why does not the splinter burn as well in each? If on being placed in either bottle the splinter is smothered out, it shows the presence of carbon dioxide.

Experiment 109. — Fill two 8-ounce wide-mouth bottles each about one third full of coarse sawdust and fill the remaining part with peas which have been soaked for a day. Pour in sufficient water to cover the sawdust. Cork one of the bottles tightly, leaving the other open. Put the two bottles in a warm sunny place. Whenever necessary, pour on sufficient water to keep the sawdust in the open bottle wet. In which bottle do the seeds sprout the better? Does air appear to be necessary for the growth of seeds? As determined by the previous experiment, what part of the air is used?

We found in Experiment 107 that if the cotyledons were cut off before the sprout had become sufficiently mature, it could not continue its growth. In Experiment 108 we found that the sprouting seeds took up oxygen from the air and gave out carbon dioxide just as animals do. Energy was needed and this energy was obtained by combining the carbon in the seed with the oxygen in the air, as it is when wood is burned. We found in Experiment 109 that the seeds could not sprout well unless sufficient air was supplied. That was because there was not enough oxygen supplied to furnish the necessary energy.

Experiment 110. — Place several sprouted seeds in each of two tumblers nearly filled with damp sawdust. Put these tumblers side by side in a warm light place. Cover one of the tumblers with a box painted black so as to exclude the light. In which do the seeds grow the better?

After the seeds were sprouted and had begun to prepare their own food, it was found in Experiment 110 that they were not able to do this unless exposed to the light of the sun. The parent plant had stored, in a latent form in the seed, energy which it had received from the sun.

This potential energy the sprout was able to change into the kinetic form by the aid of oxygen, and to use in the work of growing. After this latent energy had been expended, it had to fall back upon the direct energy of the sun which came to it in the form of sunlight.

98. **Fungi.** — **Experiment 111.** — Expose a piece of moist bread to the air for a short time and then put it into a covered dish so as to retain the moisture. Does any change take place in the bread? Examine with a magnifying glass the mold which appears.

Experiment 112. — (1) Bruise a sound apple and place the bruised part in contact with a thoroughly rotten apple. Wrap the two up together in a wet cloth and put in a fruit jar. Seal the jar to prevent the water from evaporating. (2) Plunge a pin repeatedly first into a rotten apple and then into a sound one. Wrap the sound apple in a wet cloth and seal in a fruit jar. (3) Place a lemon which has developed a green, spongy, rotten place in it in contact with a perfect lemon and keep them where they will be moist. What happens to the sound fruits?

The plants that we have so far studied are green plants and contain *chlorophyll.* They are able to prepare their food from the air and soil by the aid of the sun's energy. There is, however, another great group of plants which have no chlorophyll and which are obliged to live upon the food that green plants have prepared. They find this food either in the living or in the dead parts of plants or animals, the animals having digested it from plants or other animals who originally obtained it from plants.

Plants that have no chlorophyll and live upon the food green plants have prepared are called *fungi.* The *bacteria* belong to this group. If plants live upon living plants or animals, they are called *parasites,* if upon dead ones, *saprophytes.* Plants of this kind are exceedingly important, although many of them can be seen only with the microscope. Without them the earth would soon become uninhabitable. Some of them are injurious to plants and animals, but a large number are most beneficial.

These plants cause the decay of dead animal and vegetable matter. If it were not for them, all the plants and animals that die upon the earth would encumber its surface indefinitely with their bodies, and none of the material that they have taken from the soil would return to fertilize it. These plants make possible the manufacture of vinegar, some cheeses and a great many other things which we use daily.

MISTLETOE GROWING ON AN OAK.
An interesting parasitic plant.

On the other hand, the decay in fruit, the mold on bread, the corn smut, the smut on oats and barley, the potato blight, the scabs of apples and potatoes, the rusts on grains and many other common plant diseases are simply fungus plant growths. The wheat rust alone costs the United States many millions of dollars each year. Thousands of feet of timber are destroyed yearly by the wood-destroying fungi. Dry rot of timber, as it is called, is due to a fungus growth. The fight against these harmful fungi costs millions of dollars each year.

But some fungi are exceedingly useful. The fungus most commonly made use of is the yeast plant. In bread making, yeast which contains the little yeast plants is mixed thoroughly into the material which is to compose the bread, and the bread is then put into a warm place to rise or, more exactly, to grow yeast plants. If the materials and the temperature are right, the yeast plants grow very rapidly, feeding upon the material of the dough and changing the sugar into carbon dioxide and alcohol. Little bubbles of gas are developed throughout the dough, making it slightly porous.

The bread is then kneaded to mix the greatly increased number of yeast plants still more thoroughly and is allowed "to rise" again. The plants are by this time very uniformly scattered through the dough and they develop little bubbles of carbon dioxide throughout the mass so that a light sponge results. When this is heated in the oven, the tiny bubbles of gas expand, making a more porous sponge, the alcohol evaporates, and the dough hardens, thus forming light bread. Although the study of these minute fungi is very interesting, it must be done by aid of the microscope and will not be attempted here.

We are most of us familiar with some of the larger fungi such as the mushrooms (Fig. 103) and toadstools. Mushrooms are widely used as a delicacy and their growth is an important industry in some sections. They are grown in soils very rich in humus and generally in dark, cellar-like places. The mushrooms that grow wild in the woods are abundant in some localities but should not be used for food unless most carefully examined by some one who is expert in determining the different species. There are several species of mushrooms which are exceedingly poisonous. For one of these there is no known antidote. The general structure of these larger fungi can be seen by examining a mushroom obtained from the market.


Fig. 103.

Experiment 113. — Place a slice of freshly boiled potato in each of five clean 4-ounce wide-mouth bottles. Close the mouths of the bottles with loose wads of absorbent cotton. Place four of these bottles in a sterilizer and sterilize for half an hour. Allow one bottle to remain unsterilized. (A sterilizer can be made by taking a covered tin pail and putting into the bottom of it a bent piece of tin with holes punched in it to act as a shelf on which to put the bottles. A shallow tin dish with holes in it is good for the shelf. There must be holes so that the steam will not get under the shelf and upset it. Fill the sterilizer with water to the top of the shelf and place the bottles on the shelf. Keep the water boiling.) A reliable inexpensive sterilizer is the pressure cooker shown in Figure 104.

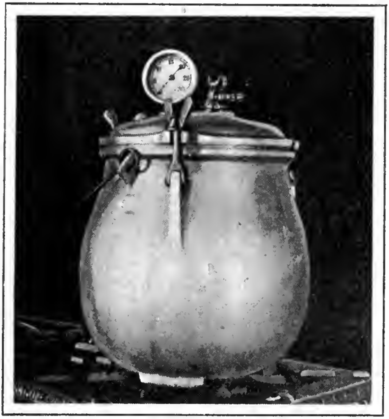


Fig. 104.

Take the bottles out and allow them to cool. Remove the cotton from one of them for several minutes and then replace. Run a hat pin two or three times through the flame of a Bunsen burner to sterilize it and place it in the water of a vase which has had flowers in it for some time. Carefully pulling aside the edge of the absorbent-cotton stopper in the second bottle, insert the pin and place a drop of the vase water on the surface of the piece of potato. After having sterilized the pin again, rub it several times over the moistened palm of the hand and then, using the same precautions as before, scratch the potato in the third bottle. Keep the fourth bottle just as it was taken from the sterilizer, as an indicator, that is, to see whether the bottles were thoroughly sterilized. Put all of the bottles away in a warm place and observe them each day for several days. The spots appearing on the pieces of potato are bacteria colonies.

99. **Bacteria.** — The nitrogen-fixing bacteria were considered, to some extent, under soil, but, as these soil bacteria

are but few in comparison with the great number of species found existing almost everywhere upon the earth's surface, bacteria will be further considered here. In Experiment 113 we found that if substances are left exposed to the air they soon undergo certain changes, which they are free from when properly protected. These changes are due to bacteria.

The bacterium is a single-cell plant, probably the simplest of all plants; it can only be seen with a high-power microscope. Bacteria are rod-shaped, thread-shaped, screw-shaped or have various other forms (Fig. 105). The protoplasm in the cell of bacteria has the power to assimilate food and build more protoplasm. When the cell has grown sufficiently, it divides into two cells.


Fig. 105.

A healthy bacterium grows fast enough to be ready to divide about once an hour. If it divided once an hour and each division continued to divide once an hour, in the course of twenty-four hours there would be nearly seventeen million bacteria produced. If this were kept up for some weeks, the mass of bacteria would be as large as the earth. Of course, this would mean that each bacterium had plenty of room to live in and plenty of food to live on and nothing to injure it. These conditions are not found, and each bacterium has to struggle for existence just as every other plant does. As it is, however, bacteria are numberless.

Since bacteria and fungi cause the "spoiling" of food, it is necessary to find means of stopping their growth. It has been found that thoroughly smoking fish and meat preserves it; that salt acts as a preservative; that if fruit is heated to a boiling temperature and tightly sealed in cans it will keep, and that fruits do not spoil if placed in strong sugar sirups.

These and many other methods are used to keep bacteria away from food and to prepare the food in such a way that bacteria cannot live in it. It is found that bacteria do not

PREPARING SMOKED FISH AT GLOUCESTER.

thrive as well if placed where it is cold, so foods are kept in cold places. Many bacteria cannot stand the sunlight; that is one of the reasons why it is so much more healthful to live in sunny rooms.

Steam is sufficient to kill bacteria as they usually exist. Under some conditions they can, however, withstand a greater temperature than that required to boil water. We found that they did not pass through absorbent cotton. It has been discovered that certain substances, like formaldehyde and hydrogen peroxide, prevent their growth. These substances are called *disinfectants.*

Certain bacteria thrive in the living flesh; it is therefore necessary to disinfect cuts or else blood poisoning, which is a bacterial disease, may set in. Sometimes when a rusty nail is run into the hand or foot, if the wound is not properly disinfected and cared for, lockjaw, another bacterial disease, is developed. After a wound is disinfected, it is usually dressed with absorbent cotton in order to keep out the bacteria.

Bacteria are the cause of many diseases, such as pneumonia, tuberculosis, smallpox, typhoid fever and others. People having diseases of these kinds throw off great quantities of bacteria, usually called *germs.* If such germs are breathed into the lungs or swallowed into the stomach and intestines of other people, they give them these diseases. It is necessary, therefore, in diseases of this kind to take every precaution that the germs shall not be scattered abroad.

Tuberculous patients should be exceedingly careful to use individual dishes, to cover their mouths with cloths when sneezing or coughing, otherwise they will scatter vast numbers of disease germs and become a menace to society. Although thousands are afflicted each year with tuberculosis, largely through the carelessness of those having the disease, it is a readily preventable and curable disease. The vile and dangerous habit of spitting should be abolished everywhere and public drinking cups and towels should be abolished.

When diseases are very virulent, like smallpox or diphtheria, the patients are usually kept by themselves, quarantined, their rooms kept disinfected and every precaution taken that people who are susceptible to the disease shall not be exposed to the germs.

When disease bacteria get established in the system, they secrete a poison called *toxin*, which is absorbed by the blood and carried throughout the body, thus poisoning many other parts beside those immediately attacked by the bacteria. The cells of the body at once begin to secrete a substance to counteract this poison, an *antitoxin*. If the vitality of the patient is great enough, sufficient antitoxin will be secreted to neutralize the effect of the toxin and the disease will be overcome.

Of late years it has been found that these antitoxins can be artificially supplied or caused to develop. Thus the system may be aided in neutralizing the effect of the toxin, and in warding off the disease. By injecting these antitoxins or stimulating their development, people are now protected against smallpox, diphtheria and other diseases.

Fig. 106.

Disease bacteria are not only found in the air, but also in water and milk and other kinds of food. We must therefore be very careful to keep these germs from our water, milk and food supply. Many cases of typhoid fever have been directly traced to the milk supplied by a dealer in whose family was a case of the fever. Flies (Fig. 106) are great carriers of bacteria and, by crawling over food, spread diseases.

Germs thrive particularly in sewers, cesspools and unsanitary places, so that these should be especially watched. The best guards against disease, however, are plenty of sunshine and air, wholesome food, sufficient rest and a tranquil mind. With these aids, the body is usually prepared in itself to kill the germs that come into it. Every day each person probably receives into his system thousands of disease germs and usually it is only when the vitality of the body is low that these germs are able to establish themselves. Right living is the great disease preventer.

As has already been stated, however, disease bacteria are only a small portion of the bacteria group of plants and the usefulness of the other members of this group is far greater than their harmfulness. Science each year is becoming more and more able to fight the disease germs, but it is entirely unable to supply the necessary aid given by the useful bacteria to animals and plants and, through them, to man.

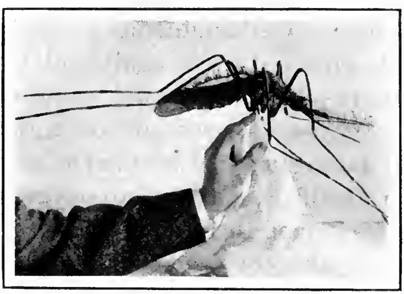
100. Animals. — Animals do not take their energy directly from the sunlight, but indirectly from the latent energy stored up in the foods prepared by green plants. These foods may be eaten as stored by the plants, or they may have passed through the medium of other plants and animals. The energy thus stored up is liberated by combining the carbon with oxygen. Carbon dioxide is freed.

The green plants use this carbon dioxide again and, by the aid of the sun's energy, free the oxygen and store up the carbon. Thus the cycle goes on, over and over, the plants freeing oxygen and taking up carbon dioxide, and the animals freeing carbon dioxide and taking up oxygen. The cells of plants which feed upon the food prepared by the chlorophyll of the leaves use oxygen and give out carbon dioxide just as the animal cells do; so also do other plants to some extent, but this is in small quantities.

101. Classification of Animals. — For convenience of study the animal kingdom has been divided into two great classes — the *invertebrates* (without backbone) and the *vertebrates* (with backbone). The invertebrate is the much more numerous class as it contains the worms, shell-fish, insects and those almost countless forms of animal life which have no internal bony skeleton and backbone. The higher animals, like fishes, amphibia, reptiles, birds and mammals, belong to the class of vertebrates. Man himself is the highest of the vertebrates, and as the purpose of this book is to study the earth and its relation to man, his structure will be studied later.

102. Invertebrates; Protozoa. — The very lowest form of animal life, the *protozoa*, are single-celled animals. In some species they are very difficult to distinguish from plants. They are microscopic in size and most of them live in water. Our chief interest in them in the present study is that they are the cause of several kinds of disease which can readily be prevented with proper care. Malaria, and the terrible African disease called the *sleeping sickness*, and probably yellow fever are due to these little animals.

Unlike bacteria, the protozoa do not cause disease by passing directly from one person to another, instead they need to live in some insect between whiles. In malaria and yellow fever the insect in which they live is the mosquito, and in the sleeping sickness they live in a fly called the *tsetse*. If a mosquito of the right species bites a person afflicted with malaria or yellow fever, some of these little animals, the protozoa, are sucked up with the blood and enter the mosquito. They grow in its body,



A Disease-bearing Mosquito.
Greatly magnified.

undergoing several changes, until the animal germs are ready to be injected into their victim, when they pass into the salivary glands of the mosquito. In biting, the mosquito always injects a little saliva into the wound and with this go the germs. These enter the blood, multiply rapidly and cause the disease.

If mosquitoes can be kept from biting people who have

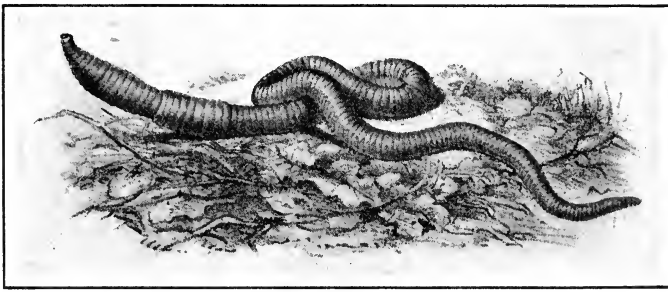
A "MALARIAL" SWAMP.
A breeding place for mosquitoes.

these diseases or if infected mosquitoes can be kept from biting other people, such diseases will not spread. The best way to keep mosquitoes from biting is to exterminate them. Since mosquitoes breed in stagnant water, all old dishes or small pools where water accumulates should be emptied and drained. Larger stagnant pools should be drained or have a film of kerosene spread over their surface by frequently pouring a little of the oil on the water.

This will keep the mosquitoes from breeding and prevent the diseases.

Thus mosquitoes and flies, the summer pests, are not only exceedingly annoying, but are very likely to spread disease. The Texas fever which has caused such great financial losses to the cattlemen of the United States is caused by a protozoan injected into the cattle by the bite of a tick.

103. Worms. — Another class of invertebrates is the *worms*. One of these, the earthworm, was found in the



EARTHWORM.
A great helper of the farmer.

study of soilmaking to be very important and should be considered in this place. If an earthworm is examined, it will be seen that the body is made up of segments or rings, and that it moves by successively shortening and elongating its body. Extending through the middle of the body is an alimentary canal consisting of a mouth, gizzard for grinding food, stomach and intestines.

Near the head is a little nerve center. The whole animal may be regarded as built up by the joining of a number of essentially similar segments. A more minute examination will show that these segments have been materially modified in some portions of the animal, but they have not been in any respect organized, as have the different parts of higher animals. This simple animal, as has already been seen, is an untiring worker in preparing and fertilizing soil for plants, and thus is a most efficient helper to man.

104. Insects. — **Experiment 114.** — Procure a bumble-bee or honey-bee, as a type insect, and inclose it in a small glass-covered box. Into how many parts is the body divided? Describe these parts. To which part are the legs attached? The wings? How many legs are there? How many wings? Notice the largest part into which the body is divided. Notice the eyes and the feelers, or *antennæ*, on the head. Write a short description of the general characteristics of the bee's body.

The *insects* are among the most important of animals. This class contains more than half the known animal species. They are spread widely over all parts of the earth.

BUTTERFLIES ON ALFALFA.

Both good and bad insects abound. Economically, they furnish millions upon millions of dollars worth of produce every year and on the other hand destroy hundreds of millions of dollars worth of crops and trees. It has been estimated that in the United States insects destroy every year crops and trees which have a value of $50,000,000, to say nothing of the countless losses due to diseases spread by flies and mosquitoes. Not many years ago grasshoppers nearly devastated several of the middle western states.

The most productive insects are the silk worms and the bees. Without the silk worm (Fig. 107) there would be no silk produced, and without the bee, no honey. These two products each year run into hundreds of millions of dollars. We have already seen that bees and other insects are needed also for the fertilization of flowers.

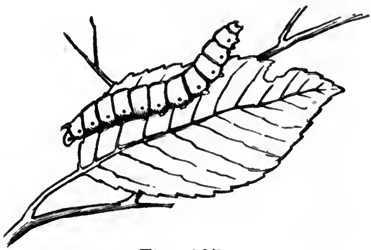


Fig. 107.

Among the most interesting of the insects and perhaps, everything considered, the most valuable, is the *honey-bee.* This is the great flower fertilizer; it would fertilize about all the plants man really needs except the red clover. In the United States alone there is produced by it about twenty-five million dollars worth of honey and wax each year.

In Experiment 114, it was found that the body of the bee, like other insects, is divided into three parts. These parts are called head, thorax and abdomen. The eyes and the feelers, or antennæ, are on the head. The mouth is a very complex organ, fitted both for biting and for sucking. The six legs and four wings are on the thorax. The hind leg of each working bee is so shaped and fringed with hairs that it forms a pollen basket.

Honey-bees live in large colonies and in the colony there are three kinds of bees, the male bees, or drones, the workers and the queen or female bee. The workers are the ones that make all of the honey and wax, do all the work of the hive and feed the grubs on rich food formed in their own stomachs, as well as on pollen mixed with honey. The grubs are the first stage in the development of the bee from the egg. The queen lays all the eggs, sometimes as many as a million. There is but one queen in each swarm. Whenever another queen is ready to be hatched, the old queen takes about half the colony and goes off to form another swarm.

The wax is secreted from glands in the abdomen of the

BEEHIVES.

Hundreds of dollars worth of honey are produced here each year.

workers and with this the bees build the comb. Each cell is hexagonal in cross section and the comb is so constructed that the least possible amount of wax will inclose the greatest possible amount of honey. The nectar at the bases of flowers supplies the bee with the material from which it makes the honey. It is in seeking for this that the bee visits so many flowers and scrapes the pollen on to the different parts of its body to be borne away to fertilize other flowers which it enters. Such an interesting animal and so exceedingly useful is the bee that hundreds of books have been written about it, more than about any other domestic animal. Some of these should be read for further information concerning this most instructive animal.

105. Vertebrates. — **Experiment 115.** — If possible, secure the skeleton of some vertebrate animal, preferably man. Notice how the bones are fitted to each other and how the joints are arranged to allow movement. Observe how carefully the brain and the spinal cord are protected, and also the thorax, which contains the heart and lungs. If a human skeleton is procured, notice the curving of the spine which enables the body to stand erect.

We have just studied briefly some of the invertebrates most closely related to the welfare or injury of man. Man himself belongs to the other great class, vertebrates. The higher animals which furnish him with the greater part of his animal food also belong to this class. Although there are great variations in the structure of vertebrate animals, yet they are alike in having a backbone and an inner supporting skeleton.

A Human Skeleton. Notice how the bones are arranged to protect the delicate organs.

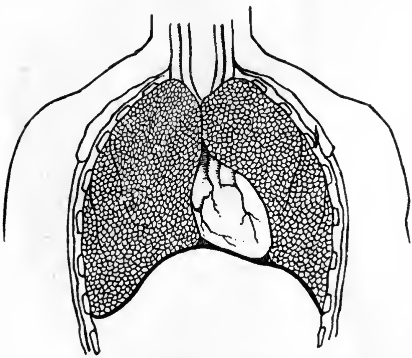
The bony *skeleton* in the higher forms of animal life consists of a vertebral column, skull, ribs and appendages. The main skeleton protects the most delicate organs and acts as a support for the attachment of the muscles. The appendages, like the legs and arms in man, are jointed to the central part of the skeleton, and it is the action of the muscles in moving these about the joints that makes movement from place to place possible.

In the skull is situated the great nerve center of the animal, the *brain*, and from this through the vertebral column passes the great nerve distributor, the *spinal cord.* From the spinal cord, *nerves* are sent to all the muscles of the body, to the skin and to those organs, like the eye and the ear, which transmit to the brain impressions received from without the body. These nerves give the stimulus which causes the muscles to expand or contract. In fact, all the voluntary movements of animals are controlled from the brain just as the movements of trains on a railroad are controlled from the despatcher's office.

THE NERVOUS SYSTEM OF MAN.
Notice how the nerves are distributed to all parts of the body.

106. Respiration. — All animals must have a way to breathe, or energy cannot be supplied to carry on the activities of the body. Different animals breathe in different ways, but in the higher vertebrates and in man it is the same. Respiration in man will, therefore, be taken as the type.

Air enters the body through the nose or mouth, and passes down through the windpipe into the *lungs*. In order to keep out dust and germs, the opening of the nose is supplied with a large number of hairs projecting from the mucous membrane which lines the whole nasal chamber. These hairs and the secretion from the membrane catch and hold most of the harmful particles. At the back of the mouth the windpipe and the throat come together.



THE LUNGS.
They are here pulled aside to show the heart.

When food is being swallowed, the passage into the windpipe must be closed, and this is done by the little valve-like *epiglottis*. If, in swallowing, the epiglottis is not able to close quickly enough, something may pass into the windpipe and cause choking. The windpipe, at the upper part of the chest, branches into two parts, one branch going to each of the lungs.

The lungs fill the upper part of the chest and enfold the heart. In them the air tubes divide again and again, forming a vast network of tubes which grow smaller and smaller until they end in little air sacks. Interlacing with these air tubes are veins and arteries which carry the blood. The tiniest parts into which the blood vessels are divided, the *capillaries*, form close networks within the linings of their sacks. The air and blood are thus separated by an exceedingly thin animal tissue, which allows an exchange of soluble materials. Thus the blood is able to take up the oxygen needed and to rid itself of the carbon dioxide and other waste products which it has accumulated.

The air-tight thoracic cavity in which the heart and lungs are situated is inclosed and protected by the ribs and at the lower part by a dome-shaped muscle called the *diaphragm*. Air enters the lungs because the muscles of the chest pull the ribs so that they move upward and outward and the muscles of the dome-shaped diaphragm cause it to move downward. These two actions enlarge the thoracic cavity. The air enters in the same way that it enters a hollow rubber ball that has been compressed and then set free. When the ribs move downward and the diaphragm upward, the air is expelled as in the rubber ball when compressed.

There are then two ways in which air can be made to enter the lungs, the "raising of the chest" and the movement of the diaphragm. In the proper kind of breathing these two movements go on together. The lungs are filled throughout and not simply at either the top or bottom. If this is to be accomplished, the body must be free and not restricted by tight clothing about the chest or the lower part of the trunk of the body, the *abdomen*. Not only is the right kind of breathing necessary for properly supplying the blood with oxygen, but also that the lung tissues themselves may be properly nourished and cared for. We should be particularly careful about this now that infectious diseases of the lungs are so prevalent.

107. Circulation. — **Experiment 116.** — If a compound microscope can be procured, tie a string tightly around the end of a clean finger, and when it has become full of blood, prick it quickly with a sterilized needle. Rub the drop of blood that comes out on a glass slide and quickly examine under the microscope. Notice the great number of round disk-like bodies, red corpuscles. Try to find an irregular-shaped body which, while the blood remains fresh, slowly changes its shape, a white corpuscle. These are rather difficult to find, but can be seen if the drop of blood is thoroughly examined quickly enough.

In order that all parts of the body may be provided with the materials used in building their cells and in doing the work necessary for continued existence there must be a distributory system. This is necessary wherever diversified work is to be carried on. This necessity has brought into effect the railway and canal systems of the world. The body is a little world by itself, and it has a most complete and wonderfully adapted system for supplying the material needed and for removing the waste. The center and motive power of this system is the *heart*. The medium of circulation is the *blood*.

When the blood is examined, it is found to consist of a watery liquid, called the *plasma*, a great number of little disk-shaped bodies, the *red corpuscles*, and some irregular whitish bodies, the *white corpuscles* (Fig. 108). The white corpuscles are protoplasmic cells having various functions and possessing the power of movement and even of working their way out of the blood vessels. The main function of the red corpuscles is to carry oxygen from the lungs to the different living cells of the body. They contain a pigment, *hæmoglobin*, which carries the oxygen and gives the blood its color. The plasma, an exceedingly complex fluid, is composed largely of water, but contains the nutrient and waste materials supplied by the different organs of the body.

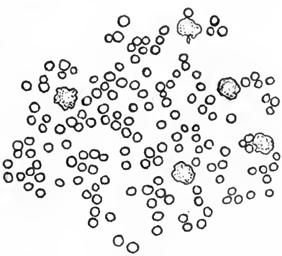
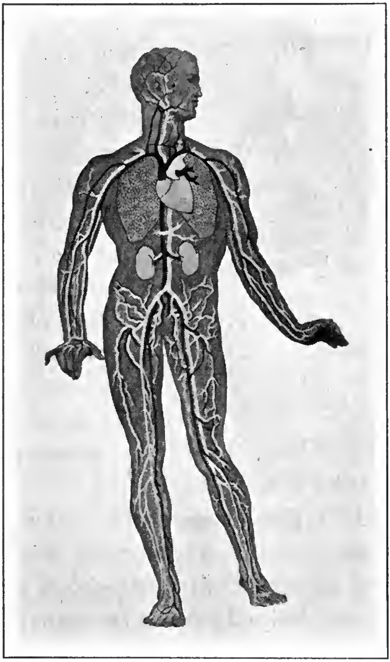


Fig. 108.

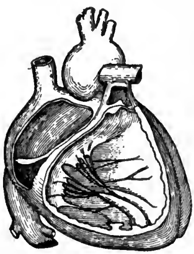
The blood passes through different kinds of vessels. Those leading from the heart are called *arteries*, and those returning to the heart are called *veins*. As the arteries proceed out from the heart they divide continually, becoming smaller and smaller until they terminate in very small thin-walled vessels called *capillaries.* These capillaries unite and form veins. Thus the blood is continually flowing from the heart through the capillaries into the veins and back to the heart.



THE CIRCULATORY SYSTEM.
Notice that the veins (white) are outside of the arteries (black).

As a rule the arteries are below the surface of the body, where they are protected, but if the finger is placed on the wrist or the side of the face near the ear, an artery can be felt through which the blood is pulsing. The veins can be seen in the back of the hand and a pin piercing the body anywhere will break open some of the capillaries and cause blood to ooze out. The capillaries spread throughout the entire tissue of the body and supply with food and oxygen the different living cells of which the body is composed.

The heart is a muscular force pump composed of four chambers, two *auricles* and two *ventricles.* It is shaped somewhat like a pear and is situated almost directly behind the breastbone. The blood coming back from the veins flows into the right auricle, a chamber with rather flabby walls. From here, it passes through a valve into the right ventricle, which is a chamber with very thick muscular walls. From the right ventricle, the blood is driven out through the arteries, capillaries and veins of the lungs, where carbon dioxide is given off and oxygen absorbed by the red corpuscles.



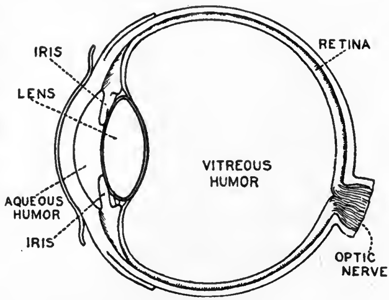
CROSS SECTION OF THE HUMAN HEART. Showing auricle, ventricle and ventricle valve.

Returning from the lungs, the blood enters the left auricle and when this becomes full, passes through a valve into the left ventricle. This has such powerfully muscular walls that it is able to force the blood throughout the body and back again to the right auricle. As the blood leaves either ventricle, there are valves that close and prevent its return. If the hand is placed a little to the left of the breastbone, the strong contraction of the ventricle can be felt.

108. The Senses. — In order that the brain may communicate with the outside world and so be able to protect the animal from destruction and to provide for its well-being, animals have become provided with a number of *sense organs* which communicate with the brain by the nerves. The most conspicuous sensations of the human body are sight, hearing, taste, smell and touch.

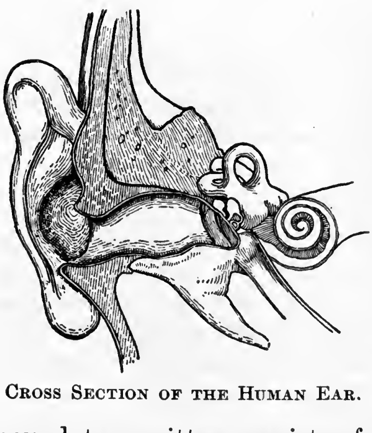
The organ of sight, the *eye*, is an exceedingly sensitive, automatically adjustable camera that records through the nerves. The camera box is the hard bony socket in which it is placed, the *eyelid* is the shutter, and the *iris*, the diaphragm. The iris is the membrane in the front of the eye which opens or contracts to let in more or less light. In the center of it is a hole, the *pupil*.

Back of the shutter, or iris, is a small adjustable *lens* and beyond this the sensitive plate, the *retina*. Between the iris and the front of the eye is a watery-like material, the *aqueous humor*, which keeps the front of the eye extended into its rounded form. Back of the lens is a thick, transparent, jelly-like material, the *vitreous humor*, which holds the retina extended and keeps the eye from collapsing.



CROSS SECTION OF THE HUMAN EYE. The pupil is the opening between the upper and lower parts of the iris as shown in the figure.

Instead of moving the retina back and forth to focus a picture, as is done with the ground-glass plate in a camera, the eye lens is capable of adjusting itself so as to focus objects which are at different distances. Leading back to the brain from the retina, is the *optic nerve*, which carries the impressions made on the retina to the brain where they are interpreted into the sensation of *sight*.



CROSS SECTION OF THE HUMAN EAR.

This rough comparison is by no means a description of the eye, for it is a most complex and wonderful organ, vastly superior in construction to a camera. A technical description would, however, be out of place here.

The *ear*, which is the sound transmitter, consists of the outer ear, which is so arranged as to catch the sound waves and converge them upon the ear drum. The *ear drum* is a thin membrane stretched tightly across a bony opening and vibrating when the air waves strike it, as a drum does when struck by the drumstick. On its inner side the drum is attached to the inner ear by a chain of three bones. The sensitive cells of the inner ear transmit the impressions made by the sound vibrations through the *auditory nerve* to the brain, where they are interpreted into the sensation of *sound*.

On the *tongue* and in the *nose* are cells which transmit to the brain the impressions produced upon them by different qualities, the one of solutions and the other of gases. The sensations thus produced are called *taste* and *smell*.

The sensation of *touch* originates in the skin and is much more acute in some portions than in others. The tips of the fingers in the blind are often trained to such delicate perception that they, in a great degree, take the place of the lacking sense organ. These sensations, like all others, are carried to the brain by the nerves and there interpreted into the sensation of touch.

109. Food. — **Experiment 117.** — Chop a piece of the white of a hard-boiled egg into pieces about as large as the head of a pin and place in a test tube. Chop up another piece much finer than this and place it in a second test tube. Make a mixture of 100 cc. of water, 5 cc. of essence of pepsin and 2 cc. of hydrochloric acid. Pour into each test tube enough of this mixture to cover the white of egg to a considerable depth. Shake thoroughly and put in a place where the temperature can be maintained at 37° C. or 98° F. A fireless cooker or a bucket of warm water is good for this. Allow to stand for several hours, keeping the temperature constant. The white of egg is dissolved, the action being more rapid in the second tube. Try the same experiment using water; using dilute hydrochloric acid. Do these have the same effect as when used with the pepsin? The pepsin solution is an artificial gastric juice.

In order that the work of the body may be carried on, food is required. This food may be supplied by either animals or plants. The original source of all animal and plant food, as has been seen, is in the chlorophyll manufactory of the leaf and green stem. After this leaf food has been manufactured, it is simply modified by the plants and animals through which it passes. The food is used (1) in growing new cells, (2) in repairing cells that have been used up or destroyed, (3) in providing energy to carry on the activities of the body and maintain its heat or (4) in doing external work, such as moving the body itself from place to place or moving other bodies.

To furnish any of this energy, the cells must be able to combine food with oxygen. To do this the food must be digested or prepared so that it can pass through animal tissue. In the higher animals, a complicated apparatus is provided to accomplish this. In man, it is briefly as follows: a long continuous tube, the food-tract or the *alimentary canal* (Fig. 109), extends through the body.

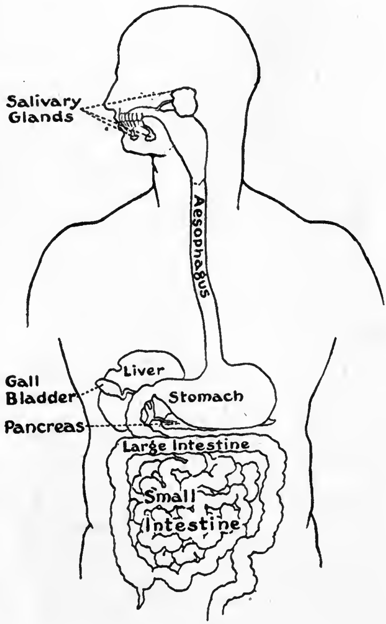


Fig. 109.

Different portions of this tube are adapted to different processes. In the mouth, the teeth grind the food into small bits and mix it with the *saliva*. This is an exceedingly important part of the process, because if the food is not ground fine, the digestive juices cannot readily get at it, and the whole process of digestion is greatly retarded. Thus much more energy is expended than otherwise would be. The saliva is necessary to digest some of the starch and to aid in the further digestion.

The food passes from the mouth down the throat and through a valve into the *stomach.* This is a large pouch which will hold usually from three to four quarts. It has muscular walls which enable it to contract and expand, thus keeping the food moving about so that it is thoroughly mixed with the *gastric juice.* The gastric juice is secreted by little glands thickly imbedded in the lining of the stomach. Artificial gastric juice was made in Experiment 117. Some of the proteins (Experiment 119) are digested in the stomach, although the larger part of digestion takes place in the small intestine.

From the stomach the food passes through a valve into the *small intestine.* This is a complexly coiled tube which fills the larger part of the abdomen. The inner wall of the tube is lined with glands which secrete digestive juices, and into the intestine are poured the secretions from two large glands, the *pancreas* and the *liver.* The small intestine is the great digestive organ of the body. Here the fats and oils (Experiment 120) are digested and the digestion of the starches and proteins is completed. The small intestine opens through a valve into the *large intestine,* a tube five or six feet long decreasing in size toward the exit to the body. There is little digestion in the large intestine.

The changes that take place in the food as it passes through the alimentary canal are very complex, but during its progress the valuable part of the food is so changed and prepared that it can be absorbed by the blood and transported by it to the different parts of the body where its energy is needed. Absorption takes place all along the alimentary canal wherever the food has been sufficiently prepared.

110. Necessary Foods. — **Experiment 118.** — Place in different test tubes small amounts of (1) corn starch, (2) grape sugar, (3) scrapings from a raw potato, (4) flour, and (5) the white of an egg. Pour in a little water and shake thoroughly. Drop into each tube a few drops of the iodine solution prepared in Experiment 100.

Experiment 119. — Place in test tubes small quantities of (1) the white of a hard-boiled egg, (2) tallow or lard, (3) grape sugar, and (4) any other food which may be handy. Pour a little concentrated nitric acid into each tube and allow to stand for a minute. Be careful not to get the nitric acid on the clothes or hands. Pour the acid out into a slop jar and wash the substances with a little water. Pour off the wash water and pour on a little strong ammonia. If the substances turn a yellow or orange color, proteins are present. Which substances contain proteins?

Experiment 120. — Gasoline vapor is very inflammable, so be sure in this experiment that there is no flame in the room. Place about a spoonful of (1) both the white and the yellow of an egg, (2) flaxseed meal, (3) yellow corn meal, (4) white flour, and (5) other foods it is desired to test in separate evaporating dishes or beakers near an open window. Pour on to these enough gasoline to more than cover them and stir thoroughly. Cover the evaporating dishes and allow to stand for ten or fifteen minutes. Pour the gasoline off into a beaker and set the beaker outside the window until the gasoline has evaporated. If there is anything left it must have been dissolved from the food. If a substance remains, place a drop of it on a piece of paper. Smell of it. Try to mix it with water. Rub it between the fingers. Try any other fat or oil test of which you can think.

Experiment 121. — In a place where there is a good draft so that odors will not penetrate the room, burn in an iron spoon over a Bunsen burner (1) small pieces of meat, (2) a little condensed milk or milk powder, (3) part of an egg, and (4) any other food. Is there a residue left after burning? If so, this is mineral matter.

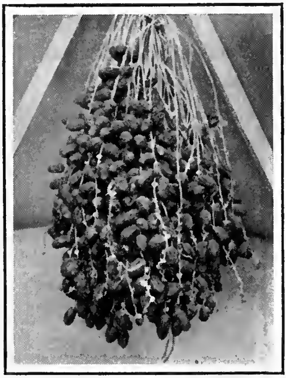
In Experiments 118–121 we found that our ordinary foods are of three great groups of chemical compounds, carbohydrates (starches and sugars), proteins, and fats or oils. The common foods that consist largely of proteins are lean meat, cheese, eggs, beans, and peas. Those largely composed of carbohydrates are most cereals, vegetables and fruits. The fats are butter, pork, nuts and chocolate. Milk contains all three of these compounds in approximately the proportion needed by the body.

A DATE PALM.

Careful experiment has shown that the average, full-grown American needs each day two to three ounces of proteins, about four ounces of fats and a pound of carbohydrates. The weight of food eaten, however, is very much greater than this, as all foods are composed largely of water. The proteins are needed for growth and repair, since the living part of the cells, the protoplasm, is composed of proteins. The rest of the food furnishes energy.

Until recently, it was thought that a great deal of meat was necessary to furnish the energy needed for hard muscular work. But now investigation has shown that this energy can better be supplied by other foods and that eating too much meat is not only needlessly expensive but bad for the system. The staple food of northern Africa and southwestern Asia is the date palm, which is admirable for hot climates. In cold regions where the body requires great energy to keep up its heat, much fat is eaten and sugar, if procurable. The exact kind of food used must always depend largely on its availability and on the tastes of the individual, but the diet should be so varied as to contain sufficient of each of the three great classes of foods.

Besides the necessary foods, most individuals desire especial additions for relishes and beverages. These commonly consist of spices, tea and coffee and other like materials. When used in moderation, they are usually a benefit, as they stimulate the appetite. But excessive use is harmful.


A Bunch of Dates.

Alcohol, except possibly in exceedingly small quantities, cannot be considered a food, and as a stimulator for the appetite it should not be used. Many careful experiments have shown that while it may stimulate the body temporarily, it does not enable it to do more work. Instead, those using it cannot do as much work, or withstand as great physical or mental strain, as those not using it. Even if it were not for the ungovernable appetite which its use almost invariably engenders, and for the degrading influences with which its use is usually surrounded, its physiological action is such as to lessen the body's vitality, decrease its resistance to disease, and dull its nervous and mental efficiency.

Careful scientific experiments have also been made upon the effect of tobacco. Although there are differences of opinion about its effect upon fully matured adults, there is no such difference of opinion in regard to its effect upon those who have not stopped growing and are not yet fully matured. Measurements and comparisons made in regard to the physical development, endurance and mental ability of a large number of college men has shown conclusively that those who have not used tobacco, as a rule, have better physiques, are better students and can stand more physical exercise than those who have used it. In the competition for athletic teams it is found that only about half as many of those who have used tobacco make good, as of those who have not used it.

COFFEE PLANT.

Showing the clusters of beans from which coffee is produced.

111. Preparation of Foods. — When foods are appetizing, look good, smell good and taste good, both the saliva and the gastric juice are secreted in larger quantities, so that this sort of food, when taken into the system, is more readily digested than food which is not attractive. One of the reasons for cooking food is to render it appetizing, and this should never be lost sight of by the cook. Cooking also softens and loosens the fibers of meats and causes the cell walls of the starch granules to burst, thus rendering it possible for the digestive juices to attack the food more readily. In addition, cooking kills the germs and other parasites that are sometimes found in foods.

To cook food properly is a fine art and requires most careful study and great skill. The science of providing economically the kinds of food necessary and of cooking these properly so that they will be attractive, easily digested and will lose none of their nutritive value, is one that is at present in its infancy. Human beings, like other animals, must have a balanced ration or diet if they are to be most productive economically. They differ from other animals in having a much greater range of food possibilities and in being much more sensitive as to the appearance and taste of food.

Summary. — Plants and animals form the live part of the earth. Most plants consist of root, stem and leaves. The root takes in all the plant's food except carbon and oxygen. These are supplied through the leaves. The leaves are the original food manufactories for all plants and animals. They are supported on the stem, of which there are two great classes, *monocotyledonous* and *dicotyledonous*.

The stems also support the flower, which usually consists of calyx, corolla, stamen and pistils. The chief function of the flower is to produce the seeds by which the plants are reproduced. The pollen grains which are necessary for the fertilization of the egg cells are carried and spread by the wind and by insects and birds. The seeds are also scattered by the wind and by animals and sometimes by floating down streams.

Besides these green plants there is another class called *fungi.* Instead of preparing their own food by the help of the sun and the soil, they live upon the food prepared by the green plants.

Probably the simplest plants are the *bacteria*, single-cell plants, which multiply very rapidly. Bacteria and fungi cause many diseases as well as most of the spoiling of food. Disease bacteria are usually called *germs*. Their effects may be counteracted by the use of disinfectants and antitoxins.

Animals take their energy indirectly from the foods prepared by green plants or by other animals. They are usually classed as *invertebrate* and *vertebrate*. The lowest form of invertebrate is the protozoön. Worms and insects are other forms of invertebrates, the importance of which is seldom realized.

Vertebrates usually have a backbone, skull, ribs and appendages. In the skull is the brain, connected to the various parts of the body by nerves. Vertebrates breathe by "drawing" air through the windpipe into the lungs. This is done by the muscles of the chest and diaphragm. The lungs purify the blood, which circulates from the heart through the arteries and capillaries and back through the veins.

The five senses are sight, hearing, taste, smell and touch. These sensations are carried to the brain by the nerves, and they come from the eye, the ear, the nose, the mouth and the skin, respectively.

For all the activities of body and brain, food is required. As food passes through the alimentary canal, various juices are mixed with it and certain parts of it are digested and absorbed into the body. Foods are of three kinds, proteins, carbohydrates and fats, and we need a certain percentage of each for proper nourishment. Usually foods are most nourishing and most appetizing when properly cooked.

Questions

Why should plants and animals, like other earth phenomena, be studied in this course?

What are the three parts into which most plants can be readily separated? In what three respects are plants and animals alike? What do the plant roots do for the plant? How do they do it? Describe some different kinds of stems that you have seen, and explain their adaptability or lack of adaptability for making the best of the conditions where they were.

What do the leaves do for the plant? How do they do it?

What is the value to the plant of the flower? How are the flowers prepared to carry out their part in the life struggle of the plant? Describe any way in which you know that animals have been of assistance to plants.

How do plants provide for the dispersal of their seeds?

How does the seed develop into a plant?

With what useful or what harmful fungi have you ever had any experience?

In what ways are bacteria helpful and in what ways harmful to mankind? How are harmful bacteria guarded against?

How are plants and animals mutually helpful to each other?

Name and describe some of the invertebrate animals you know.

How have we found that the angleworm benefits the soil?

What is the use to the vertebrate of the skeleton and the nervous system?

Describe how vertebrate animals breathe. Why is it vitally necessary for them to breathe freely?

What is the use of the blood? How does it get around to where it is needed?

Describe the ways in which man becomes aware of what is outside his body.

Why is food needed? How and where is it digested?

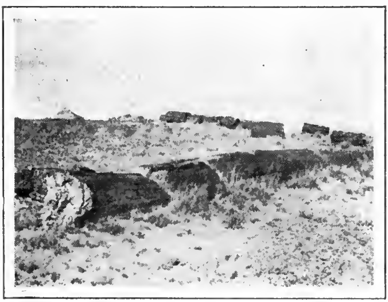
What are the three great groups into which foods are divided? Why should you not use alcohol or tobacco?

Why is cookery one of the most useful arts?

CHAPTER VII

LIFE OF THE EARTH AS RELATED TO PHYSICAL CONDITIONS

112. Ancient Life History. — As the rock layers of the earth are explored, *fossils* of different kinds of plants and animals are discovered. The fossils of the more recent rock layers correspond very closely to the plants and animals that are found upon the earth to-day, but the older the layers, the less they correspond. There seems to have been a gradual development in life forms through the past ages, a fragmentary record of which is engraved upon certain of the sedimentary rocks. Rocks which were formed under different conditions contain different species of life forms, showing that throughout all time the geographic condition has had a marked influence upon plants and animals.



PETRIFIED TREES.
Found near Holbrook, Arizona.

The rocks and fossils show that the geographical conditions of certain areas also have varied greatly. Some regions have been below and above the sea several times. Regions now cold have been warm, and those now dry have been wet, and *vice versa.* Thus the life in certain areas has suffered great changes by the geographical accidents to which the region has been subjected. The petrified forests near Holbrook, Arizona, show some of the most remarkable tree fossils ever found and indicate that the region has been subjected to remarkable geographical changes.

113. Distribution of Life. — Plants and animals are found wherever the conditions are suitable for their existence. In ice-covered areas, like the interior of Greenland, and in exceedingly dry regions, like the Sahara and certain parts of southwestern United States, there is little life of any kind. With a few such exceptions, however, the surface of the earth is a universal battlefield of plants and animals struggling to exist and to increase. They extend themselves wherever attainable space is opened. But barriers may oppose their spread and geographical accidents may drive them from areas which they had heretofore held. The retreat of the sea may cause a change in the position of shore life. In the water a land barrier or an expanse of deep water may prevent the spread of shore forms. On the land a mountain uplift, a desert area, or a water barrier may limit the space occupied by animal and vegetable species.

GILA MONSTERS.
The most poisonous reptiles of the southwestern American desert.

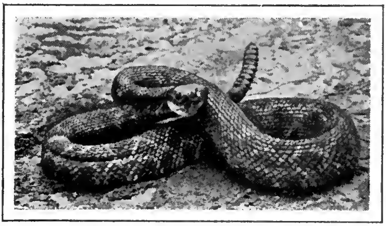
Certain plants and animals are much more widely distributed than others. Plants like the dandelion and thistle, whose seeds are easily blown about by the wind, spread rapidly, while trees like the oak and chestnut spread slowly. As plants have not the power to move about, they cannot distribute themselves as easily as animals. Certain birds which are strong of flight are found widely distributed over regions separated by barriers impassable to other animals.

CANADA THISTLE.
One of the most widely distributed of plants.

Some of the present barriers to life distribution have come into existence in comparatively recent geological time. There is good reason to believe that the British Isles and Europe were formerly connected, and that in very ancient times Australia was joined to Asia. It is also believed that for long ages North and South America were separated by a water barrier and that even after they were once connected, the Isthmus of Panama was again submerged.

These are but a few illustrations of the changes in the earth's surface which have affected the distribution of animals and plants. Climatic changes like that which brought about the great ice advance of the Glacial Period have affected in a marked degree the distribution of life. It is thus found that when a study is made of the present distribution of life, careful attention must be given to the present and past geographical conditions of the region.

114. Adaptability of Life.— There is hardly a place on the earth's surface not adapted to some form of life. Even upon



A RATTLESNAKE COILED READY TO SPRING.

The color of these reptiles makes them hardly distinguishable from the surrounding desert.

CACTI.

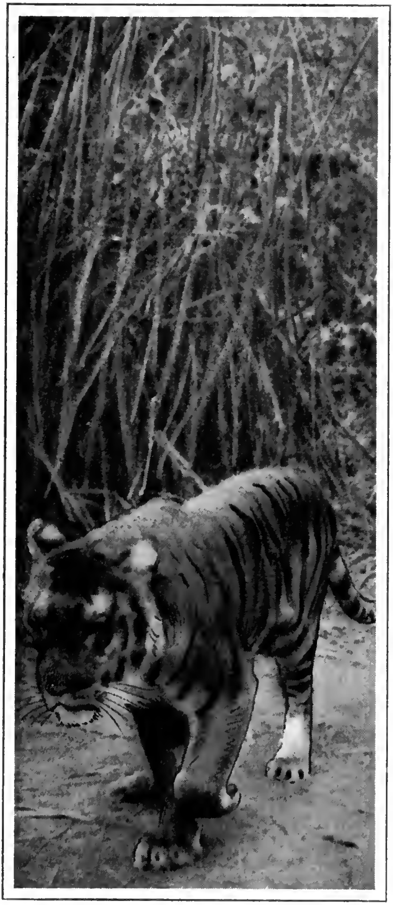
These are adapted to desert life because they have no leaves from which water can evaporate.

the ice-bound interior of Greenland a microscopical plant and a tiny worm have found a home. The dry desert regions have a few plants with small leaves or, like the cactus, with no true leaves. This prevents the evaporation of the water from their surfaces and so protects them from drought. To protect them from animals, many of these plants are armed with thorns.

A HERD OF REINDEER.

This animal is of invaluable service to man in polar regions.

Another example of adaptability is the fact that the small animals of the desert are generally of a sandy color, which makes them hardly distinguishable from their desert surroundings. The large ones are swift strong runners, like the antelope and ostrich, or, like the camel, are able to travel for long distances without water.

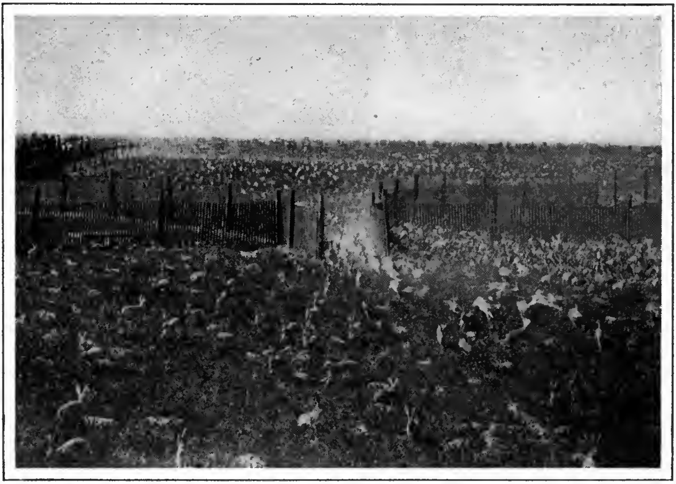


TIGER.
One of the most widely distributed of animals.

In the colder regions the plants have the power of rapid growth and germination during the short season when the snow has melted away. Then, during the long winter, they lie dormant but unharmed under the snow and ice. The animals are either able, like the reindeer, to live upon the dry mosses, lichen and stunted bushes, or else upon other animals. Their color, like that of the polar bear, often blends with their surroundings.

Some animals have a wide range of adaptability, like the tiger, which is found from the equator to Siberia. But usually the range of an animal species is much more restricted, since it is seldom able to adapt itself to widely differing conditions. The surrounding region, the elevation, the temperature, the amount of moisture, the soil, the kinds of winds and their force, all have a marked effect upon the *fauna* (animals) and *flora* (plants) of a country.

The species that thrive in a region must have adapted themselves to the existing conditions, yet other animals and plants may be as well adapted for certain regions as



A California Rabbit Drive.

In some communities rabbits become such a pest that the inhabitants turn out in a body and drive them into enclosures.

those now inhabiting them. Striking examples of this are the English sparrow and the gipsy moth, which have spread with such tremendous rapidity since their introduction into this country. The rabbit in Australia and southern California is another striking example. The adaptability of plants to a new region is also illustrated by the Russian thistle which was introduced into this country in 1873 and which has now become a national pest.

115. Life of the Sea. — The plants living in the sea are nearly all of a low order. The mangrove trees which border some tropical shores represent their highest type. The most abundant of sea plants, the seaweeds, have no

DIFFERENT KINDS OF SEAWEED.

flower or seed or true root, although most of them have an anchoring device by which they are attached to the bottom. Their food is absorbed from the surrounding water. They have developed little supporting tissue, but instead have bladder-like air cavities or floats, which enable them to maintain an erect position or to float freely in the water. Usually they abound near the shore where the water is shallow.

The vast surface of the open sea supports few plants except the minute one-celled plants, the *diatoms*, of which there are many species and an almost infinite number of individuals. These furnish about the only food for the animals of the open sea except that obtained by preying upon each other.

A great quantity of detached seaweed (*Sargassum*), filled with multitudes of small marine animals and the fishes which prey upon them, covers the surface of the middle Atlantic, the center of the oceanic eddy. Through this Columbus sailed from the 16th of September to the 8th of October, 1492, greatly to his own astonishment and to the terror of his crew, who had never before heard of these "oceanic meadows."

The animals of the sea vary in size from the microscopic *globigerina*, whose tiny shells blanket the beds of the deeper seas, to the whale, that huge giant of the deep, in comparison with which the largest land animals are but pigmies. Although monarch of all the finny tribe, it is not a fish at all, but a mammal which became infatuated with a salt-water life and so through countless ages has more and more assumed the finny aspect. It is obliged to rise to the surface to breathe. It cares for its young like other mammals.

A SMALL SHARK.
Photographed under water.

Here, too, are found the jellyfish, the Portuguese man-of-war (Fig. 110), some fishes, many crustaceans, a few insects, turtles, snakes and mammals. Most of these animals are lightly built and are well equipped for floating and swimming. Some sea animals, like the oyster, barnacle and coral polyp, are fixed, and rely upon the currents of the water to bring them their food, while others, like the crab, the lobster and the fish, move from place to place in search of prey.

Fig. 110.

In the warmer seas the surface water is often filled with minute microscopical animals which have the power, when disturbed, of emitting light, so that when a boat glides through these waters, a trail of sparkling silver seems to follow in the wake.

Between the surface and the bottom of the deep ocean there seems to be a vast depth of water almost devoid of life. This region, like the bottom of the ocean, has been little explored and there may be life here which has not been discovered. From the bottom of the sea the dredge has brought up some very curious forms of life. Here under tremendous pressure and in profound darkness have been developed species of carnivorous fishes.

FLYING FISH.
Notice how the front fins have become wing-like.

Some of these have large peculiarly well-developed eyes and others have not even the rudiments of eyes. As the light of the sun never penetrates to these depths, it would seem at first that eyes could be of no use to animals, but it has been found that some of the animals of the ocean bottom have the power of emitting light in some such way as the glowworm and firefly do, and it is probable that it is to see this phosphorescent light that the eyes of the animals are used. There are no plants here and the life is much less abundant and less varied than near the surface.

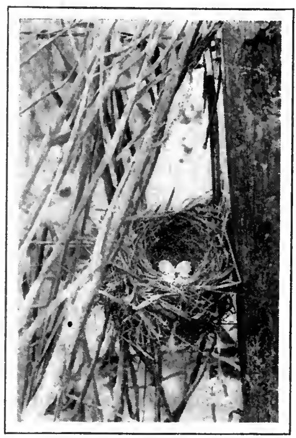
There is but little variation in the conditions surrounding the animals of the sea, so the organs corresponding to these conditions are not diverse. Living in a buoyant medium dense enough to support their bodies, and of almost unvarying temperature, the sea animals have never required or developed varied organs for locomotion, like the wing, the hoof and the paw, or for protection from cold, like the feather, the hair, or wool. It is true that certain sea dwellers, like the seal, are covered with hair, but these air breathers were probably originally a land type and have acquired the habit of living in the water. The highest traits of animal life, such as are found in land animals, have not been required or acquired by the sea animals, and although the number of species and kinds is very great, there is not found among them the same grade of intelligence or power of adaptability, as among the land animals.

SEALS.
Originally land animals.

116. Life of the Land — The highest development of both plant and animal life is found upon the land. Here at the meeting place of the solid earth and its gaseous envelope, subjected to great variations in amount of sunlight, moisture, temperature and soil, the plants and animals have acquired a marvelous variety of forms and structures to adapt them for their varied surroundings, and enable them to secure a living.

Prickly Phlox.
Notice the thorns by which it protects itself.

Some plants lift their strong arms high into the air to intercept the sunbeams before they strike the earth, while others clothe the surface with a dress of varied green. In some plants, odor, nectar or juicy berries attract the animals whose aid is needed for fertilizing and scattering their seeds, while in others, noxious odors, prickles, thorns and acrid secretions warn away animals destructive to their welfare. The highest perfection of beauty, utility and productiveness among plants has been reached by those of the land.



Bird's Nest.
A simple home.

The animals of the land, surrounded by the air, which bears no food solutions to inert mouths, must be well endowed with the power of motion in order to procure their food. They must either crawl over the surface or be provided with appendages to support their weight against gravity. There is no floating supinely in the air as in the water. Movement, exertion, search are the requisites of this realm. The eggs and young, as a rule, cannot be cast adrift to hatch and care for themselves; the nest, the burrow, the den must be provided. This is the realm of homes.

The land animals are also the most intelligent. Birds long ago solved the problem of flight for a body heavier than air, which is now being successfully solved by man after years of effort. Certain animals, like the bee, the ant and the squirrel, have the provident habit of storing up food in the summer against a day of need. Other animals, like the birds, have learned to migrate to a warmer

A BEAVER DAM.
Notice the two beavers on top of the dam.

clime when winter comes. The beaver is probably the pioneer in hydraulic engineering. When he feels the need of a water reservoir, he builds a dam and makes it. To-day many a swamp in the northern states owes its origin to him. Wonderful indeed is the intelligence of many of the land animals, due in large part to their development amid varied geographical conditions.

117. Distribution of Animals. — An examination of a globe shows (1) that the land is massed around the north pole, (2) that the three continental masses to the south are separated from each other by wide seas, and (3) that while two of these are connected by narrow strips of land to northern continents, the third is entirely separated from all other land.

But slight changes in elevation would connect the northern continents with each other. As they are so closely related to each other, it might be expected that the animals of these continents would resemble each other, particularly in the more northern parts. This is true. Bears, wolves, foxes, elk, deer and sheep of nearly related species are found distributed over the northern continents.

OSTRICHES.
The largest of all birds.

The animals of the southern continents are much less nearly related. The ostrich, giraffe, zebra and hippopotamus are among the characteristic animals of Africa which are not found elsewhere. In South America the tapir, great ant eater, armadillo and llama are among the animals not represented elsewhere. Both of these continents, however, have animals closely related to those of other great divisions, showing that their present isolation has not continued far back in geological time.

The animals of Australia differ greatly from those of the other continents. The quadrupeds here are *marsu-*

pials, animals which usually carry their young in a pouch. The only members of the family existing at present elsewhere are the American *opossums*. The largest of the marsupials is the great kangaroo which measures between seven and eight feet from its nose to the tip of its tail. Although it has four feet, yet it runs by making extraordinary leaps with its strong hind feet. Here is also found one of the most singular of all living animals, the

OPOSSUM.
Many opossums have no pouch but carry their young on their backs.

A KANGAROO FEEDING.
Notice the peculiar position it is forced to take because of its short front legs.

duckbill, the lowest of all quadrupeds, which in its characteristics resembles both quadrupeds and birds.

All this seems to show that the distribution and development of the animals of the different continents have been largely dependent upon the former geographical relations of the land masses. The native animals of a region are not necessarily the only ones suited to it; animals from other places may be even better adapted, but they have been kept out by some natural barrier. This is particularly evident in the case of Australia, where the weak native animals would have been readily displaced by the stronger animals of Asia could these have reached that isolated continent.

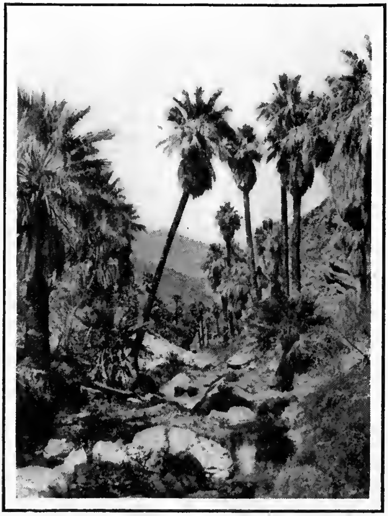
118. Life as Affected by Climate. — Climate has had a great effect upon the distribution and development of life.

TIMBER LINE ON A HIGH MOUNTAIN.

But the life on the earth cannot be grouped into climatic belts, as certain animals and plants are able to endure a wide range of climatic conditions. Moisture, sunlight and temperature are the chief factors which determine the growth and development of plants. If the temperature is too high or too low, they cannot exist. If sunlight or moisture is wanting, they cannot build their tissues.

In regions where the temperature is constantly below freezing, there can be no plant life. Where the temperature is above freezing for only a short time in the year, plant growth is slight and whatever plants there are must be small and stunted. Only where there is a long grow-

MESQUIT BEANS.
From this desert plant some Indian tribes made their bread.

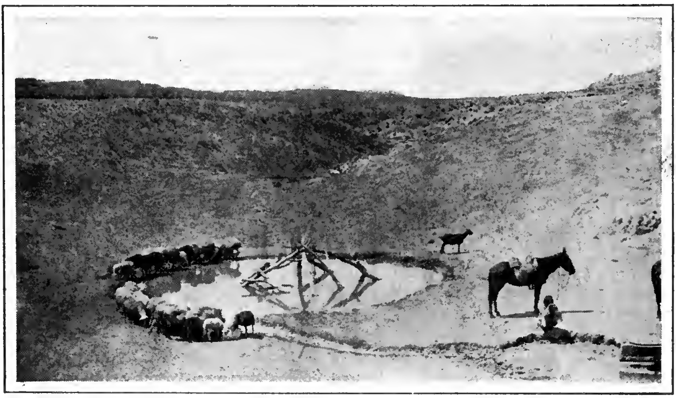


AN OASIS IN THE MOJAVE DESERT.

ing period can large plants exist. That is why there is almost no plant and therefore almost no animal life on the upper parts of lofty mountains, while somewhat farther down the life is stunted, and still lower down life flourishes. Changes in latitude have the same effect.

Where moisture is lacking, no plants can grow. Where there is but little moisture, only those plants can grow which are able to make the best possible use of the available moisture. In dry regions the plants are few and so constructed that little moisture can be evaporated from them. In dry desert regions, except where water finds its way to the surface in considerable quantity, forming *oases*, there can be but little forage for animals, and what there is, is scattered. The desert animal must therefore be a wanderer, able to subsist upon meager fare.

This is true of the human inhabitants of the desert as well. They must rove about in small bands living in



A WATER HOLE IN THE DESERT.

tents, picking up a precarious living for themselves and their animals, and they must be hardy and capable of withstanding privation. They must move rapidly and carefully over the long distances separating the patches where food can be found. They must therefore be fine horsemen, like the Arabs of Arabia and the Sahara, or strong and swift runners, like the Indians of the southwestern United States.

The life of man on the oases, although much less miserable than that on the desert, is subject to great disadvantages. These spots are of limited extent and frequently of limited moisture. They are often separated by almost untraversable areas from the other inhabitants of the world. There can be but little commerce or intercourse with the

A DESERT AND OASIS.

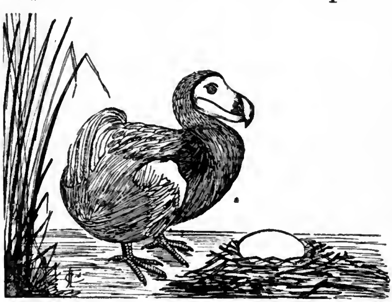
Notice the oasis at the foot of the gully where a spring comes to the surface.

rest of mankind. Although the oasis may appeal with a poetic charm to the dweller in the desert, yet to the inhabitant of a fertile country it is but a sorry place.

In regions where there is plenty of moisture, sunlight and heat, the growth of plants and animals is abundant and is only limited by space and food. Here life is at its best.

119. Life on Islands. — Islands which rise from the continental shelves were probably at one time connected with the continents, but have since been separated by the submergence of the intervening lowland. The animals and plants of such islands are similar to those of the adjacent large land masses. But *oceanic islands* possess only those types of plants and animals which originally were able to float or fly to them over the surrounding water expanse. Indigenous mammals, except certain species of bat, are wanting. Birds are abundant.

On the tropical islands the cocoanut palm is the main supply of vegetable food, clothing and building material. Many of the species of both plants and animals are different from those of the nearest continent and even of the adjacent islands. So complete has been the isolation of the life of these islands for so long a time that it has been possible for great differences in species to develop. Large unwieldy birds unable to fly or run rapidly have been found on some oceanic islands, the *dodo* of Mauritius, now extinct, being one of the most notable.



THE DODO.
Although the dodo is extinct, sufficient remains have been found to enable scientists to tell how it looked.

The absence of predatory animals has probably made the development of such forms possible. The great species of tortoise from the Galapagos Islands perhaps owes its development to the same cause. Nowhere else have such huge tortoises been found. The remarkable fauna and flora found on oceanic islands may be regarded as due to their geographical isolation.

120. Life as Affected by Man. — Wherever man has established himself, he has become a dominant factor in the distribution and existence of plants and animals. Forests are cut down, swamps are drained and streams dammed. Shade-loving plants suddenly find themselves exposed to the full glare of the sun, plants which need much water find themselves in a dry soil, and other plants which need a dry soil are flooded by the impeded streams. They cannot stand these sudden changes of environment

ORIGINAL FLORA SUPPLANTED BY NEW PLANTS.

and die out. The plow overturns the sod and the fields are sown with seeds the natural home of which may have been thousands of miles away across the sea.

In the course of years the original flora of the region is represented by only a few species inhabiting places man has not deemed it worth his while to cultivate. New plants suited to man's wants have taken the place of those which through thousands of years of struggle have shown themselves the best adapted to the geographical conditions in the region.

The animals share the same fate as the plants. Domestic animals replace the wild denizens of the country. Only in inaccessible and waste places are a few lone remnants of the native fauna left. If the area which man enters is limited and bounded by impassable barriers, as in the case of islands, certain animals may be entirely exterminated, as wolves and bears have been in England. If the animal is a unique species, its extermination from its native island may mean its total destruction, as in the case of the dodo of Mauritius.

121. Forestry. — One of the notable ways in which modern man has affected the life and industries of the earth is

BAD FORESTRY.
The débris was left to feed the forest fires, and all the standing timber was ruined.

in his treatment of the forests. In North America, before the coming of the white man, there were probably extensive areas where the growth of forests had been checked by fires set by the Indians. The prairie regions were probably much enlarged by the annual grass fires.

Tree-covered areas, too, were often burned over, and the growth of the trees checked, in order to make hunting less difficult. The greater part of the country was, however, covered with thrifty forests.

In recent years the demand for lumber and wood pulp and the careless and wasteful way in which the forests have been handled by the lumbermen has greatly reduced the forests of the United States. It has been authoritatively stated that if the present waste of our forest land

BAD FORESTRY.
The forest was razed, leaving no small trees for future growth.

continues, the timber supply of the country will be exhausted before 1940. Not only are the forests being recklessly cut down, but forest fires are each year destroying millions of dollars worth of timber. When the importance of lumber to all kinds of industries is considered, the rapid exhausting of our forest supplies becomes almost appalling.

But not only is the destruction of the forests a menace to the industries in which lumber is necessary, but the effects are far reaching in many other directions.

Slopes from which the forests have been removed become an easy prey to the forces of erosion, and the soil which for thousands of years has been accumulating may be swept away by the rainfall of a few seasons, leaving the slopes bare of soil and devoid of vegetable life. Thus the

BAD FORESTRY.
The hillside was stripped, leaving it a prey to erosion.

sites of valuable forests, which by proper care might have been continual wealth producers, are rendered nearly profitless deserts.

The harmfulness, however, does not stop here. The rain that falls upon these slopes, and which was formerly retained by the roots and vegetation, so that it slowly crept downward into the valleys and streams, now runs off quickly, flooding the rivers and doing damage to regions at a distance. Streams which formerly varied but little in their volume during the entire year, now become subject to great extremes of high and low water. This renders them less useful for manufacturing, commerce and water supply to say nothing of the frightful damage done each year by floods.

The destruction of the forests tends also to exterminate the wild animals and deprives man of a chance to get away from his artificial surroundings and obtain a knowledge and an enjoyment of life and nature which has been unaffected by his own dominant influence.

GOOD FORESTRY.
Notice how carefully the underbrush has been removed to guard against fire.

In many European countries the forests have become a national care and not only is the cutting of trees, except under certain restrictions, prohibited, but the greatest care is maintained to guard against fires. In our own country the government has recently established a number of forest preserves which are carefully patrolled, and here the destruction from forest fires is rigidly guarded against. Great care of all forests should be taken by hunters, campers and all others who visit them, and also by the railways passing through them. Loggers and lumbermen should see that it is to their interest to maintain growing forests and not wantonly to destroy them.

When the native forests are destroyed, trees of other kinds may in time replace those removed, but frequently these are of less commercial value. Thus, when the conifer forests of the northern states are cut off, birches and

GOOD FORESTRY.
Notice how the underbrush and small limbs have been cleaned up.

poplars replace them. If only the larger trees had been cut, leaving the smaller and younger trees to hold the ground, the more valuable forests might have been retained.

122. Flora of the United States. — The United States has such a great range of climate, soil, elevation and other geographical conditions that it possesses a large variety of plants. About five hundred different kinds of native trees have been listed, and there are many different kinds of shrubs and smaller plants. To these native plants must be added many useful as well as ornamental plants and not a few noxious weeds, which have been imported from other countries and have found an agreeable home here.

The largest and perhaps most remarkable trees in the United States are the Big Trees of California, a species of redwood. Trees of this species have been measured which

A CALIFORNIA BIG TREE.
Notice the size at the base.

were 325 ft. high, more than 100 ft. higher than Bunker Hill Monument, and others which were more than 90 ft. in circumference. A plant which has probably appropriated more territory than any other plant in the world is the "sage brush" of the arid western plains. These low grayish shrubs cover hundreds of thousands of square miles. They are useless except for fuel. In the well-watered part of the country, plants are abundant and varied, ranging from the subtropical palms of the Gulf coast to the semi-arctic types of the northern border.

123. Fauna of the United States. — As the wide treeless plains and prairies of the central part of the country contained few coverts for skulking animals of prey, they were admirably adapted to the wants of gregarious grazing animals. Here were found the countless herds of antelopes and buffaloes which in the early days of transcontinental travel swarmed over the territory crossed by the railroads and not infrequently forced the trains to stop and wait until they had crossed the track. To-day they are almost exterminated.

The forests of the northern regions with their grassy glades and meadows, once the home of great herds of caribou and great numbers of moose, have too frequently resounded to the sound of ax and gun still to contain many of these noble creatures.

Coyote.
The prairie wolf of the western plains.

Among the mountains with their rough surfaces and rugged fastnesses the black, brown, and grizzly bear once roamed supreme, but now they find security only in the most inaccessible places. Wolves once skulked in bands far and wide over almost the entire country, ready to pull down and devour weaker animals, but now both they and their prey have almost vanished.

The fur-bearing animals which inhabited the streams and dales and whose valuable pelts tempted the early hunters to explore the unknown regions of the country and mark out the trails afterward followed by the pioneers, have almost entirely disappeared. Small animals, like the fox, the prairie dog, the skunk, the woodchuck, still remain, the puny survivors of a once varied fauna. Plain and valley, hill and mountain are at present nearly devoid of their native inhabitants. The horse, the cow, the mule are the chief members of the present fauna.

PRAIRIE DOG.

Summary. — Physical conditions have a great effect on the distribution of life upon the earth. It is hard for living things to cross high mountains, broad oceans or vast deserts. When confined to certain climates and areas, plants and animals naturally adjust themselves to these.

Life in the sea is so simple that plants and animals there are not forced to become as highly developed as are those of the land. On land there are greater ranges of climate and other physical conditions, so that plants and animals have been forced to a high development in order to survive. Probably the two greatest forces affecting land life are climate and man. Man transplants and transports animals and plants according to his desires. The physical conditions decide whether or not they shall live.

By his treatment of forests man can also have a great effect upon the wealth and beauty of the country, upon the safety of its rivers and the reliability of its water power.

Much more money has been lost in the United States through the floods and fires caused by bad forestry than has been gained by the people who cut the trees.

Because of the wide range of climate and the variety of physical conditions, there are a great many different kinds of plants and animals in the United States, but the wild animals have been steadily killed off as man has needed their haunts for his farms and dwellings.

Questions

What do the rock layers show in regard to the history of life?

Give several reasons why the same kind of plants and animals are not found all over the earth.

What animals do you know that are peculiarly adapted to the conditions under which they live?

If you could take a trip in a submarine capable of traveling over and through the sea, what kind of animals would you expect to find? Under what different conditions would these animals be living?

How are land animals prepared to meet the conditions about them?

Describe how the distribution of animals has been influenced by geographical conditions.

How are animals affected by climate?

What influence have oceanic islands had on life?

How has man in many places changed the life of the land?

Why is the proper care of forests so important to the well being of man?

To what plants and animals is the United States the "home land"?

CHAPTER VIII

THE SEA

124. The Sea. — On looking at a map of the world or at a globe, one is immediately impressed by the predominance of the sea. The whole area of the globe is about 196,940,000 square miles, 72% of which is water. The

THE OCEAN.
From a photograph taken in mid-Atlantic.

larger part of the land is in the northern hemisphere, and of the water in the southern hemisphere. A comparatively small land area extends below 40° south latitude, about the latitude of Philadelphia in the northern hemisphere. Most of the maps of the world do not represent the southern hemisphere below latitude 60°, which is about the latitude of Petrograd (St. Petersburg) in the northern hemisphere. Thus the equator is usually considerably below the center of the map.

125. Divisions of the Sea. — Although most of the surface water of the earth is connected, yet for many purposes it is better to put this water area into somewhat arbitrary divisions. We thus speak of the Atlantic, the Pacific, the Indian ocean, each of which may be divided by the equator into a northern and a southern part, and the Arctic and Antarctic oceans which surround either pole. Sometimes a division is made from the parallel 40° south and this great body of water, almost without land boundaries is called the Southern Ocean.

The boundaries of these oceans are irregular in shape, but with the exception of the great Southern Ocean and of the Arctic Ocean, which is really an inclosed sea, they narrow toward the north. They have a number of partially landlocked seas connected with them. In some instances these penetrate far into the land, as in the cases of the Mediterranean Sea and Gulf of Mexico. The surface of the sea is level, unstable, easily moved and always rising and falling in rapid and changeful undulations.

126. Continental Shelf. — Around the border of the continents and of those islands which are near the continents, there extends, in some cases to a distance of two or three hundred miles, a gradually deepening ocean floor. This gradually deepening border is called the *continental shelf.* When this floor has reached the depth of about 600 feet, the gradual slant suddenly changes into a quick descent to the depths of the ocean, two or three miles.

Upon this shelf lie the great continental islands, like the British Isles and the East Indies. It is this that furnishes the great fishing banks of the earth, such as the Grand Banks of Newfoundland and those around Iceland and the Lofoten Islands, where fishermen for ages have obtained vast supplies of fish. There is no equal area of the earth where the life is so varied and the struggle for existence so great as on these shallow continental borders.

CONTINENTAL SHELF.
A model showing the sea floor off the coast of Southern California.

Here the mud and sand brought down by the rivers is spread out and the sedimentary rocks formed. It is the elevation of this shelf which has formed the low-lying coastal plains which border many of the continents. There is good reason to believe that the deep floors of the sea have never been raised into dry land, and that the vast extent of sedimentary rocks which make up the larger portion of the land has almost all been laid down in regions which were at the time continental shelves.

127. Composition of Ocean Waters. — Experiment 122. — Into a dish of fresh water put a demonstration hydrometer or stick such as was used in Experiment 35. Mark the depth to which it sinks. Place the hydrometer now in sea water and mark the depth to which it sinks. If sea water cannot be obtained, dissolve in a pint of fresh water about 15 g., or half an ounce, of salt. This will give the water about the same amount of dissolved solid material as sea water would have. About how much more of its length does the hydrometer sink in fresh water than in sea water? Will a piece of ice project more out of salt water than it would out of fresh water?

Experiment 123. — If ocean water can be obtained, boil down about a pint of it in an open dish. Taste of the residue which is left. What is the principal constituent of this residue?

There is probably no water on the surface of the earth which is absolutely pure. Water is the greatest solvent known, and it dissolves to a greater or less extent almost all substances with which it comes in contact. When the rivers run into the sea, they carry with them whatever their water has dissolved from the land, and when the sun evaporates the water, and it is borne away again to fall upon the land, the dissolved material is left behind in the ocean.

Thus the sea has for all time been receiving the *soluble contributions* from the land. It is easy to prove that it contains salt, for we can taste it. It must contain lime, for corals and shell animals depend upon this for the hard parts of their bodies. There must be organic food material in it, or else fixed animals like oysters could not get food. It contains air, for without air fishes could not breathe. These are the principal substances which we need to consider in the study of the ocean water, but the chemist can find many other substances dissolved in it. On account of the materials dissolved, sea water weighs more than fresh water, or has a greater *specific gravity*. A cubic foot of fresh water weighs about 62.5 lbs. whereas a cubic foot of sea water weighs over 64.25 lbs.

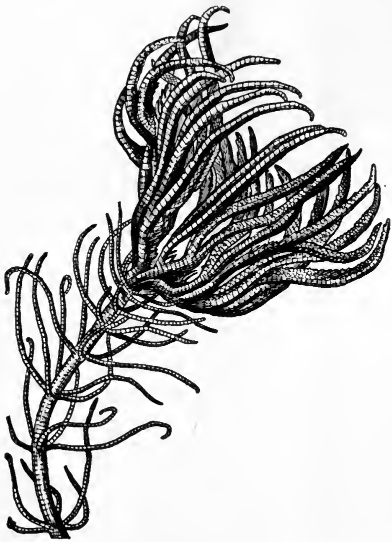
128. Ocean Depths. — The greatest depth thus far found in the ocean is nearly six miles. This was found in the Pacific Ocean near the Ladrone Islands. The greatest depth in the Atlantic Ocean thus far discovered is a little over five miles at a point north of Porto Rico. The average depth of the sea is probably about two and one half miles.

Although the pressure at the bottom of the ocean must be tremendous, yet so incompressible is water that a cubic foot of it weighs but little more at the bottom of the sea than it does at the top. Thus a body which sinks will in time reach the bottom no matter what the depth may be. At a depth of two miles the pressure is over 300 times as much as at the surface of the water and here, as we have already found, it is about 15 pounds to the square inch.

If a bag of air which had a volume of 300 cubic inches at the surface were sunk in the ocean to a depth of two miles, it would have a volume of less than a cubic inch, and the pressure upon it would be about $2\frac{1}{2}$ tons. It thus happens that deep sea fishes when brought to the surface have the air in their swimming bladders so expanded that the bladder is often blown out of their mouths.

129. Condition of the Ocean Floor. — The ocean floor is a vast, monotonous, nearly level expanse whose dreary, slimy and almost lifeless surface is enveloped in never-ending night and is pressed upon by a vast weight of stagnant, frigid water. Here and there volcanoes rise upon it with gradually sloping, featureless cones, and sometimes a broad wavelike swell reaches within a mile or so of the surface. Such a swell extends along the center of the Atlantic Ocean through Ascension Island and the Azores.

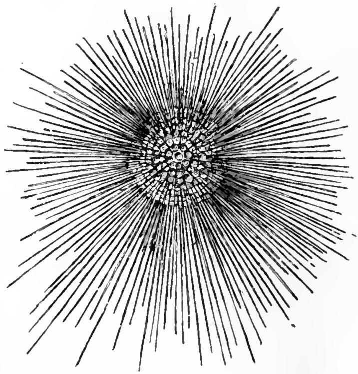
There are no hills and vales, no mountain ranges having sharp peaks and deep valleys. Gradually rising ridges and volcanoes, sometimes topped with coral islands, alone vary the monotony. It is the nether world of gloom and unaltering sameness. Here the derelicts of ages past, after their fierce buffeting with wind and wave, have found a quiet, changeless haven where they may lie undisturbed until absorbed into the substance of the all-enfolding water. Some animal species which lived in the light of former geological ages have here found a resting place where the strife of progress is stilled and the laggard in the race of development may live in peace.



CRINOID.
An animal now found only at considerable depths in the ocean.

130. The Carpet of the Ocean Floor. — Near the shore, the floor of the ocean is covered with sand and mud derived from the waste of the land. In the deeper sea the covering is a fine-textured material of animal origin called *ooze*. It is composed of the shells of minute animals that live near the surface. The most abundant shell is that of a minute animal called the *globigerina*, hence the deposit is often called the *globigerina ooze*.

At a depth of about 3000 fathoms (18,000 feet) these shells disappear and a reddish clay appears. This clay is believed to be due to meteoric and volcanic dust and to the insoluble parts that remain after the calcareous (lime-like) material of the minute shells has been dissolved in sinking through the deep water. No layers of this kind have ever been found on the land, and this is one of the reasons for believing that the depths of the sea have never been elevated into dry land, but that what is now deep ocean has throughout all time been deep ocean.



GLOBIGERINA.

131. Waves. — **Experiment 124.** — Take a long flexible rubber band or tube and having fastened one end, stretch it somewhat. Now strike down on it near one end with a small stick. A wavelike motion will be seen to travel from end to end of the band. It is evident that the particles of rubber do not enter into the lateral movement, but that they simply move up and down, whereas the wave movement proceeds along the band. A piece of paper folded and placed lightly upon the band will move up and down but not along the band. Thus wave motion does not necessitate lateral movement of the particles taking part in the wave.

When the wind blows over water, it throws the surface into motion and produces *waves.* The highest part of the wave is called the *crest* and the lowest part the *trough.* Trough and crest move along rapidly over the surface of the water. The particles of the water themselves, however, move somewhat like those in the rubber band. That the water itself does not move with the wave can be seen when a floating bottle is observed. It moves up and down but does not move forward. If the water moved along with the waves, it would be next to impossible to propel a boat against the direction of the wave movement.

That it is possible to generate wave movement without the particles themselves moving along with the wave is seen when a field of grain is bending before a gentle wind. The troughs and crests move one after the other across the field but the heads of grain simply vibrate back and forth. The crest of a water wave, however, is often blown forward by the wind and thus a drift in the direction of the wind is established at the surface.

OCEAN WAVES.

When great waves are raised by the wind at sea, there is danger that the mighty crests may be blown forward and engulf a ship. To calm the waves ships sometimes pour "oil on the troubled waters." The oil spreads out in a thin film over the water and forms a "slick" which prevents the wind from getting sufficient hold upon the water to topple over the crests, and thus the danger of being swamped is averted. It has been found that oil will spread out even in the direction of the severest wind.

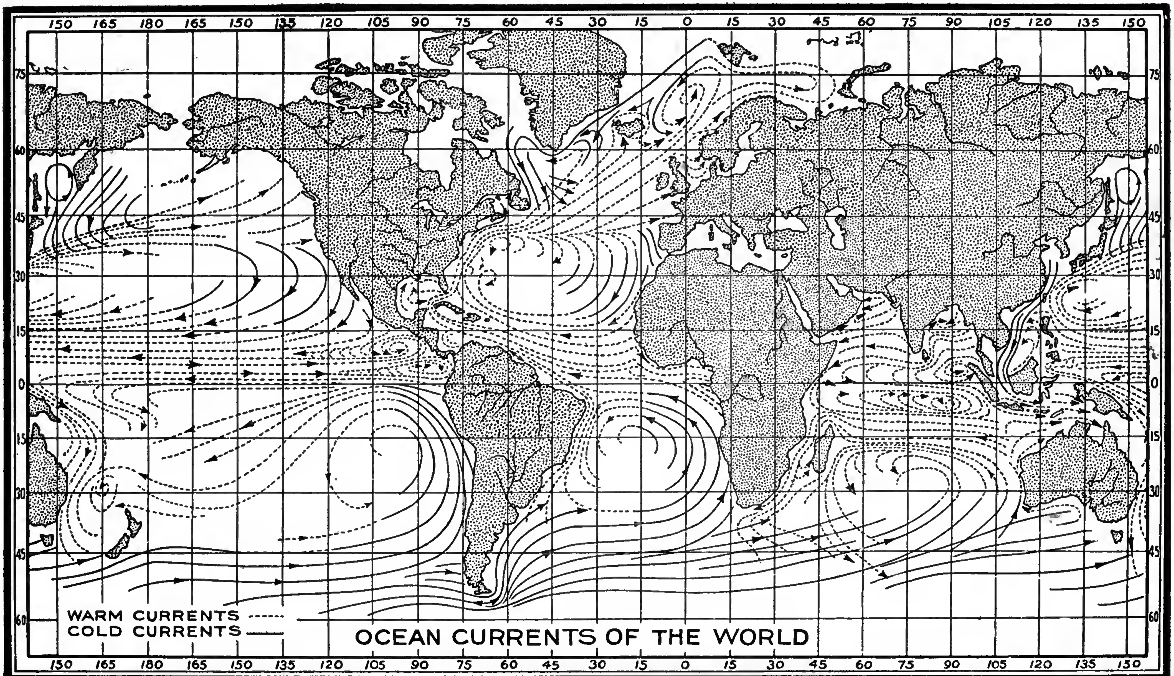
Although sometimes waves are spoken of as "mountain high," it rarely happens that the height from trough to crest is over 50 ft. The length of these great ocean waves, or the distance from crest to crest or from trough to trough varies from 300 to 1500 ft. or more. The velocity is sometimes as great as 60 miles per hour, but usually not more than half of this. The movement of the waves stirs up the water and enables it to absorb the air which is so necessary for the existence of water animals.

Earthquakes occurring under the sea sometimes generate great waves which sweep in over the land destroying coast towns and shipping. These waves sometimes rise to a height of even a hundred feet above sea level. Ships have been carried by them a long distance inland and left high and dry. These waves, wrongly called *tidal waves*, have no connection with the wind.

132. Temperature of Ocean Waters. — **Experiment 125.** — Fill a flask of about 500 cc. with water. Press into the mouth of the flask a cork through which a glass tube about 30 cm. long extends. The tube should be open at both ends and should not extend into the flask below the bottom of the cork. When the cork is pressed in, the water will be forced up into the tube for several centimeters. See that the cork is tight and that there are no bubbles of air in the flask or tube.

Now place the flask for fifteen or twenty minutes in a mixture of ice and water and carefully mark with a rubber band the point at which the water in the tube comes to rest. Take the flask out of the freezing mixture and notice immediately whether the water in the tube rises or falls. Continue for five or ten minutes to notice the action of the water in the tube. The volume of the water is not the least when it is at the temperature of melting ice, 32° F., but when it is a little above this temperature.

Unlike fresh water, which is densest at a little above freezing, sea water continues to decrease in volume and grows denser as it is cooled, until it reaches its freezing point at 28° F. Hence the cold water near the poles



OCEAN CURRENTS OF THE WORLD

gradually sinks and creeps under the warmer water of lower latitudes maintaining a temperature of 32° to 35° on the bottom, even at the equator. This steady creep of cooled surface water along the bottom supplies the animals of the deep ocean floor with the air which they must have. Without it the water at great depths would have its air exhausted and all life would be destroyed.

At the surface of the ocean the temperature of the water varies in a general way with the latitude; it is over 80° at the tropics and about the freezing point at the poles. Near the poles and near the equator there is very little variation in the temperature of the surface water during the year, but in the intermediate latitudes the annual variation is considerable. Below the surface the effect of solar heat rapidly diminishes and at a depth of 300 ft. it is probable that the annual variation in temperature is nowhere more than 2° F. Below 600 ft. there is probably no annual change in temperature.

On the surface the daily average range of temperature is not more than 1° F. and the annual range does not exceed fifteen degrees, except where the same surface is washed at different seasons by currents of different character, and near the shore, where the heat of the land affects it. This contrast in temperature conditions between the ocean and the land is most marked. The life conditions in one are uniform and unvaried while in the other they are most changeable and are subject to extremes of temperature. That is why the land animals must be much more highly organized than those of the sea in order to survive these changeable conditions.

133. The Best-known Ocean Currents. — The ocean is a region of never-ceasing motion. At considerable depths its motion is very slow, but near the surface, where the prevailing winds can affect it, the movement is considerable. Circulating around each ocean there is a continuous drift of surface water extending to a depth of from 300 to 600 feet and varying in rate from a few miles up to fifty or more miles a day. In fact these rotating currents are the chief natural basis for the division of the oceanic area into six oceans, as our geographies generally divide them.

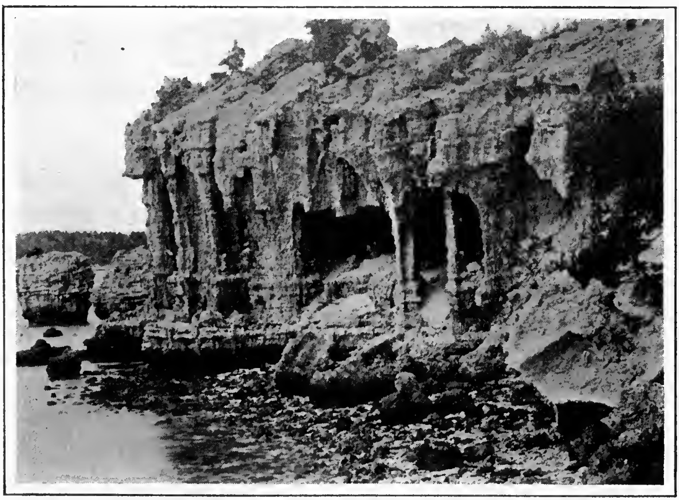
These currents circulate in the northern hemisphere in the direction in which the hands of a watch move and in the southern hemisphere in the opposite direction. In the centers of these rotating areas the water is nearly motionless and here are often found great masses of floating seaweed filled with a great variety of small animals. These accumulations of seaweed are called *sargasso seas* (page 249).

That these surface drifts have a definite direction of movement is indicated by observations made on the courses taken by a great number of wrecks. The direction of these movements has also been determined by throwing from ships in different parts of the ocean thousands of bottles in which had been placed the date and a record of the latitude and longitude of the ship. The places where the bottles came ashore showed the direction of the currents.

If the movement of the water is slow, ten or fifteen miles a day, it is called a *drift;* if faster, a *current.* The principal currents have been given names and have been most carefully charted. The warm current that flows northeastward off the southeast coast of North America is called the *Gulf Stream.* That off the east shore of Asia, which also flows northeast, is called the *Kuro Siwo* or *Japan Current.* The cold current off the east coast of Labrador flowing southeast is called the *Labrador Current;* and the cold current which flows northward off the west coast of South America is called the *Humboldt Current.* Other names are given to different parts of the ocean movement, but those mentioned here are the most important.

Where the ocean currents are unimpeded by the land, they flow in the direction of the prevailing winds. It has been found that the currents change their directions with a change in the direction of the prevailing wind, such as occurs in the Indian Ocean when the heat equator is farthest north of the earth's equator. It appears that ocean currents are primarily a result of the wind circulation.

134. Effects of Ocean Currents. — A knowledge of ocean currents is of importance to mariners, as the course and speed of a vessel may be considerably affected by them. They also greatly affect the conditions of animal life in



Coral Formations in the Bermudas.

different parts of the sea. Not only do these currents bring food to animals which have not the power of motion but they determine the area in which certain animals may live.

The Bermudas, 32° north of the equator, are coral reef formations, while the Galapagos, almost on the equator, are surrounded by too cold water to have any such reefs. At 68° north, near the Lofoten Islands, are the great cod fisheries of Europe. On the western side of the Atlantic these fisheries are on the Grand Banks, latitude 45° north. Many other similar illustrations of the effects of these currents on the distribution of animal life might be cited.

The temperature of winds blowing from the sea is modified by these currents and greatly affects the habitability of the earth for man. Hammerfest at 71° north is a flourishing seaport, but there are no important settlements above 50° on the western side of the Atlantic. Alaska, the prevailing winds of which are warmed by blowing over the warm ocean, is a region which promises much for human habitation, while the region on the opposite side of the Pacific must remain almost destitute of human inhabitants. It should be noted that the effect of the warm ocean waters would be slight, except along the coast, were it not for the air movements.

135. Tides. — Probably the first thing that impresses us on visiting the seashore is the regular rising and falling of the water each day. These movements of the water are called *tides*. If we observe the tides for a few days, we find that there are two high and two low tides each day. As the tidal current comes in from the open ocean and the water rises, it is called *flood tide*, and as it runs out or falls, *ebb tide*. When the tides change from flood to ebb or ebb to flood, there is a brief period of "slack water."

If we observe closely, we shall see that the corresponding tides are nearly an hour later each day than they were the day before, and that the time required for the completion of two high and two low tides is nearly 25 hours. Continued observation will show, as Julius Cæsar stated many centuries ago, that there is apparently a relation between the phases of the moon and the height of the tides. The greatest rise and fall of the water will be found to occur about the time of full and new moon.

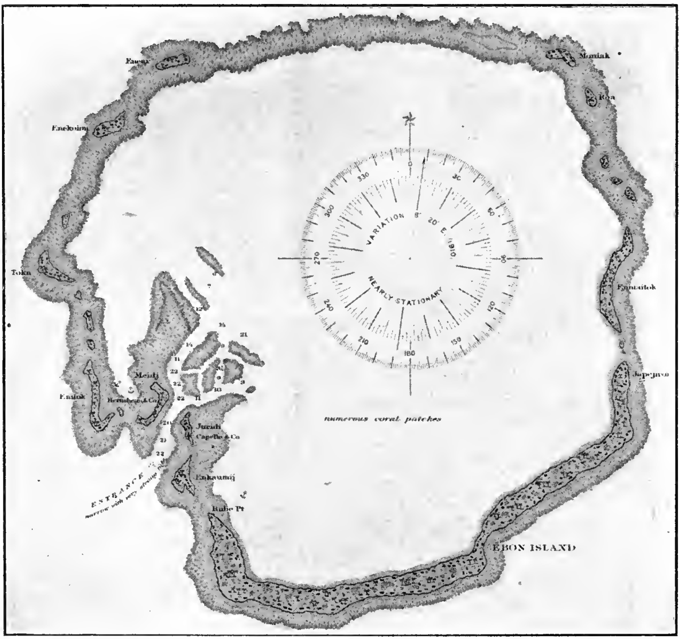
High Tide in the Bay of Fundy.

The amount of rise and fall of the tides is not the same in different places. Upon shores of oceanic islands the difference between high and low water, or the *range*, as it is called, is not more than two or three feet. In funnel-shaped bays where the tidal current is compressed as it moves in toward the bay head, the range is very much greater. In the Bay of Fundy the range is sometimes as great as seventy feet.

Low Tide at the Same Place.

Sometimes these compressed tidal currents are formed at the mouths of rivers and move up the rivers like a wall of surf several feet in height, endangering all vessels which are not securely moored. Such tidal surfs are called *bores* and are found in the Seine, Amazon and other rivers.

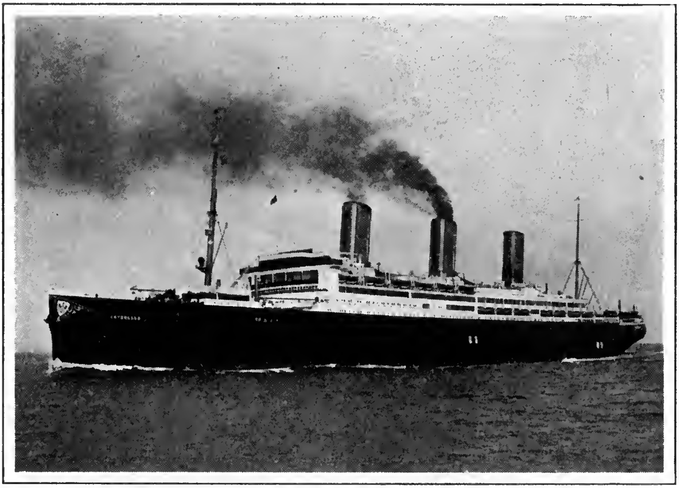
The tidal current as it sweeps between islands often forms eddies and whirlpools which make navigation very



AN ATOLL IN THE MID-PACIFIC.

dangerous. An example of this is found at Hell Gate, N. Y., and at the famous Maelstrom off the coast of Norway. On the other hand in flat countries where the rivers are shallow, ports which could not otherwise be reached are made accessible to ships of considerable burden at the time of high tide. At these places the time of leaving or making port changes each day with the time of high tide. A striking example of this is the port of Antwerp.

The tidal currents are also continually changing the water in bays and harbors and thus keeping them from becoming stagnant and foul. They also bring food to many forms of shore life which have but little or no power of movement, such as clams and other shellfish, and by exposing some of these at the ebb give man a chance to acquire them readily for food.



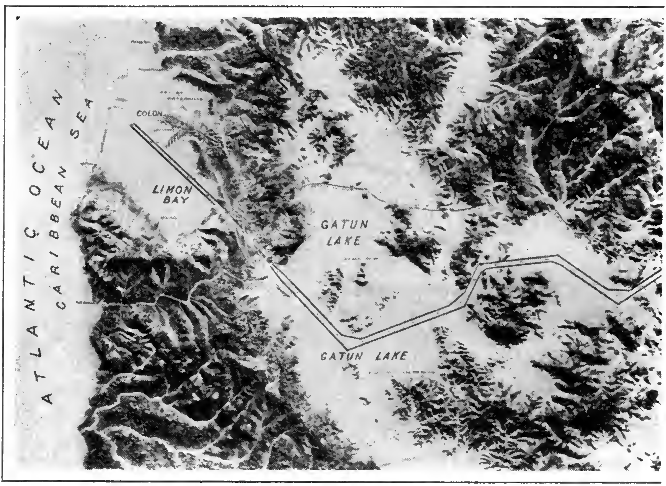
THE VATERLAND.

One of the largest vessels afloat.

It has been found that the position of the sun, as well as that of the moon, affects the height of the tide. If the earth, moon and sun lie in nearly the same line, the tidal range is greatest. This is called *spring tide.* When the sun and moon act at right angles upon the earth, the tidal range is least and this is called *neap tide.* The tidal undulations have been proved by astronomers to be due to the rotation of the earth and the gravitational attraction of the sun and moon upon its water envelop. The moon is much the more effective because it is nearer.

In the open sea the rise and the fall of the tides are of equal duration but at the head of bays the tide rises more rapidly than it falls so that low tide does not occur midway between two successive high tides.

136. Corals and Coral Islands. — In warm, clear, shallow areas of the sea are found small animals called *corals*.

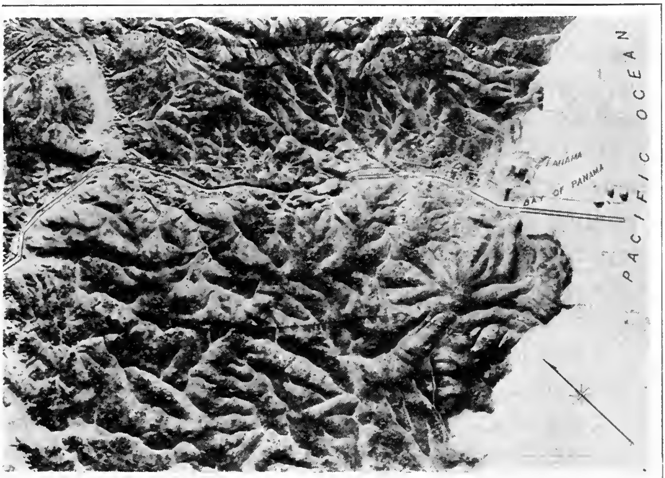


PANAMA

An example of man's domination over nature.

Great colonies of these are able by united action to build barriers capable of withstanding the waves and of raising submarine lands into islands. These reef-building corals cannot live at a greater depth than 20 fathoms (120 feet), or where the mean temperature is lower than 68° F., or where the discharge of rivers makes the water fresh or muddy. As they are fixed animals and must get their food from the surrounding water, they flourish best where the warm currents flow past continually, bringing a fresh supply of food. In tropical seas many islands are fringed by reefs built by these animals.

In the tropical Pacific circular coral reefs are found nearly inclosing large shallow lagoons. Soundings outside of these reefs show that the sea rapidly sinks to great depths. Islands of this kind are called *atolls*. How these atolls were formed is still an open question. As reef-



CANAL.

Two great oceans artificially united.

building corals cannot live below 20 fathoms, it is evident that corals could not have built up the reefs from the bottom of the deep sea.

137. Man and the Ocean. — At first thought it would seem better for the life of the world if the proportion of land and water were reversed. Yet when we consider that almost barren wastes constitute many continental interiors and that plenty of rainfall is necessary to make land habitable, the utility of the great water surfaces becomes apparent. From the evaporation of the ocean surface comes nearly all the water which supplies man, land animals and plants.

It is not only true that all streams eventually run to the sea but it is also true that all their water comes from the sea. Other things being equal, the smaller the surface for evaporation the less the water supplied to the land. Besides supplying the land with water, the ocean has a great effect on its climate. The animals of the sea also furnish food for thousands. A large part of the earth's population is now, and always has been, located not far from the shore of the ocean.

In early times before the advent of railways almost all commerce was carried on over the sea. Even now this is the cheaper way of transportation. Modern methods of conveyance have enabled man to live with comfort at a considerable distance from the ocean, but the dry interiors of continents still remain sparsely inhabited. All commercial nations must have an outlet to the sea and to obtain it much blood and treasure have often been spent. Man for his commerce has even broken through the barriers by which nature has separated seas and oceans, as in the case of the Suez and Panama canals.

Summary. — The sea occupies nearly three quarters of the area of the globe. It is usually spoken of as divided into oceans, the Atlantic, Pacific, Indian, Arctic and Antarctic. Although some parts of the ocean are nearly six miles deep, the most interesting and most extensively inhabited part of it is that above the *continental shelf*. This shelf is the gradual slope from the edge of the different continents to a depth of about six hundred feet. Beyond this the descent becomes rapid.

On the surface of the sea are *waves* varying in height from a few inches to fifty feet. These stir up the water and enable it to absorb more air, which is so necessary to the living things in the sea. Not only is the surface of the sea constantly in motion, but there are also great *currents*, such as the Gulf Stream, which carry the water from one latitude to another. These currents are caused almost entirely by the winds.

The *tides* are due primarily to the action upon each other of the earth, moon and sun. The range of tides varies from two or three feet on oceanic islands to about seventy feet at some places in the Bay of Fundy. The tides help drainage and assist vessels over bars that would otherwise be impassable.

Questions

What portion of the earth's surface is sea? Into what divisions is the sea usually divided?

What is the continental shelf? Why is it of especial interest to man?

Of what is the sea water composed? How does its composition affect animals?

If you were able to take a trip from the nearest beach over the ocean bed to another continent, describe what you would probably find along the way.

What are waves? What causes them?

What is the temperature of the ocean water in different parts of its surface and at different depths?

Describe the best known ocean currents. What is the cause of these? Why is a knowledge of ocean currents important to mariners and also to those who would explain the climates of different places?

What are tides? What causes them? What are their effects?

How are coral reefs formed? What are atolls?

In what ways is the ocean useful to man?

CHAPTER IX

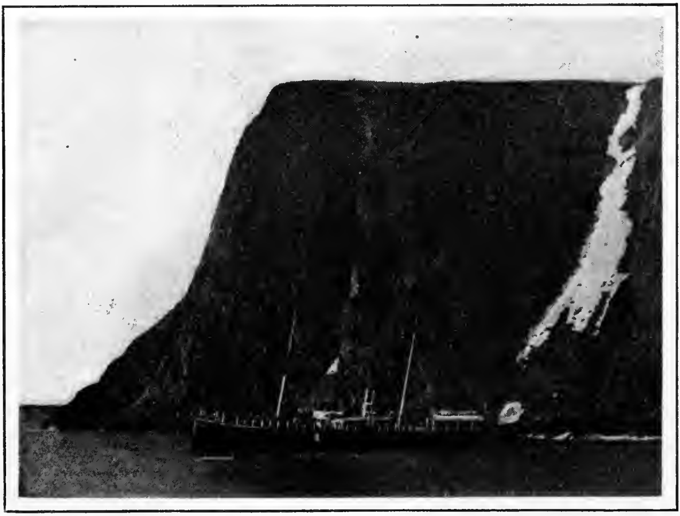
COAST LINES

138. Coast Lines. — On examining a map or chart of an extended coast one cannot fail to be impressed with its irregularity. Although it may extend for long distances

POSITANO.
A precipitous and densely populated coast.

in an almost unbroken straight line, as along the south-eastern part of the Bay of Biscay, yet if we follow even this coast far enough in either direction, it becomes markedly irregular. Islands composed of the same material as the coast itself are often found near, separated from it only by shallow arms of the sea. These are evidently a part of the adjacent mainland with a submerged portion between.

Sometimes in warm latitudes where conditions are suitable, the coast is bordered for a long distance by coral reefs. The northeast coast of Australia affords a marked



NORTH CAPE.

A famous promontory which defies the waves of the North Atlantic.

example. Here a barrier reef extends for a thousand miles along the coast, protecting it and leaving a smooth water channel 10 to 30 miles broad for coastwise navigation.

A coast in warm regions may also be protected by the growth of dense thickets of mangroves. This tree grows in shallow water and sends down from its branches roots upon which crabs and oysters live and among which mud and débris accumulate. Thus low shores are slowly being built out into the sea. Shore borders of this kind are found extending many miles along the coasts of southern Florida and Texas and in many other places.

In extreme northern and southern latitudes the coast may be fringed for long distances with ice. In middle latitudes, however, the coast is generally composed of rock,

Fingal's Cave.

sand or mud and is sometimes protected by a thick seaweed mantle. Here, besides the usual forces of erosion and deposition found active on the land, are the forces of the waves and currents.

139. **Wave Cutting.** — Wherever the waves strike on an unprotected shore, they wear it away. The rapidity of the cutting and the forms carved depend upon the strength of the waves and the kind of shore. Wherever there is a point of weakness along the shore, there the waves cut back more rapidly. The harder parts stand

out sharply as points and promontories. In some cases the waves cut back so rapidly on lofty coasts that high cliffs are formed.

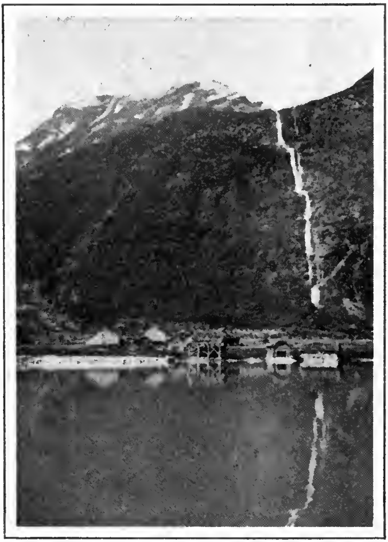
If the material of the coast does not readily break off when undercut by the waves, a sea cave may be formed. Such is the well-known Fingal's cave on an island off the coast of Scotland where the structure of one of the igneous rock layers allows the waves to quarry it comparatively easily. Spouting holes and caves are usually due to an easily eroded place in the shore where the waves are able to cut back a somewhat horizontal tunnel and by their impact upon the end of the excavation form an opening to the surface through which spray is ejected. The hole may be at some little distance from the shore.

AN ELEVATED ROCK BENCH.

Since waves have the power of cutting only to a small depth, it may happen that an exposed rocky coast will have a bench cut along it, under the surface, backed by a sea cliff against which the waves are still cutting. If such a coast becomes elevated, the rock bench will appear with a cliff terminating it on the landward side. If a coast stays at the same elevation long enough, or if its material is easily eroded, large areas of what was formerly dry land may be cut away and brought under the sea.

In 1399 Henry of Lancaster, afterward Henry IV of England, returned from his exile and landed at Ravenspur, an important town in Yorkshire, to begin his fight for the crown. A person disembarking at the same place to-day would be so far from shore that he would need to be a sturdy swimmer to reach the beach. The entire area of the ancient town has been cut away by the waves and now lies under the sea. This is an example of what has occurred in many sea coast regions.

140. Beaches and Bars. — Unless the material pillaged from the land by the waves falls into too deep water, it is buffeted about by them and broken and worn into small pieces. These are then borne along by the shore currents until they find lodgment in some protected place where they can accumulate. When sufficient material has been accumulated, the storm waves and the wind sweep some of it above sea level and fringe the water's edge with a border of water-worn sand and pebbles. These accumulations of shore drift are called *beaches.*

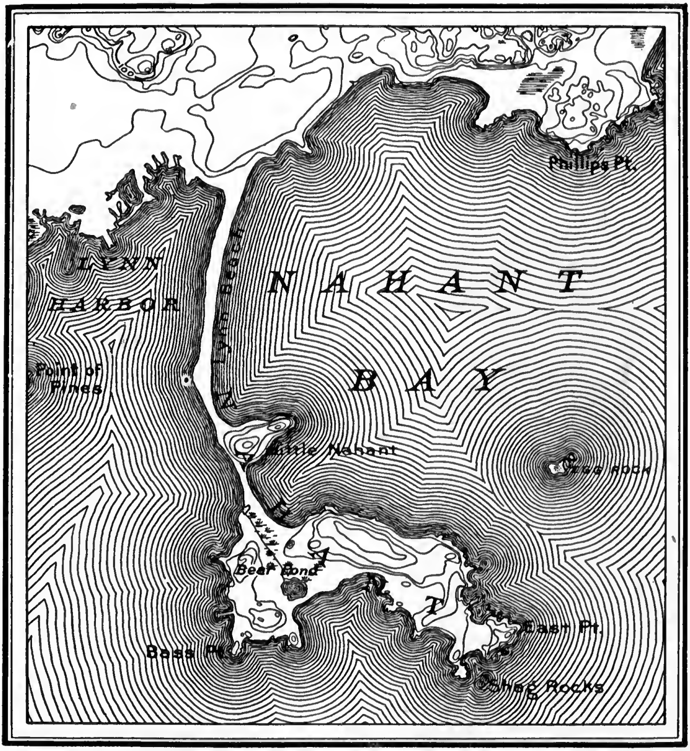


A LAKE BEACH FORMED BY STREAM AND WAVE ACTION.

A year after this picture was taken a landslide formed a wave which swept away the entire beach and village.

The incoming waves are constantly sweeping in material from the shallow bottom against which they strike, and the returning undertow bears its load seaward. Except in time of great storms the accumulation of material along a beach is at least equal to the wearing away.

The currents moving the loose material with them sometimes form it into bars which inclose or tie islands to the mainland or extend into the sea free ends, forming what are called ***spits***. A famous example of a land-tied island



NAHANT, MASSACHUSETTS.
A land-tied island.

is that of the great English fortress at Gibraltar; although now a promontory, it was once an island detached from the coast of Spain. Shifting sand bars, especially if covered with water, are exceedingly dangerous to vessels, and coasts where these are abundant need especial protection by lighthouses and life-saving stations. The greatest Mediterranean port of France during the thirteenth century, Aigues-Mortes, has been closed in by sand bars so that there is no longer access to the sea and only the relics of the former great city now exist. Thus have the moving sea sands overthrown the plans of men.

A SAND SPIT.
Formed by the waves and currents.

141. Final Effect of Wave and Current Action. — Whether the coast is shallow so that the storm waves spend their force off shore, or deep so that they batter the shore with their full strength, the tendency is to straighten the coast line. In the former case sand reefs with gently flowing outlines are built, and in the latter case the headlands are cut away by the waves and the material moved along by the coast currents to fill the protected bays and coves. As aërial erosion is constantly tending to smooth off the irregularities of the land surface, so the waves and currents of the ocean are constantly straightening out the water margins.

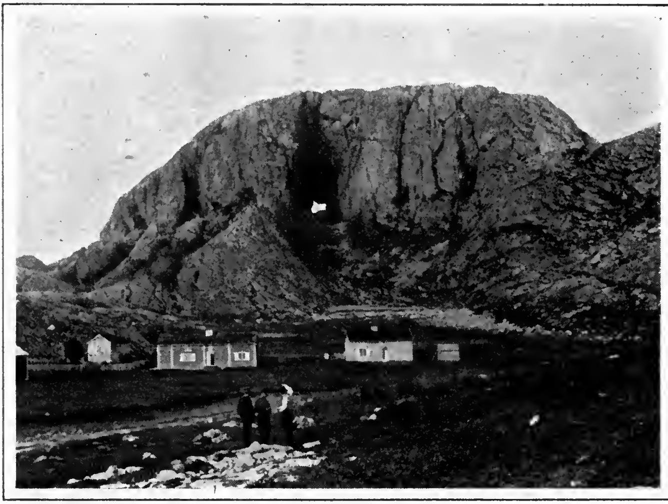
Uniformity seems to be the goal for the erosive forces. But when the results of surface erosion are brought to the sea by the rivers, deltas are formed which interfere with the straightening of the coast. If the material brought by the

A BEACH AT CATALINA ISLAND.

Notice how the water is smoothing out the irregularities of the land.

rivers is sufficient, a delta is built out into the sea in spite of the action of the waves and currents and the coast line becomes increasingly irregular. Lake shores are acted upon in a similar way and with similar results, only the forces here are less powerful than those that act upon the sea coasts.

142. Instability of Sea Coasts. — It often happens that in making excavations at a considerable distance from the sea, shells are dug up very similar to those now found on the shore. Some inland strips of land are found composed of sand and pebbles like a beach and having the beach slope. Sometimes tree trunks standing with their roots in the ground just as they do on the dry land are seen at a considerable depth in the sea. It can be proved that an

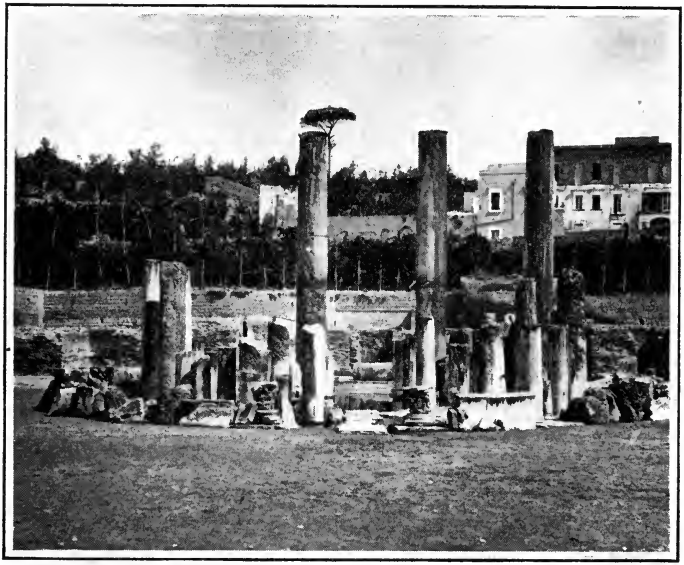


INLAND SEA CAVE AND BEACH.

This coast has been recently elevated.

old temple near Naples, Italy, has stood above and then in the sea more than once since it was built.

Facts like these show that the sea coast is not stable, but subject to upward and downward movements, some of which are slight and some great. If the land near the sea rises, the coast line is moved into the area which was formerly covered by the water and if the land sinks, a new coast line is formed where before the hills and valleys of the land appeared. Changes of this kind have a marked effect upon the outline of the coast and upon the industries of its future inhabitants. The coastal plain which borders a large part of our Atlantic coast shows the results of an upward movement. The fiorded coast of Alaska affords an example of a downward movement.



TEMPLE OF JUPITER NEAR NAPLES.

Although it can be proved that this coast has been elevated and depressed several times, so gradual has been the movement that the pillars have not been overturned.

143. Elevated Coast. — **Experiment 126.** — Tack enough sheet lead to a very rough board so that it will remain submerged when placed in water. Place the board in a shallow dish of water, lead side down. Taking the board by one edge, gradually lift this edge above the water surface. What kind of a line does the water form where it meets the board? In what way would this line be changed if the board were smoother? If it were rougher? If the edge of the board is lifted higher, does the position of the water line change? Does its form materially alter?

The main characteristics of a coast which has been *elevated*, that is, of one in which the shore line has moved seaward, will readily suggest themselves to any one who considers what has taken place. Soundings show that the continental shelf has a comparatively smooth surface. Thus the water will meet the land in an almost straight line and the deepening of the water off shore will be gradual. The material forming the shore both below and above the water line will be easily eroded, since it has been recently deposited and has not had time to consolidate.

SAND DUNES FORMED UPON A SAND BAR.

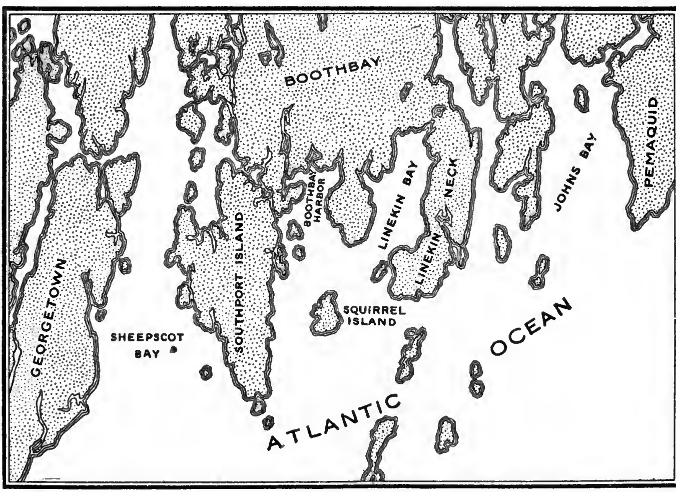
Waves rolling in upon the shore will strike the bottom at a considerable distance off shore. Thus the water rapidly loses its velocity and its power to carry eroded material shoreward, so it builds at a distance from the shore a sand reef inclosing a lagoon. The currents caused by the prevailing winds and the tide flowing along the outside of this barrier give it for long distances a smooth outline, sometimes almost straight and sometimes gently curving. Dunes are formed upon these bars. In time landward-blown sand, together with the silt brought by the streams from the mainland, may fill up the lagoon.

The filling of these lagoons, both naturally and artificially, has considerably increased the habitable land of the earth. The inclosed waterway back of the sand reefs has in some places rendered coastwise traffic safe and easy. It is proposed artificially to extend and develop certain of these inclosed water areas along the eastern coast of the United States so as to form a protected waterway from New England to the southern ports. At present the low, almost featureless shore of this region, with its shifting sand bars and capes, makes coastwise navigation dangerous, although it is protected by many lighthouses and life-saving stations.

The sand reefs along the southern Atlantic and Gulf coasts have in some places attained sufficient width and height for considerable settlements. The tidal inlet, the sea-beach resort, and the commercial city with reef-protected harbor are natural results of receding shore lines. In time the waves, by their own erosive action, will deepen the bottom off shore from the reef enough to enable them to attack its front. Thus they will drive it back over the inclosed lagoon, destroying their own work and attacking the shore, which for a time they had shielded against their own rapacity.

Where the range of tide is considerable, the reefs are frequently broken by inlets. Through these the water of the mainland streams finds access to the sea. The shapes and depths of these inlets are in some cases so rapidly altered by the tidal currents that it is impossible to foretell for any length of time where vessels can find the best channel. Thus the inlets must be left uncharted and local pilots relied upon. Bars which cannot be crossed except at high tide often make moon time, not sun time, the determining factor in the sailing schedules of vessels leaving and entering port. The general set of the shore currents has an effect upon the position and shape of these inlets, deflecting the openings in the direction of their flow. They may also singularly modify the outlines of the reefs themselves as in the formation of the three much dreaded capes off the coast of North Carolina.

144. Depressed Coast. — Experiment 127. — Cover a small board with a piece of thin oilcloth which has been most irregularly crumpled. Take the board by one edge and inclining it slightly gradually submerge it in a dish of water. What kind of a line does the water form where it meets the oilcloth? In what way would this line change if the oilcloth were more crumpled? If it were less crumpled? If the board is more submerged, does the position of the water line change? Why does its form materially alter?



PART OF THE COAST OF MAINE.
A fine example of depressed coast.

Along a coast which has been *depressed*, the shore line has moved landward and a surface rendered irregular by erosion is lapped by the inflowing water. All the irregularities which lie below the water level are filled with water and the shore line bends seaward around the projecting elevations and landward into the gullies and valleys. Isolated elevations surrounded by land low enough to be covered by the inflowing water have now become islands.

The river valleys which crossed the region now sub-

A NORWAY FIORD.

merged reveal themselves only to the sounding line, their landward extensions forming *estuaries* up which the tide sweeps far into the land. Their unsubmerged portions contain fresh-water streams, the size of which seems insignificant when compared to the size of the estuary. Sheltered coves and harbors abound, affording protection to all kinds of crafts and fitting these coasts to be of great commercial importance.

The harvest of the sea replaces what might have been the harvest of the land. The distance along the coast between two points is much longer than the straight line distance over the sea. The boat, not the wagon, becomes the important vehicle of travel. Many submerged coasts, such as those of Maine, Alaska and Norway, have been modified by ice action. Their valleys have been smoothed and rounded.

A NORWAY FIORD.
Showing large vessels anchored near the shore.

In Norway the deep fiords conduct the sea from the island-studded coast far into the interior. Their sides rise steeply, sometimes for several thousand feet from the water's edge and descend so steeply below it that large vessels can be moored close to the shore. Generally there is not sufficient level land along the sides of the fiord for building roads. The villages are usually situated where a side stream has built a little delta, or at the heads of the fiords where the unsubmerged portion of the valley begins.

A NORWAY VILLAGE.
At the head of a fiord.

These U-shaped valleys with their small streams extend back to the interior uplands, sometimes blocked toward their heads by descending glaciers. They often have hanging valleys which enter far up along their sides, the streams of which descend by abrupt falls and adorn the dark rock walls with bands of silver spray.

It was such a coast as this which bred the ancient Northmen, to whom the Sea of Darkness, as they called the Atlantic, was terrorless. While less favored and hardy sailors were dodging from bay to bay along the shore always in sight of land, they were pushing boldly west, guided only by the beacons of the sky, and discovering Iceland, Greenland and the American continent.

145. Harbors. — The importance to mankind of good harbors cannot be overestimated. No civilized country by its own products can fill all the wants of its inhabitants. Since earliest times man has been a barterer of goods. The sea offers him an unrestricted highway for his traffic. Harbors he must have to load and unload his wares safely.

Although many of the best harbors of the world are found along depressed coasts, such as the harbors of New York, San Francisco, London, Liverpool and Bergen, yet there are several other sorts of harbors. The delta of a great river may afford a good harbor, as those of New Orleans and Calcutta. Harbors may be formed by sand reefs and spits, like those of Galveston, Provincetown and San Diego. The atolls of the mid-Pacific and even the submerged craters of volcanic islands afford safe resting places where ships may ride out the storms.

146. The Safeguarding of Coasts. — As nations advance in civilization and their commerce develops, they realize the necessity of safeguarding in every way possible the ships bearing their citizens and their wealth. Thus a great system of weather signals, of lighthouses and of life-saving stations has been established. From these mariners may know when it is safe to leave port, may be warned off from dangerous shores, and, when in spite of all precaution their vessels become wrecked, may be rescued from a watery grave.

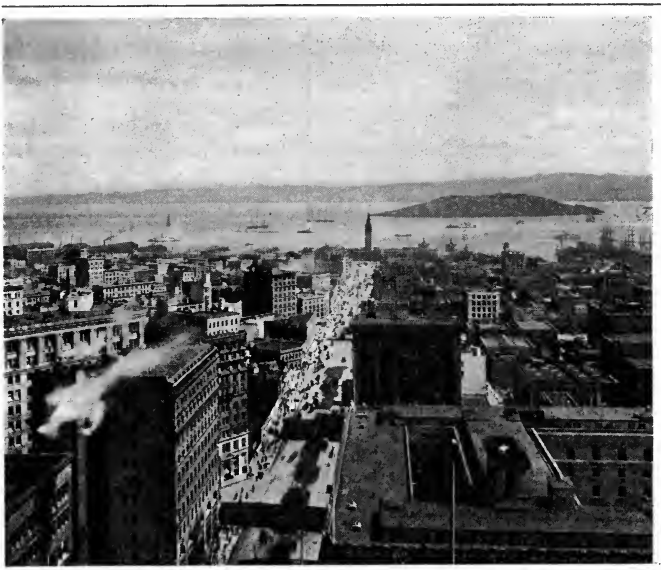
The lighthouses have lights of different kinds and colors, some fixed, some flashing, so that when unable to

SAN FRANCISCO

A harbor due to depression of the coast.

make out the coast itself, the mariner can still know his position by the kind of light seen. Indeed many wireless telegraph stations are being equipped to communicate with vessels at sea and to inform them of their position, the condition of the shore and the expected weather. Even the kinds of material which form the sea floor near the shore, and which may be brought up by the mariner's sounding apparatus, are charted for him, so that in this way he may be helped to ascertain his position.

147. The Coast of the United States. — The coast of the United States presents a great variety of features. It has long stretches of uplifted, depressed and fiorded, dune-bordered, rock-bound, coral- and mangrove-fringed coasts.



HARBOR.

One of the finest harbors in the world.

Along part of its sea border, harbors are abundant while in other portions, harbors are almost entirely lacking. Its recently uplifted western coast has still more recently been slightly depressed, thus forming the harbors of San Francisco, Portland and Seattle. This coast and the depressed and fiorded region of Alaska are paralleled, but in no way duplicated, by the elevated south Atlantic coast which has more recently been depressed in the Chesapeake Bay region, and by the depressed and slightly fiorded coast of northern New England. On the eastern side of the United States a broad coastal plain has been formed which has no counterpart on the west.

MINOT'S LEDGE LIGHTHOUSE.

148. Influence of Coast Conditions upon Inhabitants. — All natural features have a greater or less influence upon the inhabitants of the earth, but perhaps none has so directly and obviously influenced man's activities as has the kind of coast on which he lives. Europe, with its harbor-full and Africa with its almost harbor-less coasts are in striking contrast to each other. This difference between the inducements to travel and commerce which the two continents afford is one of the factors in producing the marked difference in progress attained by the people of the two continents. They stand to-day as types on the one hand of economic progress and on the other of stagnation.

The Phœnicians, the Carthaginians, the Greeks, the English and the other great nations of the world have felt the enticing allurement of a captive sea waiting in their harbors like a steed for them to mount and ride away in quest of the world's best. Thus they have extended their conquest and influence far beyond the homeland. From the time of Peter the Great, the efforts of Russia to gain suitable outlet to the sea show the importance placed by progressive communities upon ocean traffic. The struggle of all the great world powers to strengthen their navies, no matter what the cost, shows with what jealousy the products of their ports are guarded.

Coasts with harbors give their people the facilities and inducements for seeking the unknown, while the harborless coasts confine the aspirations of their inhabitants to the products immediately around them. A glance at the coast line and harbors of Greece shows one cause of its ancient civilization and a reason why the Greeks were "always seeking some new thing."

Summary. — A glance at a map shows the great variety of coast lines. The waves and tides are constantly cutting and wearing the coast. The material thus cut away is ground fine and spread out by the currents in *bars* and *beaches*, filling up coves and straightening the coast. Thus one of the results of these erosive forces is to make the coastline more regular.

Coastlines are affected not only by wind and water erosion, but by elevation and depression. When the shore rises, or is *elevated*, part of the comparatively even level of the continental shelf becomes the coastline. Thus elevated coasts are usually regular. But when the shore is *depressed*, the irregularities caused by the surface erosion on land make bays and estuaries. Thus depressed coasts are usually irregular and offer the best harbors.

Wherever there are good harbors we find seafaring people. To make ocean traffic safe, seas are charted, coasts mapped, lighthouses built and life-saving stations maintained. Water transportation is the cheapest, so good harbors are needed by all commercial nations. Nations with seacoast and harbors are usually more progressive and more civilized than inland nations.

Questions

Of what do the borders of different coasts consist?

What do the waves do to the coast?

How are beaches and bars made?

What form do the waves and currents tend to give to the coast?

How can it be shown that coasts are subject to changes in position in respect to the surface of the sea?

What are the characteristics of an elevated coast?

What are the characteristics of a depressed coast?

How are harbors formed?

How are coasts safeguarded?

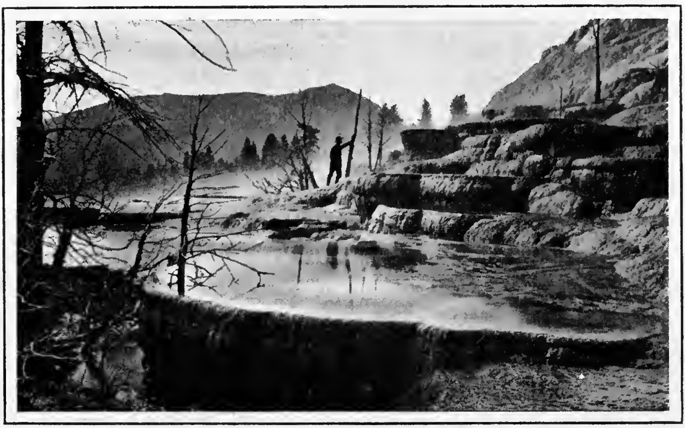
What kinds of coasts are found in the United States?

How have coast conditions influenced their inhabitants?

CHAPTER X

WATER SCULPTURE

149. Rainfall. — The water of the earth's surface is constantly evaporating, rising into the air and being distributed by the winds. Much of this water is blown over the land, where it is condensed and falls as rain. Some



A HOT SPRING IN THE YELLOWSTONE.

portions of the land receive much and some little of this aërial water circulation. When winds from warm seas, where the evaporation is great, strike lofty mountain ranges, the land upon the windward side has a large rainfall, but that upon the lee side comparatively little. This is particularly well shown in the northwestern part of the United States. Since continents, as a rule, have their mountains near their borders it happens that most continental interiors are comparatively dry.

Regions over which the prevailing winds blow from a colder to a warmer latitude have little rainfall, as the air is continually having its capacity to hold moisture increased by its rise in temperature. This is well illustrated in the Sahara region. Accordingly, the amount of rainfall in different parts of the earth varies greatly. In eastern India south of the Khasi Hills a "record" fall of over 50 feet was recorded in one year, while in desert regions a year may go by without any fall of rain.

In the United States the greatest rainfall, over 80 inches,

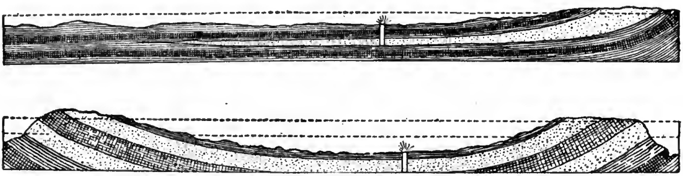


Fig. 111.

is found along the northwest coast and the least in the Basin Region of Utah, Arizona and Nevada. Whether rain falls in large or small quantities, its effect is always marked. Without it the surface of the ground is a parched and barren waste of dust and rock, with it, a green and varied expanse of never failing beauty.

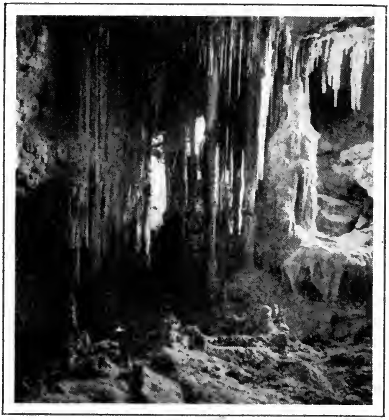
150. The Sphere of Activity of Rain. — When rain falls upon the ground, it may do one of three things. It may evaporate immediately from the surface and return to the air; or it may run rapidly off the surface and quickly join the streams and rivers which bear it to its final goal, the sea; or it may sink into the ground. In this last case part of it returns gradually through capillary action to the surface where it is again evaporated; part finds its way into springs; and part sinks deep into the soil and rock.

Which of these courses the greatest part of the rainfall will take depends entirely upon the condition of its fall and the kind of surface upon which it falls. If the rainfall comes down rapidly, the larger part of it will immediately run off; if it comes down gently, much of it will sink into the ground. If it falls in forest regions or where there is much verdure, its flow will be impeded by the plants and roots. If the surface upon which it falls is hard-packed and impervious, most of it will run off, but if it is loose and easily penetrated, much of it will sink into the soil. Even in the dry parched sands of the desert, however, the rain falls sometimes in such cloud-burst torrents that it runs off in rushing streams.

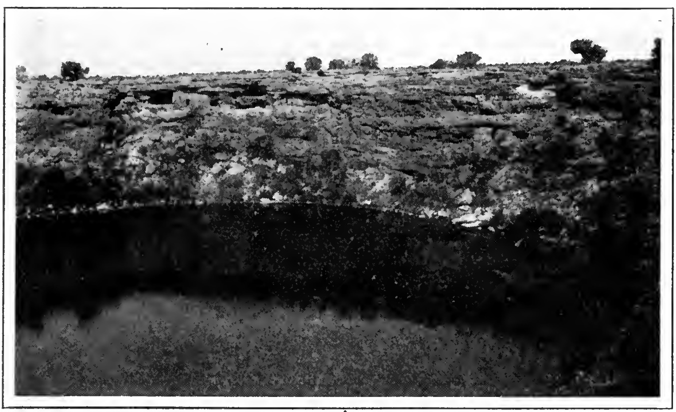
FLOWING ARTESIAN WELL.

151. **Sub-Surface Water or Ground Water.** — The rain that sinks into the ground descends slowly along the little cracks or between the particles of soil until it reaches a point where it can sink no further, or until it finds an opening through which it can flow out to the surface at a point lower than where it entered. Here it may ooze slowly out, or it may be concentrated in a spring.

If the water which comes to the spring has penetrated below the surface far enough to get away from the heating effect of the sun, it will be comparatively cool when it again emerges, and it will form a cold spring. If, however, in the region where the spring occurs the rocks are hot at the depth to which the water penetrated before it found a crack through which it could come to the surface of the land, then it will become heated and will form a hot spring.



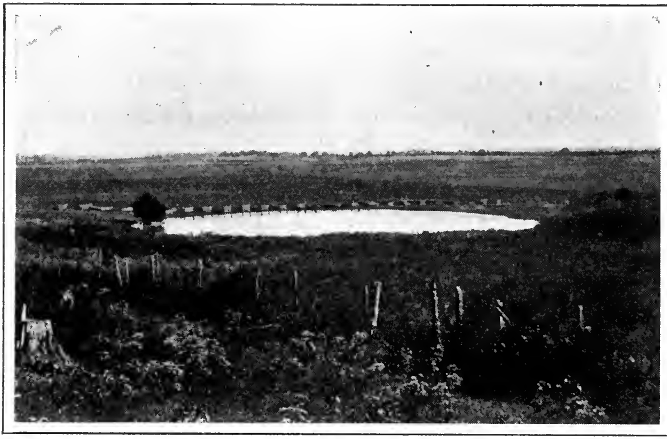
A LIMESTONE CAVE.



MONTEZUMA'S WELL.

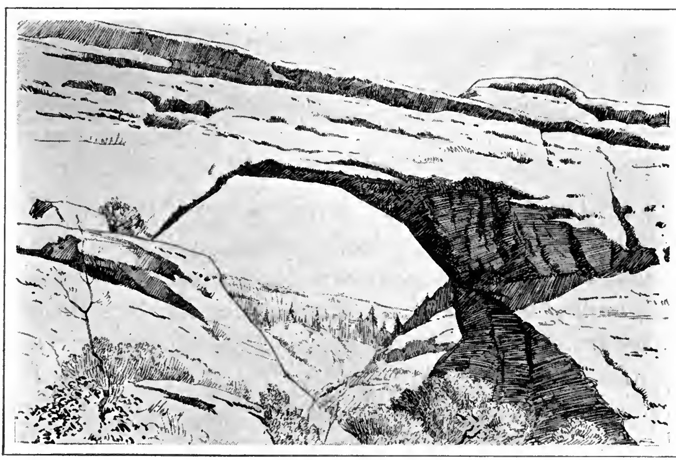
This famous water hole is due to the dissolving of the underlying rock layer.

As the crust of the earth is in many places composed of rocks in layers, the rain often falls upon the top of a



SINK-HOLE IN TENNESSEE LIMESTONE.

folded porous rock layer, below which is a rock through which it cannot penetrate. The water will then accumulate throughout the porous rock. If this rock layer in another part of its extent is overlaid by an impermeable



GREAT NATURAL BRIDGE, UTAH.

layer, its water is held in by the impermeable rocks above and below, and so is under hydraulic pressure. When a hole is made in the upper rock layer (Fig. 111), the water will flow to the surface and if the pressure is sufficient, it may gush out of the hole.

Borings of this kind form what are called *artesian wells*. These are of great importance in many regions where it is

NATURAL BRIDGE, SAXONY.

difficult to obtain sufficient surface water. In some of our western states the water from artesian wells has been obtained in sufficient quantity for extensive irrigation. Although this water often contains minerals in solution, it is free from surface contamination and is therefore usually healthful for drinking.

In some places the surface water penetrates into layers of rock which it can dissolve, such as salt or limestone. Here it forms caves and caverns, the solid material which occupied the place of the cave having been carried away in solution by the water. There are thousands of caves of this kind but perhaps the most noted in this country are Mammoth Cave with its nearly 200 miles of underground avenues and grotesquely sculptured halls, and Luray Cave with its wonderful stalactite and stalagmite decorations. Sometimes the top of one of these caves is nearly eroded away, leaving a part of its old roof standing as a natural bridge, such as the natural bridge of Virginia or of Utah. Sometimes the top falls in, leaving a *sink-hole.*

152. Geysers. — **Experiment 128.** — Fit a 250 cc. glass flask with a two-hole rubber stopper. Through one hole extend a glass tube (a) almost to the bottom of the flask and through the other hole a tube (b), 5 or 6 cm. longer than the height of the flask, to within about 1 or 2 cm. of the bottom of the flask. This last tube should be slightly drawn out at the end and bent at the top so that it slants away from the flask. Arrange the flask on a ring stand so that it can be heated by a Bunsen burner. Connect to the tube (a) a rubber tube long enough to reach into a water reservoir placed higher than the top of the flask and to one side. Fill the reservoir with water.

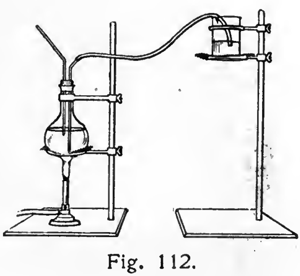


Fig. 112.

Through the tube (b) suck the air out of the flask until the water from the reservoir begins to run into the flask. A siphon will be formed which, when there is no internal pressure, will keep the water in the flask slightly above the bottom of the tube (b). Now heat the flask. When steam begins to form, hot water will be thrown out of the tube (b) until its lower end becomes uncovered and the pressure of the steam relieved. Water from the reservoir will then run in again slightly covering the end of the tube. As soon as more steam is formed, hot water will be ejected as before. Thus a spray of hot water is intermittently ejected from the flask as long as heating continues. We have here an action which resembles that of a geyser.

In the north island of New Zealand, in Yellowstone National Park and in Iceland, remarkable spouting springs called *geysers* are found. These places have had recent volcanic activity. The eruption of a large geyser is a most picturesque and startling phenomenon. Almost without warning there is thrown into the air a column of hot water from which the steam escapes in rolling clouds. It rises in some cases to a height of a hundred feet or more and is maintained at nearly this height by the ceaseless outrushing of the water for a time varying from a few minutes to between one and two hours. Then it gradually quiets down and dies away into a bubbling spring of hot water.

Giant Geyser in Eruption.

The time at which most geysers will erupt is uncertain, but there is one, Old Faithful, in Yellowstone Park, which is almost as regular as a clock, the time between its eruptions being a little over an hour. This geyser plays to the height of about 150 ft. and maintains the column of water for about four minutes. The Giant Geyser of the same region throws a large column of water to a height of 250 ft. It plays from one to two hours.

The outpouring hot water brings up with it dissolved rock and as the spray falls back and cools, this is deposited, forming craters of singular shape and grotesque beauty. On looking into these craters a smoothly lined, irregular, crooked, tubelike opening is seen to extend down into the ground. It is through this that the water finds its way to the surface. How long these tubes are nobody knows, but they must reach to a point where the heat is

CONE OF THE BEEHIVE GEYSER.
Built from the dissolved material brought up by the hot water.

sufficient to raise water to its boiling point. This heat is probably due to hot sheets of lava.

When the water in the tube is heated enough to make it boil under the pressure to which it is subjected, steam forms and some of the water is pushed out over the surface. This escape of water relieves some of the pressure, and more of the water far down in the tube expands into steam thus throwing more water out. Huge indeed must be the reservoir to which the tube in a geyser like the Giant leads, to be able to pour out such a vast quantity of water.

153. Run-off. — The rain that falls upon the land and neither evaporates nor sinks into the surface runs off as fast as it can toward the sea. It is joined sooner or later by the water from the springs and by the rest of the underground drainage. Sometimes the journey is long and there are many stops and delays in lakes and pools; sometimes the course is quite direct and quickly traveled. The run-off most profoundly affects the earth's surface. Gullies and valleys are cut, depressions are filled; in fact, running water is the chief tool which has carved the features of the earth. It has had a long time to act and it has kept unremittingly busy, so that the results of its action appear now in our varied landscape.

154. Pools and Lakes. — The water which runs off the surface first fills the depressions. As soon as these are filled, it runs over the lowest part of their rims and starts again on its course to the greatest of all depressions, the sea. If depressions of considerable size become filled with water, we call them *lakes*. As with mountains, the term *lake* gives no definite idea as to size. In some localities a water surface of a few acres is called a lake, while in other localities, the area must be several square miles to merit this name. As a rule, when the area covered by water is small, it is called a *pool* or a *pond*.

AN UNDRAINED UPLAND.

The streams that flow into lakes are continually bringing down the sand and mud they have gathered in their course, and are thus filling up the lakes. Lake Geneva in

Switzerland has had its narrow eastern end filled, for a distance of fifteen or more miles, with the coarse sediment brought down by the Rhone. The whole basin of the lake has been covered to an unknown depth by the finer sediment. The outlet to a lake tends to wear away its bed, but it does this slowly, as it has little sediment with

SUNSET ON GREAT SALT LAKE.

which to scour. Thus lakes are being constantly both filled and drained, and so are comparatively short-lived features of the earth. Rivers which have lakes along their courses must be *young* as otherwise they would have filled or drained the lakes.

Lakes are very important features to man. They filter river water so that rivers emerging from lakes are clear. Where the Rhone enters Lake Geneva, it is turbid and full of silt, but when it emerges, it is clear and without sediment. Lakes also act as reservoirs for the water that pours into them at the time of freshets. Rivers emerging from lakes of considerable size vary little in the height of their water at different seasons of the year. They are without floods. The St. Lawrence illustrates this. On the other hand the Ohio with its frequent and terribly destructive floods shows the effect of unrestrained run-off.

THE DEAD SEA.

Lakes often form most valuable internal waterways, as in the case of the Great Lakes and the Caspian Sea. Lakes are also most beautiful objects on the landscape and their rippling waters give joy and pleasure to thousands.

In some regions the rainfall is so small that the depressions never fill up sufficiently to overflow their rims. The water is evaporated from the surface as fast as it runs into the lake. Thus all the salt and other soluble substances which have been extracted from the land and brought into the lake by the rivers remain there, since only pure water is evaporated. In this way lakes without outlet become salt. Great Salt Lake in Utah is an example of this. Some salt lakes, like the Caspian Sea, were probably once a part of the ocean, so that they have always been salt.

As time goes on, more salt is brought to these lakes without outlets, and they become more and more salty.

LAKE DRUMMOND.

A lake in Dismal Swamp, Virginia, which is being filled by vegetable growth.

Great Salt Lake has something like 14 or 15% of solid material in its water and the Dead Sea about 25%. An effort to swim in these waters gives one an exceedingly queer sensation. The buoyancy is so great that a large part of the body is out of water, and one finds oneself bobbing around like a cork.

Depressions that are very shallow and are largely filled with vegetable growths are called *swamps*.

155. The Work of Running Water. — Running water has the power of carrying solid materials. If it is moving slowly, this power is not great; if moving swiftly and in great volume, it is tremendous. The carrying power of a stream increases very rapidly if its velocity is increased. A stream having its velocity doubled will carry several times as much material as before. Thus it happens that water running over a surface sweeps loose material with it, the amount varying with the rapidity and volume of the flowing water.

As this loose material sweeps over solid surfaces, it cuts

GULLIES BEING CUT BY RUNNING WATER.

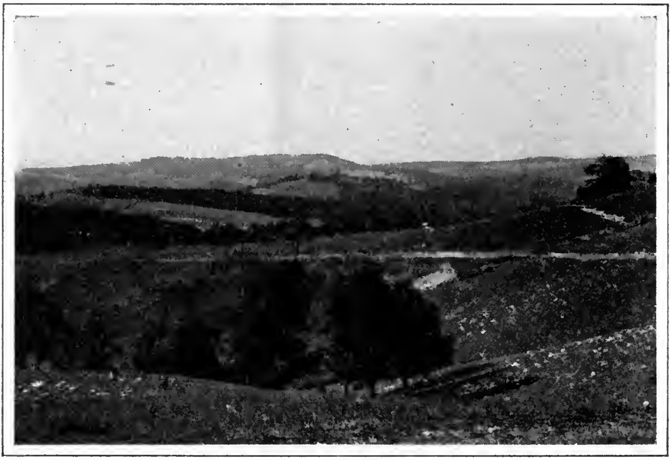
them down. Thus flowing water is continually wearing down and sweeping away the surface over which it moves. This sort of work is called *water erosion.*

When running water is concentrated into a stream, the work of erosion is also concentrated and the wearing down of the stream bed becomes comparatively rapid. This cutting down goes on irregularly, being greatest at time of flood and least when the flow is slight. It is estimated that the solid material carried by the Mississippi River from its basin lowers the basin about one foot in 5000 years; but the material which is dissolved increases the amount carried away, so that the basin is lowered a foot in from 3000 to 4000 years.

THE BAD LANDS OF DAKOTA.
Running water has so dissected this land as to render it valueless.

The channels of some of the streams in this basin are cutting down with far greater rapidity than this. We see gullies cutting down little troughs for themselves several inches deep in one rainstorm. The rapidity of cutting depends upon the material, the slope and the quantity of water. That "the waters wear the stones" was noted even in Job's time.

When rain falls upon a sloping surface of fine textured, easily eroded material not covered thickly with vegetation, this will be deeply and fantastically sculptured. An excellent example of this kind of sculpturing is found in the Bad Lands of Dakota. Here travel is exceedingly difficult. It was in these natural fastnesses that the Sioux Indians made their last ineffectual stand against the white man's civilization.



DIVIDES BETWEEN STREAMS.

The ridge in the center of the picture separates two streams flowing in opposite directions.

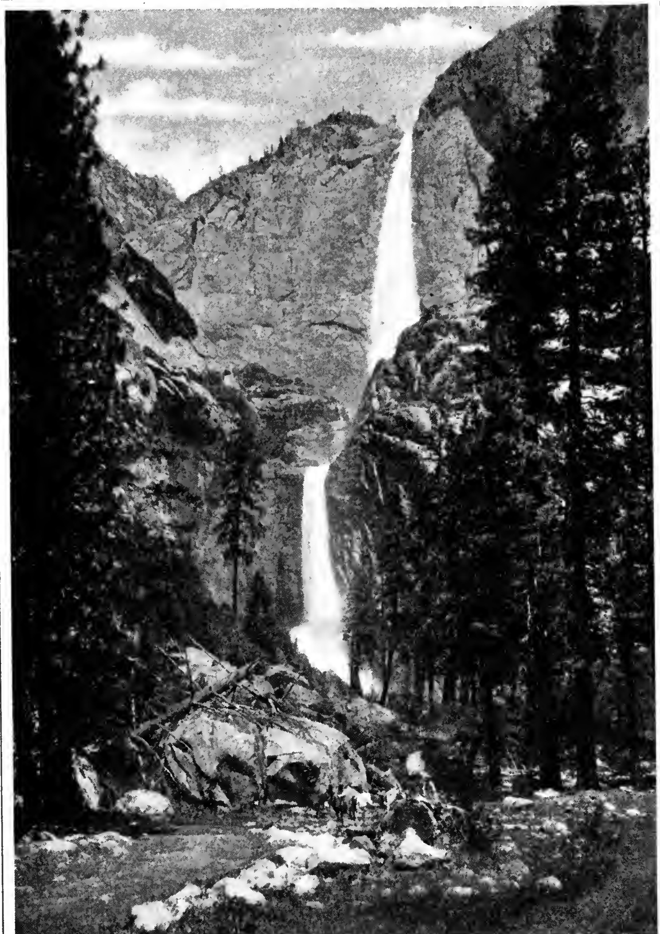
156. Divides. — If we carefully observe the drainage of a region, we find that the areas from which different streams gather their water are usually so distinctly separated from one another that a line could be drawn so that wherever water falls the rivulets on one side would flow into one stream and on the other side into another. Such a line of the highest land between the drainage areas of neighboring streams is called a *divide.* The line may be very distinctly marked, as on mountain ridges, or it may be difficult to determine, as in a flat country, but if the drainage is well established, it will be apparent.

If the drainage is not well established, areas may be found which at one time drain in one direction and at another time in another. A singular example of the shifting flow of a drainage area is found in Yellowstone Park where Two-ocean Creek shifts from one side to the other of a fan it has built, and at one time delivers its drainage into the Atlantic Ocean and at another time into the Pacific.

Near the dividing line between two drainage areas, swamps sometimes occur, which have streams flowing from them in two directions so that part of their water goes to one stream and part to another. But as these swamps become better and better drained, each stream will carry off its definite part of the water. Divides are irregular in their height, so that roads and railways in passing from one drainage basin to another usually seek out the lowest part of the divide. In mountain regions these low places are called *passes*.

Divides do not always remain in the same place, as the river on one side may from some cause become able to carry off the drainage more easily than the river on the other side. It will thus push back its headwaters and shift the divide back until the divide becomes adjusted to the abilities of the two rivers.

157. Falls and Rapids. — In many streams the flow of water is interrupted by falls and rapids. Sometimes the course of a stream is crossed by a great break in the earth's crust, one side of which has been raised above the other. This makes a fall, or, if the stream is able to cut down fast enough, a rapid. Falls or rapids of this kind have been produced in the Colorado River.



YOSEMITE FALL.

One of the most beautiful falls in the world, due to glacial action.

Sometimes the course of a stream is changed, as was the case with many of the streams in the northern part of North America at the time of the Glacial Period. In its new course the stream may fall over a cliff, as did Niagara River which used to fall into Lake Ontario over the cliff near where Lewiston is now located. Here was developed a great fall which, owing to the kind and position of the rocks over which the river flowed, has moved back, leaving a gorge about seven miles long.

The rock layers are nearly horizontal with a hard layer at the top and softer layers below. As the water strikes the foot of the falls it drives rebounding currents against the rock wall behind it, and wearing away the softer rock undermines the harder rock at the top, which breaks off in great blocks. Thus the falls maintain an almost vertical wall behind them. These falls are about 160 feet high, one of the grandest of nature's wonders and one of the greatest sources of water power in the world.

Falls or rapids may also be formed in a stream where it passes from harder to softer material, as from the old land to the coastal plain. The softer material is worn away faster than the hard material and the stream bed lowered more rapidly, thus forming a precipitous descent. Falls of this kind were also formed where the glacial ice forced the streams to make new channels for themselves across the upturned edges of layers varying in hardness.

The falls in the northern part of the United States were most of them formed by the rearrangement of the drainage lines at the close of the Glacial Period, and those in the southern part of the country by the more rapid wearing away of the softer rocks of the coastal plain. Thus we see that the hum of the spindle and the lathe are often but the modulated whispers of those ancient forces which thousands of years ago sorted the rock materials and built the vast continental ice palaces of the Glacial Period.

Streams which have falls and rapids have not flowed in their present channels a long time, as time is reckoned in considering the earth's history. If they had, the falls and rapids would have been worn back and smoothed out. Thus, falls and rapids are characteristic of young rivers.

158. **River Development.** — The rain which falls upon a flat country runs off very slowly, a large part of it soaking into the ground. Pools and lakes are formed in the inclosed basins, and sluggish streams with irregular little crooks, which show that the streams have hardly decided

NIAGARA FALLS.
A young river cutting down a layer of hard rock.

where they want to go, wander in the slight depressions down the gentle slopes and unite with other streams here and there until a river of ever increasing size is formed.

In some places the streams flow through lakes where they deposit their sediment, thus filling the lake basins. Here and there they pass over hard layers of rock which hold them up in falls and rapids. These they at once begin to smooth down. Rivers of this kind may well be called *young*, as their life work is just beginning. The Red River of the North, with its shallow narrow valley and tortuous course, and the Niagara River, with its lakes and falls, are examples of young rivers.

Where the slope of the newly exposed surface is considerable, the streams flow much more rapidly and develop their courses more quickly. The small irregularities are sooner straightened and the trough deepened, thus forming side slopes down which run little rivulets which in

YELLOWSTONE RIVER.
A young river flowing in a deep trough.

time form side streams. The heads of these, like the heads of the larger streams, are constantly working back into the undissected area. Gradually the side streams develop side streams of their own, and almost the whole surface is covered with a network of streams.

As the work of erosion goes on and the streams deepen their valleys, only a few imperfectly drained remnants of the former flat surface are left here and there. These lie between the larger streams in places which the side streams have not as yet been able to reach. Almost the entire surface is so intricately carved into drainage lines, that wherever water falls it immediately finds a downward sloping surface. The main stream by this time has probably smoothed out most of its falls and rapids and has developed long, smooth stretches.

Here it is no longer cutting down its trough, but has only sufficient slope to enable it to bear along its load of

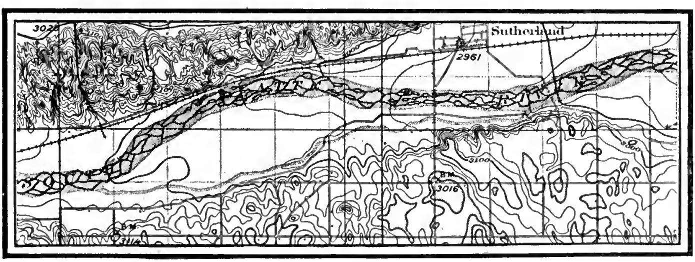
A Stream working back into an Undissected Area.

waste. It here deposits upon its valley floor about as much as it takes away. In this part of its course a river is said to be *graded.* The longer a river flows undisturbed by any deformation of its valley, the fewer falls and rapids it will leave and the longer will be its graded stretches. The Missouri River near Marshall, Missouri, is an excellent example of a graded river.

Sometimes a stream becomes so overloaded with detritus, which it has acquired in a steeper part of its extent, or

RIVER EROSION.
Cutting down the outer side of the curve and depositing on the inner.

which has been brought to it by tributaries, that it is continually being forced to deposit some of its load. Thus it silts up its course and flows in a network of interlacing



THE PLATTE RIVER.

shallow channels. The Platte as it crosses the plains of Nebraska is an example of such an overloaded river.

When a stream swings around a curve, the swiftest part of the current is on the outside of the curve and the slowest on the inside. A river that is carrying about all the load that it can, on passing around a curve, is able in its outer part to carry more than before and cuts into the bank, while on its inner part it flows less rapidly and is able to carry less, thus being forced to drop some of its load. As a river flows along its graded stretches, eroding in some places and filling in others, it broadens its valley

River Plain.

floor, leaving at the border of its channel a low plain which in time of flood may be covered with water. Such a river-made plain is called a *flood plain.*

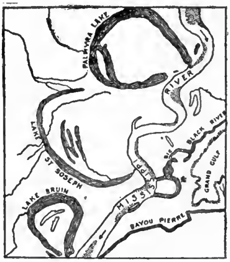
If a river once begins to swing on its valley floor, it continues to do so, since whenever it strikes the bank, it is reflected toward the other side, and is made to move in the direction of the opposite bank as well as downstream. The windings that it thus assumes on a flat valley floor are roughly S-shaped and are called *meanders*, from the name of a river in Asia Minor which was, in very ancient time, noted for having such swinging curves. The size of these curves will be proportional to the size of the river.

Great rivers like the Mississippi have a swing of several miles, while a small stream may have a swing of only a

River meandering in its Flood Plain.

few feet or rods. These meanders are continually changing their shape, owing to the cutting and filling. Since they strike the bank with the greatest force on the downstream side of the curve, they also move downstream themselves. This can be seen from maps of the Mississippi taken at different times.

The meanders sometimes become so tortuous that the downstream side of one curve approaches the upstream side of another and even cuts into it, thus causing the river to desert its curved path and straighten itself at this point. The old deserted winding looks something like an oxbow, and when filled with water, is called an *oxbow lake*. Sometimes the meanders are artificially straightened, as has been done in the lower Rhine valley, and much arable land reclaimed.



THE MISSISSIPPI AND SOME OF ITS ABANDONED MEANDERS.

In time of flood, when a river spreads over its flood plain, the velocity of the water is checked outside the channel and some of the sediment it carries is deposited. The most sudden check in velocity occurs where it leaves the

LEVEE ALONG THE LOWER MISSISSIPPI.

channel, so more material will be deposited here than elsewhere on the flood plain. The banks of the channel will thus be built up more rapidly, and the flood plain near the river will slope away from the channel instead of toward it.

This is well shown in the lower Mississippi, where the river is found to be flowing on a natural embankment, the side streams running away from the river instead of into it. In some places the embankment is fifteen or twenty feet above the rest of the flood plain. These natural *levees*, as they are called, often force the tributary streams to flow for long distances upon the flood plain before they

LEVEE OF THE SACRAMENTO.

can enter the main river. The Yazoo River is forced to flow along the flood plain some 200 miles before it can enter the Mississippi. Artificial levees are often built to keep rivers from overflowing their flood plains. Such are the high levees along the Lower Mississippi and Sacramento rivers.

Sometimes the flood plain of the main river is built up more rapidly than the tributaries can build theirs, so that they are dammed up as they enter the flood plain of the main stream and form a series of fringing lakes along its border. A fine example of this is found in the lower course of the Red River of Louisiana.

A river is said to be *mature* when it has reduced its valley to grade and is able to meander freely upon its flood plain, its side streams having appropriated all the undrained upland which they are able to obtain. The river is now carrying off in the easiest and most effective way the drainage which falls upon its drainage basin.

When a river has graded itself and built its flood plain,

An Old River.

This river has done its work and has completed a cycle of erosion.

its own active work consists largely in carrying off the materials brought to it by its side streams. Although these are now able to appropriate no new territory they continue to wear down the country and round off the divides till the whole region, unless reëlevated, is reduced to an almost level plain with its entire drainage system nearly at grade. Most of the material now carried by the river is in solution, and there is but little erosion. The river has accomplished its life work, it has borne to the sea all the burden it has to bear, its labors are ended, it has reached old age. It has reduced its drainage area to a *base level of erosion.* When a river has thus done all the wearing down of which it is capable it is said to have completed a *cycle of erosion.*

159. **Rivers in Dry Climates.** — In a region where the climate is very dry, rivers are often intermittent in their

RESULTS OF A SUDDEN FLOOD.

flow. They contain water only after rains. Such rivers may dry up before they reach any other body of water, their water entirely evaporating or sinking into the dry soil. Their development is therefore somewhat irregular.

If the slopes are steep and there is little vegetation to protect them and hinder the quick run-off of the water, rivers flood very rapidly, eroding their channels and washing away their banks. Where they descend upon level ground they silt up their old courses and acquire new channels. Thus a river which for the larger part of the year is a mere brook may after a rain become a devastating torrent, bursting its banks and carrying destruction to settlements and farm lands along its course. It may even change its entire lower course.

160. Accidents in River Development. — While a river is developing its drainage area many accidents may happen to it. The competition of other rivers in the same region affect it. The river that has the shortest course to the sea or the most easily eroded bed has the advantage. It lowers its valley more rapidly, thus giving its side streams steeper grades and enabling them to wear back faster into the upland, and thus to gain more than their share of the drainage of the region.

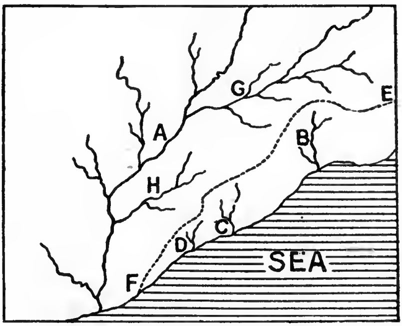


Fig. 113.

As soon as the unappropriated drainage area has been channeled, it begins to push back the divides of its neighbors, thus appropriating some of the run-off they may have acquired. In Figure 113 a case of this kind is shown. The river *A* reaches the sea by a long course, while the streams *B*, *C*, *D* have short courses. These short streams have steeper grades than *A* and thus are

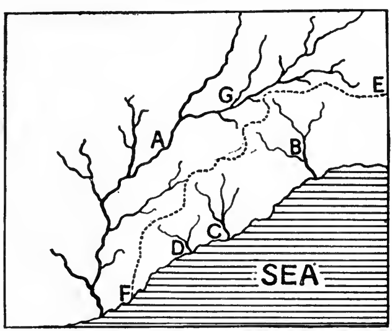


Fig. 114.

able to gnaw back and cut down their valleys faster. Thus they push the divide *EF* farther and farther toward *A*.

In Figure 114 a stage is shown in which the divide has been pushed back toward *A* and at one point has approached very near to the upper part of the branch *G*. In Figure 115 it has been pushed across this branch and the stream *B* has tapped *G* and appropriated its headwaters. This is a case of what is called *beheading* or *piracy*.

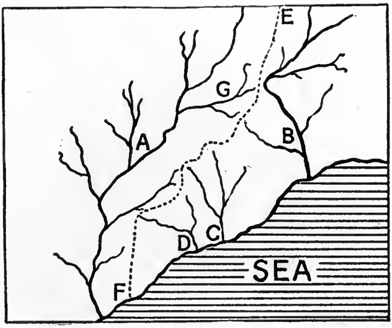


Fig. 115.

As *A* has lost some of its water it erodes its valley even more slowly than before, and a branch of the stream *D* may take away the headwaters of its branch *H*. If time enough is allowed, a branch of the stream *C* may completely behead *A*, leaving only its lower trunk as an independent river. Cases of river piracy are of frequent occurrence.

A river may by some accident have its supply of sediment greatly increased, causing it for a time to build up its valley floor instead of eroding it, thus forming a filled river valley. When the supply of sediment fails, the river begins cutting down the filled valley, leaving terraces along the sides to mark the successive levels at which it flowed.

River terraces are often very prominent along our northern rivers, since by the melting of the ice at the close of the last Glacial Period these rivers were supplied with a vast amount of sediment which they were unable to carry away and so deposited on their valley floors. When the supply ceased, they eroded their valleys, leaving terraces along the sides.

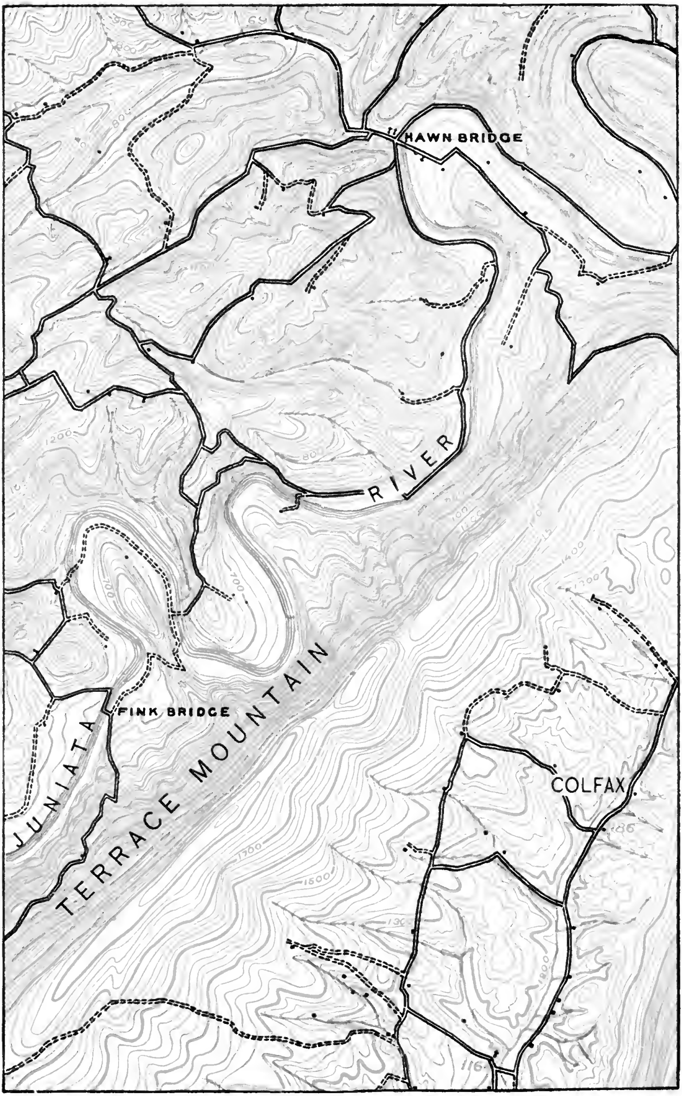
The region in which a river is situated may be *elevated*, thus affecting its normal development and beginning a new cycle in its history. The elevating may take place over its whole drainage area or only over a part of it.

RIVER TERRACES.

The river is now cutting down its former plain, leaving terraces.

If the whole region is elevated, the energy of the entire river is revived, and the river may be called a *revived* river.

The elevation may take place at any time during the history of the river. If it takes place after the river has become old and is meandering on its flood plain, the river will begin afresh to cut down its valley. But as its meandering course has been established, the trench that it now cuts is not like that of a young river, but is a meandering



Incised Meanders.

trench, and what are called *intrenched meanders* are formed. This region will have the steep V-shaped valleys characteristic of a young region and the well-developed drainage and meandering rivers characteristic of a mature region. The Palmyra, Virginia, sheet shows these characteristics. The main rivers meander in steep valleys. A profile shows these valleys to be steep and V-shaped with broad,

INTRENCHED MEANDERS.

rounded uplands between, well provided with drainage channels.

When the elevation extends beyond the mouth of the river, the river must prolong its course over the emerged land in order to reach the sea. It may happen that rivers which formerly entered the sea at different points, in extending their courses over the emerging continental shelf, join some large stream and all enter the sea through it.

This is what happened to the rivers now forming branches of the lower Mississippi when the coastal plain bordering the Gulf of Mexico was elevated. These formerly entered the extended Gulf by separate mouths, but when the land rose and forced the water of the sea back, their extended courses joined them to the great central river, thus vastly increasing its drainage area and the volume of water it poured through its mouth into the sea. Many of the great river systems of the world have been built in this way. These may be called *engrafted rivers*.

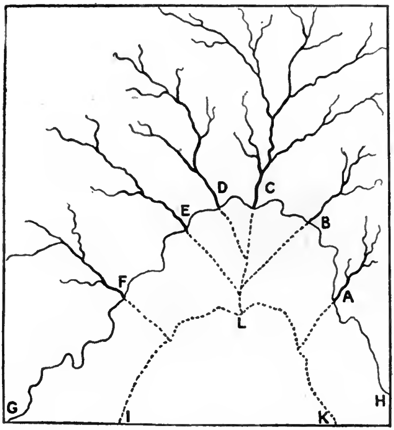


Fig. 116.

In Figure 116 the rivers all enter the sea at the old coast line *GH* by separate mouths. When this region is elevated so that the coast is at *IK*, the rivers *E*, *D*, *B* find that their easiest course to the sea is by engrafting themselves upon the river *C*, and thus they all four find their outlet at one point *L*. The rivers *F* and *A* still maintain their independent courses.

It may be that the elevation takes place over only a part of the river's course. Then the river is dammed back and *laked* on the landward side of the elevation and obliged to seek a new course for itself, thus becoming a *reversed* river, or else it is strong enough to cut its bed down as fast as the land rises, and thus maintain its course. Such a river is called an *antecedent* river, as its course antecedes the uplift which naturally would have determined its course. The Columbia River has maintained its course through uplifts which have reached thousands of feet.

Not only may a river be elevated, but it may be depressed. In this case its rate of erosion is diminished, and the river becomes marshy where the grade is low. Where the river valleys approach the sea they will be submerged or *drowned.*

ALLUVIAL CONES.
Formed at the foot of each mountain gully.

These drowned river valleys form some of the finest harbors on the coast. San Francisco Bay, Narragansett Bay and New York harbor are examples of protected harbors due to the submergence of rivers. The mouth of the Hudson was formerly some seventy miles to the east of Long Island, that of the St. Lawrence to the east of Nova Scotia. In fact the Atlantic coast north of the

Hudson furnishes innumerable examples of submerged river valleys.

The tributary streams which enter low down on a river's course, after submergence enter the sea directly in the bays formed by the submerged valley. Such rivers may be called *dismembered* rivers. Thus a coast region which was formerly well dissected by streams will on submergence become penetrated by a great number of irregular channels and bays.

FAN FILLED VALLEY.

Notice how the river is forced to wander around the edges of the fans.

Delaware and Chesapeake bays, where the early settlers each had a nice little sea inlet instead of a rough wagon road as his means of communication with his neighbors, are fine examples of submerged river systems. These drowned river valleys enabled the early settlers to penetrate easily into the country, and determined many of the early settlements, like Philadelphia, New York and Providence.

161. **Alluvial Cones and Fans.** — When a stream having a steep grade and bearing a heavy load of sediment emerges upon a flat country where the grade is suddenly reduced, it so quickly deposits its sediment as to be continually obstructing its own course and forcing itself to

LAKE DELTA.
Notice the triangular formation.

find new channels. It thus builds a *fan* or cone-shaped deposit pointed toward the place where the stream reached the plain. If the material is coarse, the deposit will have a steep slope; if fine, a gentle slope resembling a spreading fan. Sometimes these fans so overlap each other as to form an irregularly sloping plain.

Plains of this kind are found along the base of many mountain regions. If such formations occur in regions of little rainfall, they yield themselves with peculiar facility to irrigation, as ditches can be easily led out from the apex of the cone in all directions. Southern California offers many examples of easy irrigation due to such cones.

162. Deltas. — When a river enters a body of quiet water, its current is gradually checked and it deposits its material in somewhat the same way as on emerging upon a flat

CONE-SHAPED DELTA IN LAKE GENEVA.

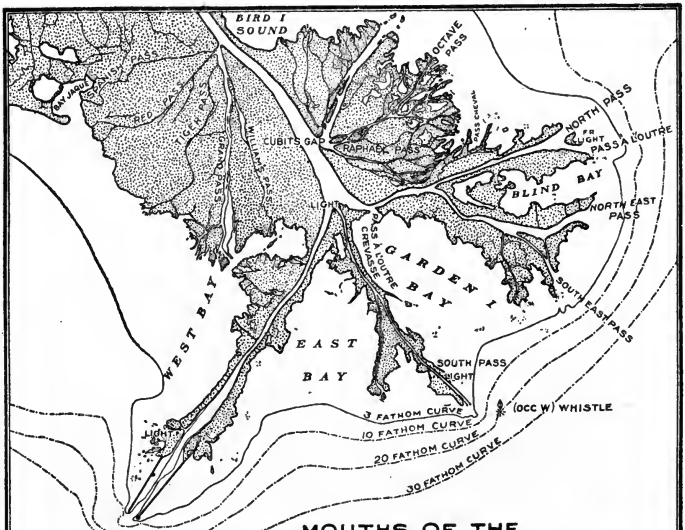
country. But here the deposition is more gradual and the slope of the deposited material less steep. The sediment, too, is sorted by the water, and the finer material is carried far out from the river mouth. Formations of this kind are called *deltas*, from the Greek capital letter Delta (Δ) which has the shape of a triangle. Few deltas have this ideal shape, but there is a general correspondence to it.

If the delta-forming stream descends steeply, it may build a delta with a steep upper surface rising cone-shaped above the water. Many of the deltas in Lake Geneva are of this kind. If the grade is slight, the delta will be simply a continuation of the flood plain of the river. Such is the Mississippi delta. The layers of sediment compos-

LAKE BRIENZ, FROM ABOVE INTERLAKEN.
A rapidly eroding stream at the extreme right has built a great delta dividing the ancient lake into two parts.

ing the delta, slope away from the point where the river enters the still water. Here, as in the alluvial cone, the river is continually silting up its outlet and being forced to seek new channels. In large deltas the river generally enters the sea through several channels or *distributaries*, as they are called. This is seen in the map of the Mississippi delta (page 352).

Deltas have rich, fine-textured soils and are very fertile. The Nile delta during all history has been noted for its fertility. But they are treacherous places, as they are liable to inundations by the overflowing of the river at time of flood. Because they are pushed out into the sea, they are peculiarly exposed to the sweep of the waves in great storms.



MOUTHS OF THE MISSISSIPPI RIVER

The rate at which deltas grow depends upon the amount of material carried by the river and upon the tides and currents at its point of outlet. In seas where the currents and tides are strong, no deltas are formed, except by very large streams such as the Yukon, the Hoang-Ho and the Ganges. In quiet seas deltas are readily built. The delta of the Mississippi is more than 200 miles long and has an area of more than 12,000 square miles. The Po in historic time has built a delta more than 14 miles beyond Adria, a former port which gave its name to the Adriatic Sea.

163. **History and Rivers.** — From earliest times rivers have played a most important part in the world's history. At first almost all human movement was along river valleys, as they offered the easiest route of travel. Here, too, men found the fertile and easily worked land so necessary in their primitive agriculture. Thus their settlements were usually placed upon the banks of rivers. In war the river offered a means of defense, as the Tiber so often did to Rome.

Before the time of railways, rivers and lakes supplied almost the only means of inland commerce. In our own country the hundred and fifty miles of unobstructed riverway stretching from New York to the north was the great road from Canada and the Lakes to the sea, fought for persistently in French and Indian Wars as well as in the Revolution. If in the Revolution the British could have obtained control of the Hudson, they would have effectually separated the colonists in the north from those in the south and would probably have been able to crush each separately.

The Mississippi River served for years as the only artery of transportation from the interior of the country to the sea. When Spain held the mouth of this river and Congress was unable or unwilling to exert itself to obtain the privilege for American boats to pass to the sea, it seemed for a time that the sturdy colonists along the Ohio and Mississippi would either form an independent country and fight for the privilege or else in some way ally themselves with Spain, so vital to them was the need of this waterway. In the Civil War vast amounts of blood and treasure were spent in fighting for the control of this river.

These are but a few examples taken from our own history of the importance of rivers. They could be duplicated in almost every country of the globe.

164. Great Rivers of the United States. — There are four great river basins wholly or partly within the United States: the St. Lawrence, the Mississippi, the Columbia and the Colorado. The first two of these are navigable for great distances and furnish unexcelled interior water-

DRAINAGE BASINS OF THE UNITED STATES.
Notice the positions of the divides separating the different drainage areas.

ways. Notwithstanding the great development of railways they still exert a vast influence upon the commerce of the country.

The *St. Lawrence* River with the Great Lakes, which are geographically a part of it, is the greatest internal waterway in the world. From the head of Lake Superior to the mouth of the St. Lawrence, a distance of about 2400 miles, by aid of the canals which have been built around the rapids and falls, vessels of 14 feet draft can pass to the sea. More tonnage passes through the "Soo" canal between Lake Superior and Lake Huron than passes through the Suez canal. Here pass the greatest fleets bearing wheat, iron, and lumber that the world has ever seen.

The old river which once drained this region passed through various vicissitudes before the present noble

THE "SOO" CANAL AT SAULT STE. MARIE.
Notice the "whale-backs," a type of boat peculiar to the Great Lakes.

waterway was formed. From Montreal to the sea it has been drowned by a depression of the land. Its upper basin has been enlarged in places by the action of the glacial ice, and in other places it has been dammed, thus causing lakes and falls.

The *Mississippi* and its tributaries offer navigable waterways of about 9000 miles. It is the greatest navigable river system in the world. From the Rocky Mountains on the west to the Appalachians on the east and from the northern border of the country to the Gulf, the spreading arms of its tributaries stretch out ready to bear to the

THE JETTIES OF THE MISSISSIPPI.
To keep the river from silting up its channel, it is confined between jetties and made to flow swiftly.

ocean by cheap and easy paths the products of this vast interior basin. By the aid of the Panama canal these varied products may travel directly by water without more than one or two re-shipments from their source in

DELTA LAND OF THE LOWER MISSISSIPPI.

the vast continental interior to the uttermost parts of the earth.

This noble river presents in its eventful history an epitome of the geographical history of our continent. It winds its masterful way over the oldest and youngest rocks. For part of its course it follows a valley built long before the Glacial Period shrouded the northern part of the continent in ice. In the northern part of its course the blanket of débris left by this vanished ice choked its path and forced it to seek a new channel. For the south-

THE COLUMBIA RIVER AND ITS OLD FLOOD PLAIN.

ern part of its course its mighty sediment-laden waters built new lands that it might extend its dominion.

At times in its history its might has been greater than now and at times less. But through all its history it has borne to the ocean the ceaseless current flowing from the heart of our continent. To it the modern geographer turns again and again as an inexhaustible record of geographical development. The geographical, political, industrial and commercial history of this continent are closely connected with this, its mightiest artery.

The *Columbia* River, although navigable for a distance of only 500 or 600 miles, and thus never destined to have the commercial importance of the St. Lawrence and the Mississippi, presents features of great interest. Guided by this stream the first settlers found their way to our northwest territory. Along its depressed mouth the rich and prosperous states of Washington and Oregon were nurtured through their infancy. Over its possession Englishman and American long contended.

This contention of man, however, was but an echo of the long contention of the river itself to hold its course. Flowing in a region of growing mountains, it was forced again and again to cut its way through barriers uplifted across its path. Sometimes for a time it was checked and forced to raise itself into a lake in order to surmount the obstruction placed in its way, but its strength never failed, and so through new-born ridges, through lake beds born of its own struggle, through growing depressions filled by its own labor, it held its course steadfastly to the sea. For part of its way it flows through cañonlike valleys, and its main tributary, the Snake, has built for itself through great beds of horizontal igneous rocks a cañon but little inferior to that of the Colorado.

The fourth great river, the *Colorado*, has industrially and commercially attained but little usefulness. Although navigable to about 400 miles from its mouth there is little need in the country it traverses for transportation in the direction of its course. But what it lacks in utility, it makes up in scenery. To no river on the face of the earth has the opportunity been given to show its sculpturing power as to the Colorado.

Flowing as it does through an arid region of nearly horizontal rocks, it has carved a giant trough for itself, leaving upon the lofty sides the uneffaced chisel marks of all its erosive helpers. The rill, the rivulet, the intermittent torrent, the sand blast of the scouring wind, the pull of gravity, the varied resistances of the rock layers, the structure and composition of these layers have each and all left their peculiar impress upon the resulting sculpture. Standing beside this mighty chasm, one is impressed, as nowhere else, with the mighty power of erosive agents.

THE COLORADO RIVER.
Flowing through a deep-cut, narrow valley.

And yet here is seen only the beginning of the vast work which these forces have before them. They have built only the narrow trough of what must be developed into a wide and gently sloping valley, and have hewn out here and there a ravine in that great upland which in time they must carve into the mature forms of a thoroughly dissected country. If the region had not been so dry, the work of dissection would have progressed much farther before the river had been able to sink its channel so deep. The water that falls hundreds of miles away is doing a mighty work which the meager rainfall of the region through which it passes cannot supplement. Majestic, awe-inspiring, stupendous, this gigantic trench is but a prank of the river's boisterous youth.

Summary. — Just as the waves and ocean currents work upon the coastlines, so the rain and the streams are constantly wearing down the surface of the land. All streams come from rain or melting snow, which condenses in the air after evaporating from water surfaces. The rainfall varies from nothing at all in some places to over fifty feet a year in others, but in the United States the greatest rainfall is about eighty inches a year.

Some of the rain evaporates at once after falling; some flows away on the surface of the land; some sinks into the ground, to return as springs, wells and geysers. The water which flows along the surface has the greatest effect upon the land. It forms the little streams which remove the surface water, the huge rivers which drain the country and form great arteries of trade, and the beautiful lake-reservoirs which hold back floods and offer easy transportation to mighty ships.

But most important of all is the *erosion* caused by flowing water. It wears down the hills and spreads them out in fertile fields, in deep trenches and broad valleys; it fills lakes and builds great deltas. By its falls and rapids it furnishes water power for manufactures.

Rivers that have not yet widened their valleys and still have falls and rapids are called *young;* an *old* river is one whose bed has been worn smooth, and which has built for itself a broad level valley, through which it wanders, doing little if any erosive work. Rivers sometimes develop *flood plains* through which they wander in S-shaped *meanders*. Sometimes a river cuts back its divide so far that it reaches another river, thus *diverting* another stream through its channel.

If the region of a river becomes elevated, the river may be *revived*, and if it is an old river with meanders, *intrenched meanders* may be formed. Sometimes the elevation of the land causes a river to be *laked* or reversed; if it maintains its previous course in spite of the elevation, it is called *antecedent*.

If a river region becomes depressed, the river may be *drowned* and its branches may enter the sea separately as *dismembered* rivers. Many rivers build *deltas* where they empty into still bodies of water and when the slope is steep, they may form *fans*.

Rivers have always played a great part in history, from the time Egypt was first called the "Gift of the Nile" to the influence of the Mississippi and St. Lawrence on the settlement and development of the United States.

Questions

What conditions influence the amount of rainfall of a place?

What determines what will become of the rainfall when it falls upon the ground?

What does the water do which sinks into the ground?

Where are geysers found? What are they?

Trace the probable journey of the water that fell near your home during the last heavy rain until it reaches its journey's end.

What determines whether a lake is fresh or salt? What are the great benefits derived from lakes?

Describe some effects of running water that you have seen.

Why does not all the water that fell in your town during a heavy rain flow by your home? Where is the 'divide'?

What are some of the causes which have formed falls and rapids?

Describe the life history of a river.

What peculiarities have rivers of dry climates?

Describe some of the accidents which are liable to happen during a river's history.

How are alluvial cones and fans formed?

Where and how do rivers build deltas?

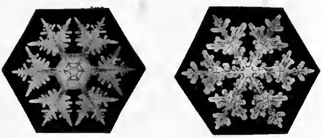
What have been the effects of rivers upon history?

Describe the four great rivers of the United States.

CHAPTER XI

ICE AND WIND SCULPTURES

165. Snow in Winter. — When the temperature of the air falls below the freezing point, its moisture congeals into little flake-like crystals and falls as *snow*. Where the cold is continuous for a considerable time, the snow may accumulate in deep layers over the ground. If the heat of the summer is not sufficient to melt all the snow which falls in the winter, then the layers of snow will increase from year to year.

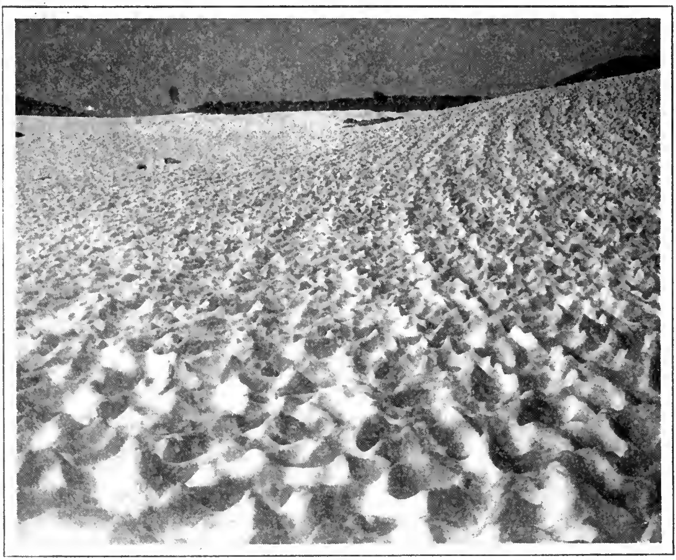


SNOW CRYSTALS.

To have this occur the temperature for the whole year need not be below the freezing point, but the heat of the summer must not be sufficient to melt the snow which fell in the colder season. Lofty mountains, even in the tropics, have their upper parts snow-covered. In the far north and the far south the line of perpetual snow falls to sea level, inclosing the mighty expanse of the Arctic and the Antarctic snow fields.

166. Glaciers. — Wherever there is not enough heat in the warm season to melt the snow which accumulates during the cold season, a thick covering of snow and ice will in time be formed. The ice is due to the pressure exerted on the lower layers by the weight of the snow above and to the freezing of the percolating water which comes from the summer melting of the upper snow layers.

Although ice in small pieces is brittle, in great masses it acts somewhat like a thick and viscid liquid. It conforms itself to the surface upon which it lies, and under the pull of gravity or pressure from an accumulating mass behind, slowly moves forward, resembling in some ways thick tar creeping down an incline or spreading out when heaped into a pile. The exact manner of glacial movement, however, is not fully understood.



SNOW FIELD AT THE HEAD OF A GLACIER.

In mountain regions where the snow holds over through the summer, the wind-drifts and the snow-slides carry great quantities of snow into the upper valleys, until ever accumulating masses of snow and ice, hundreds of feet thick, are formed. The ice then slowly flows down a valley till a point is reached where the melting at the end is equal to the forward movement. An ice stream of this kind is called a *valley glacier* or an *Alpine glacier*, because first studied in the Alps.

THE GORNER GLACIER.
A typical Alpine Glacier.

Although the moving ice conforms to the bed over which it passes, it does not yield itself to the irregularities as easily as does water. When it passes through a narrows or over a steep and rough descent, it is broken into long, deep cracks called *crevasses*. These make travel along glaciers sometimes very dangerous. The travelers are usually tied together with ropes, so that if one of the

CREVASSES IN A GLACIER.
The danger points in travel over glaciers.

party slips into a crevasse, the others will be able to hold him up and pull him out.

A glacier, like a river, is found to flow fastest near the middle and on top, and slowest at the bottom and on the sides. The rate of motion in the Alpine glaciers varies generally somewhere between 50 feet and one third of a

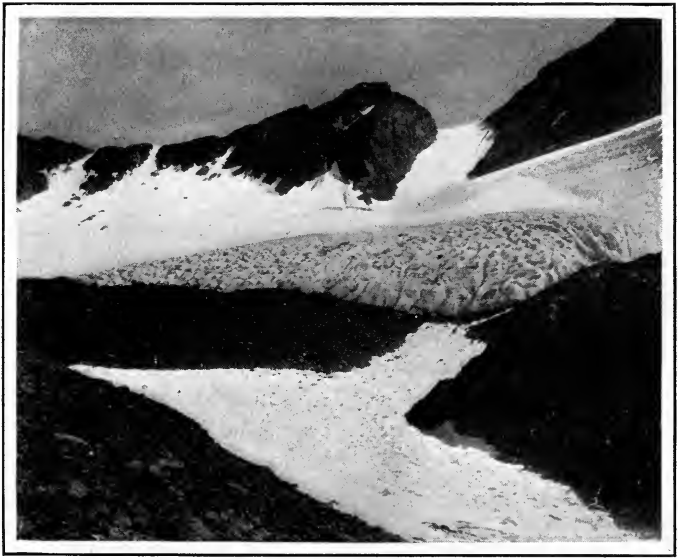
THE COE GLACIER, MOUNT HOOD.

mile in a year, being greatest in the summer and least in the winter.

Alpine glaciers are found not only, as the name would indicate, in the Alps, but also in Norway, in the Himalayas, among the higher mountains in the western United States, on Mt. Shasta and in fact wherever the snow accumulates in the mountain valleys year after year.

As glaciers creep down the valleys, dirt and rocks fall upon their edges from the upper valley sides and are borne along upon the ice. If two glaciers unite to form a larger one, the débris upon the two sides which come together forms a layer of dirt and rocks along the middle of the larger glacier. At the end of the glacier this material which it has borne along is deposited in irregular piles of rocks and dirt.

The accumulations of débris along the sides are called *lateral moraines*, those in the middle, *medial moraines*, and those at the end, *terminal moraines.* Great bowlders may



THE DANA GLACIER IN THE HIGH SIERRAS.

be carried along on the ice for long distances without the edges being worn, since they are carried bodily and not rolled as in streams.

On the under surface of the glacier, rocks are dragged along firmly frozen into the ice. The weight of the glacier above presses them with tremendous force upon the surface over which the glacier passes. In this way scratches or grooves are made in the bed rock underlying the glacier, as well as upon the bowlders themselves. Scratches of this kind are called *glacial scratches* or *striæ*. They are found abundantly in places that have been glaciated. The rubbing of the rocks upon each other wears them away and grinds them into fine powder called *glacial flour*, which gives a milky color to the streams flowing from glaciers.

THE FIESCH GLACIER.
Notice the medial moraine.

If a glacier extends over a region where the surface has been weathered into soil, this fine material may be shoved along under the ice for great distances. When a glacier melts, all the material which it has moved along under it, as well as that which it has carried on its surface or frozen into it, is deposited, forming what is called *ground moraine*. This is the formation which constitutes the soil of many of our northern states.

The melting of glacial ice, whether by the sun's heat on top, by friction on the bottom or from whatever cause, produces streams which flow in the ice-cut channels under the glacier and emerge in front, laden with rock, glacial flour, and silt. Where the amount of material these streams carry is great, it is usually deposited in an alluvial plain near the end of the glacier.

The length of a glacier does not always remain the same, but increases and decreases slowly in conformity with the amount of snow which falls in successive years. Like rivers, only more slowly, they are subject to the

A Terminal Moraine.

changing conditions of atmospheric precipitation.

Wherever glaciers are easily approached they form a great attraction for the summer tourist. The glistening white snow fields circled by the green foliage of the lower slopes, with the glaciers descending in long, white arms down the valleys, pouring out turbulent, milky-colored streams from their lower ends, and here and there covered with bowlders and long, dark lines of medial moraines, form a picture

A Bowlder borne along on Top of a Glacier.
Notice its size as compared to the umbrella.

which once seen is never forgotten, and the enticement of which lures the traveler again and again to revisit the

A STONE SCRATCHED BY A GLACIER.

fascinating scene. The exhilaration of a climb over the pathless ice with the bright summer sun shining upon it, the bracing air, and the ever changing novelty of the surroundings make a summer among the glaciers almost like a visit to a land of enchantment.

ROCKS POLISHED BY A GLACIER.
The glacier in the background recently extended down over these rocks.

For this reason Switzerland has become the summer playground of Europe and America, and there the tourist crop is the best crop that the natives raise, and the scenery is more productive than the soil. Norway, with the additional beauty of its fiords, is fast becoming another Mecca of the tourist, and this region, denuded and made barren by the ancient glaciers, is now becoming rich and prosperous because of the glacial remnants still left. The high Sierras are each year enticing greater and greater numbers of travelers to enjoy their wonderful beauties and their invigorating climate.

MOUNT HOOD.

A view taken in the fall when the mountain is covered with snow, although the surrounding country is still green.

167. Greenland and the Antarctic Ice Fields.—The whole of the island of Greenland is covered with a deep sheet of ice except a narrow border along a portion of the coast and the part of the island north of 82°, which has little precipitation. The extent of the ice sheet is nearly equal to the area of all the states of the United States east of the Mississippi and north of the Ohio. The depth of the ice is not known, but probably in some places is at least several thousand feet. Although along the coast mountains rising from 5000 to 8000 feet are not uncommon, yet in the interior the thickness of the ice is so great that no peaks rise above it.

The surface of the inland ice is a smooth snow plain. Extending from this ice field are huge glaciers having at their ends a thickness of from 1000 to 2000 feet. One of these has a rate of motion of nearly 100 feet per day in summer, the highest rate ever observed in a glacier. The average movement throughout the year on the border of the ice sheet is probably not more than two inches a day.

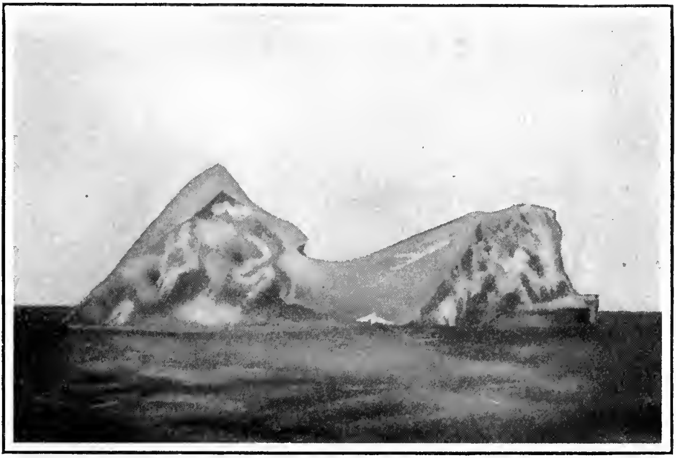
A VIEW OF THE JUNGFRAU.
Showing the snowy mountains and verdant valleys which make Switzerland the delight of the tourist.

In the Antarctic region an area vastly greater than Greenland is covered with ice probably of a greater thickness. Although little is known about this ice cap, it is thought by some explorers to be nearly as large as Europe and to rest partly on an Antarctic continent and partly on the sea bottom.

168. **Icebergs.** — **Experiment 129.** — Fill a beaker so full of ice water that if any more is added it will run over. Put carefully into

the beaker a piece of ice, and catch in another beaker the water which runs out. After all the water which readily overflows has been caught in the second beaker, carefully push the ice into the water till it is entirely submerged, and catch in a third beaker the water which overflows. The experiment must be done with considerable quickness, so that the ice will not melt between the two steps.

The water in the second beaker is equal to the volume of the ice submerged when it floats, and that in the third beaker to the volume



An Iceberg.

of the part out of water when the ice floated. The two together are equal to the whole volume of the ice. Measure in a graduate or weigh on a balance these two volumes of water. (A cubic centimeter of water weighs a gram.) Determine the part of a floating block of ice that is out of water. Would the amount of ice out of water be greater or less if the water were salt? This can be demonstrated by dissolving a considerable quantity of salt in the ice water and very rapidly repeating the experiment.

When a glacier extends out into the sea, the water tends to float the ice. If it extends out into deep enough water, the buoyancy of the water will be sufficient to crack the ice, and the end of the glacier will float off as an iceberg. Glacial ice is about eight ninths under water when it floats.

Icebergs may float for long distances before they melt. In the North Atlantic the steamer routes are changed in the summer months for fear of running into floating bergs. Some of the most appalling disasters of the sea have been due to ships colliding with icebergs. As the berg melts, the rocks and gravel or whatever it

BOWLDERS AND SAND LEFT BY A RETREATING GLACIER.

may have upon it drop into the sea, so that the waste brought down to the sea by the glacier may be spread over the sea bottom far away from the place where it originated. Much of the knowledge of the geology of the Antarctic continent has been gained from the bowlders dredged up at sea.

Although icebergs in the northern seas are sometimes very large, those in the Antarctic region are vastly larger. They have been seen extending above the water 200 or more feet with broad flat tops miles in length. They were indeed huge floating islands of ice.

169. Glacial Formations. — In a region which has been glaciated, peculiar deposits are found which occur nowhere else. Sometimes the end of a glacier remains comparatively stationary over an area for a considerable time, owing to the advance of the ice being just balanced by

A Drumlin.

These low, smooth, rounded hills, like that seen in the background, usually extend north and south.

the melting. In this case, the morainic material which has collected on the top is deposited over the surface, forming irregular heaps of bowlders, gravel and sand, with inclosed hollows between. This material is unstratified and without any uniformity in its arrangement.

When the glacier has retreated, ponds and lakes are formed in the depressions, and streams wander about in the low places between the heaps and receive the overflow of some of the lakes and ponds. Others of these lakes and ponds are so fully inclosed and receive the drainage from so small a surface that not enough water enters to overflow the rim. The arrangement of the streams is unsymmetrical and without order. The whole surface is a hodgepodge of glacially dumped material, a terminal moraine country.

Further back from this morainic dumping ground may be found other kinds of glacially deposited material. If a glacier is pushing along under it a mass of material and it meets some obstruction, or if on account of melting or a decrease in the rate of its flow it has not the power to carry its load, it deposits a part of it. The ice slides over

AN ESKER.

the deposited material and rounds it off, but leaves it as a river leaves its sand bars.

But this material is not stratified, like the material left in water. When the glacier melts away, these rounded deposition heaps are left as hills of greater or less height. Since the material forming them has been continually brought from the direction from which the ice came, they will have their greatest extension in that direction. Such hills have received the name *drumlins*.

Where there are stream channels in the under surface of the ice, the streams may aggrade or fill up their beds as rivers do when overloaded. When the glaciers retreat, ice walls which bordered the channels melt away, and the sand and gravel which the streams had laid down along their beds are left as long, irregular ridges, at the end of which sometimes an alluvial fan or delta may be found. Such long ridges are called *eskers*.

GLACIAL ROCK LAKE.

Where the glacier has little load, as near its source, the bed rock is stripped bare, smoothed, polished, and scratched by the material which the ice has scraped over it and borne away. Where the rock is soft, it is scooped out, and hollows are formed, afterward making lakes ; and where it is hard, rounded ridges are made.

The valleys through which glaciers go are rounded out and left shaped like a V. If side glaciers join the main glacier, they may not be able to wear down their valleys as fast as the main glacier, so the mouths of these V-shaped valleys may be much higher than the bottom of the main valley. These are called *hanging valleys*. (See § 44.)

A V-shaped Valley in Norway.

This has been rounded out by glaciers. The moisture in the atmosphere makes it necessary to hang the hay up to dry, as seen in this picture.

The bowlders which are borne along by the ice are deposited irregularly over the surface in all kinds of positions when the ice melts. Some of them are very large and are left perched high up on the hillsides where no other known force besides moving ice could have carried them. These irregularly distributed perched bowlders are called *erratics*.

170. Glaciated Areas. — Over large areas of what are now the most thickly populated regions of North America and Europe are found widespread formations similar to those described in the preceding paragraphs. The soil throughout is not like that of the underlying rock; it must have been transported. Careful examination of all the surface formations has led geologists to believe that at a former period in the earth's history, perhaps not more than a few thousand years ago, the northern part both of North America and Europe was covered with a thick layer of ice, which after several advances and retreats finally disappeared, leaving the country as we now find it.

A HANGING VALLEY.

Although the border to which the ice extended and many of the changes which the ice made in the surface of the country have been carefully studied and mapped, yet the cause of this extension of the ice and the exact time at which it occurred have not yet been determined. Many theories have been brought forward to account for it, but none of them explains all the facts.

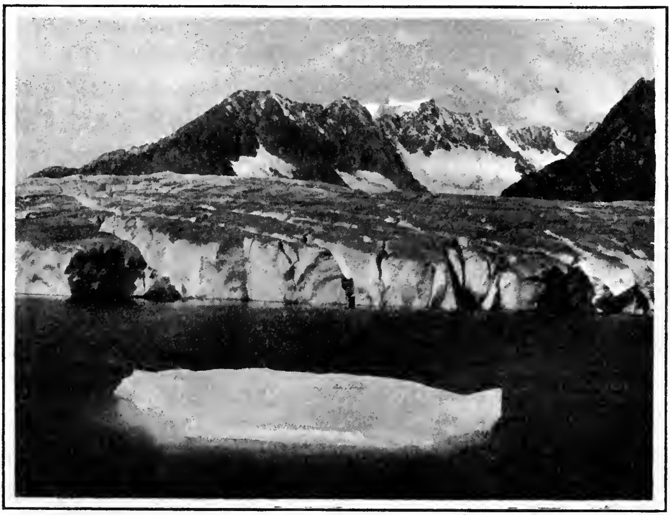
That the ice was here seems to be sure, but exactly when or why is unknown. This period when the ice was of great extent is called the *Glacial Period*. Probably during the earth's history there have been several of these periods, but to the last is due the great changes wrought upon the present surface of the country and upon its plants and animals.

A Huge Perched Bowlder.

171. Glacial Lakes. — In northern countries are found ponds and lakes filling the irregular depressions in the deposit left by the retreating ice. Lakes of another kind are also sometimes formed in glaciated regions. The advancing or retreating ice may happen to make a barrier to the escape of the drainage, and thus may form a lake with an ice dam at one end. The lake will continue to exist only as long as the ice obstructs the drainage.

The Märjelen Lake in Switzerland is a well-known example of this. The Aletsch glacier, the greatest of all the Swiss glaciers, obstructs a lateral valley, forming an ice wall about 150 feet in height, behind which the drainage of the side valley accumulates and forms a lake. Pieces of ice from the glacier fall off into it, forming icebergs which float upon its surface.

Sometimes a crevasse opens in the ice wall, and then the lake quickly drains and floods the valley at the end of the glacier. This formerly caused so much damage that a canal has been constructed across the head of the valley, so that now no great quantity of water can accumulate behind the ice dam. When the lake drains, the bottom is left as a comparatively level, dry plain until the crevasse closes and the lake again forms.



MÄRJELEN LAKE.

Toward the close of the Glacial Period a vast lake of this kind was formed in the northern part of the United States, the region now drained by the Red River of the North. The slope of the land is here toward the north, and as the ice retreated it formed a barrier to the drainage and dammed back a great sheet of water in front of it. When the ice melted, the lake was drained, leaving the flat fertile plain through which the Red River now flows. The ancient glacial lake has received the name of

Lake Agassiz in honor of the great scientist who did so much toward the explanation of glacial phenomena. Glacial lake plains of this kind are found not infrequently. They now form fertile areas of great agricultural value.

172. Waterfalls Due to Glaciation. — As the ice spread over the country it filled the river valleys in many places with débris. When the ice melted away, some rivers could no longer find their old courses and were forced to seek new ones. It frequently happened that in deepening these new channels the river came upon buried ledges, and in wearing these down, rapids and falls were developed. In this way many of the water powers of New England and the northern states were produced.

NIAGARA FALLS.
Due to rearrangement of the drainage by the ice of the Glacial Period.

The Merrimac furnishes a fine example of water power due to glaciation. The great manufacturing cities of Lowell, Lawrence and Haverhill would not exist had not the river been displaced from its previous channel by the glacial ice, and in developing its new valley come upon ledges which it is now trying to reduce to grade. The Niagara is another notable example of vast water power due to the displacement of drainage by the ice. It is probable that in pre-glacial time there was a river which carried off the drainage of the area now drained by the Niagara, but it did not flow where the Niagara now flows.

173. Glacial Period. — Evidences of an ancient ice covering are seen in North America, even as far south as the Ohio River and extending over a vast region which now enjoys a temperate climate. The greatest ice invasion during this period extended from northern Canada across New England into the sea, across the basins of the Great

AREA COVERED BY THE ICE OF THE GLACIAL PERIOD.

Lakes and the upper Mississippi valley and across a part of the Missouri valley. It wrapped in its icy mantle almost the entire region between the Ohio and Missouri rivers and the Atlantic Ocean.

Another great ice invasion spread out from the highlands of Scandinavia. As in later days the Norsemen, so at that time the glacial ice overspread northern Europe, carrying Scandinavian bowlders across the Baltic and what is now the basin of the North Sea, forerunners of the Scandinavian sword which in later ages carried devastation to these regions.

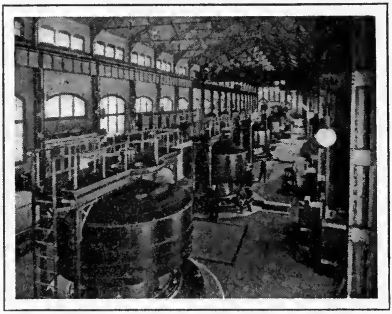
The thickness of the ice over these central areas was very great, probably approaching a mile. The pressure on the ground below must have been tremendous and the scouring and erosive effect vast indeed. The soil which previously covered the surface was swept away and borne toward the ice margin, leaving the rocks smoothed and bare.

Prehistoric man probably saw the great ice mantle; he may even have been driven from his hunting grounds by its slow encroachment. His rude stone implements are found mingled with the glacial gravels. But like the spreading ice he has left no record from which the time or cause of the *Glacial Period* can be determined.

174. Effect of the Glacial Period upon Plants and Animals. — All plants and animals were forced either to migrate before the slowly advancing ice or to suffer extermination. Individual plants, of course, could not move, but as the ice spread toward the south with extreme slowness and with many halts, the plants of colder latitudes found conditions suitable for their growth ever opening toward the south. They were thus induced to spread in that direction, so that at the time of the greatest extension of the ice the plants suitable to a cold climate had penetrated far to the south of their former habitat.

As the ice receded, these cold-loving plants were forced to follow its retreat or to climb the mountains in order to obtain the climate they needed. They did both, so that in areas covered by the ice, plants similar to those of far northern regions are found on the tops of the mountains in middle latitudes. What was true of the plants was true also of the animals. Thus the conditions at the time of the Glacial Period explain some of the most difficult problems in Botany and Zoölogy.

175. **Man and the Glacial Period.** — Although the Glacial Period occurred thousands of years ago, probably before man was widely spread over the earth's surface, yet its influence upon him has been most marked. His manufacturing depends largely for its power upon the falls and rapids due to the rearrangement which the glaciers made in the drainage. Some of the most fertile soil of middle latitudes is due to the pulverized rock left unexhausted by plant life as the glacier retreated. Since the soil was largely brought from the inhospitable northern regions where man cannot easily exist, it has increased the extent of arable land suitable for his cultivation.



ELECTRIC PLANT AT NIAGARA.
Man's use of the power which the glaciers arranged for him.

By the mingling of unweathered yet valuable soil-producing rocks over the surface, the permanence of the soil's fertility has been increased, although the difficulty of tillage is greater. The surface has been beautified by innumerable lakes which furnish man excellent water supplies and restrain the rivers from excessive floods. Glacial lake beds of great productiveness have been formed for his cultivation. Hardy plants from the north have been brought to cover the mountain sides in middle latitudes. In fact, man's whole condition in these latitudes has been modified by the ancient ice invasion.

176. Wind Work. — The wind must be considered among the forces affecting the earth in its relation to man. Whenever the wind blows over dry land, particles of dust and sand are blown away and deposited elsewhere. The interiors of our houses often become covered with dust blown from the dry streets. Even on ships at sea, thousands of miles from land, dust has been collected.

In volcanic eruptions great quantities of dust are thrown into the air and spread broadcast over the earth. On the highest and most remote snow fields particles of this dust have been found. In the great eruption of Krakatoa, dust particles made the complete circuit of the earth, remaining in the air and causing a continuance of red sunsets for months.

Sand is not carried as far as dust, but at times of strong wind it is often borne for long distances. Even houses, trees and stones of considerable size may be lifted and moved by a fierce wind storm. The wind-swept detritus has been known even to obstruct and modify the course of streams. Where the wind blows dust constantly in one direction, deposits of great thickness are sometimes made.

In Kansas and Nebraska there are beds of volcanic dust, reaching in some places to a thickness of more than a score of feet and yet there are no known volcanoes either past or present within hundreds of miles. In China there is a deposit of fine dustlike material, in some places a thousand feet thick, which is thought by some to be wind blown. This forms a very fertile and fine-textured soil and supports a great population. Many of the inhabitants of the region live in caves dug in the steep banks of the streams, so firm and fine textured is the material. Wind deposits of this kind are called *loess beds*.

177. Wind Erosion. — Not only does the wind take up particles of dust and sand and carry them from one place to another, but it uses these particles to cut and erode obstacles in its path. The artificial sand blast is in common use. In it a stream of sand is driven with great velocity upon an object which it is desired to etch. In nature the same kind of etching is done by the wind-blown sand.

TREE BEING DUG UP BY THE WIND.

The glasses in the windows of lighthouses along sandy coasts are sometimes so etched as to lose their transparency. Rocks exposed to the winds are carved and polished; the softer parts are worn away more rapidly than the harder parts, just as in all other forms of erosion. In certain regions where the prevailing winds are in one direction, one side of exposed rocks is found to be polished, while the other sides remain rough.

178. **Wind Burying and Exhuming.** — In exposed sandy regions where there are strong winds, objects which obstruct the movement of the air cause deposition of the transported sand just as obstructions in flowing water cause sediment to be deposited. And just as sand bars may be deposited by a river and then carried away again, owing to a change in the condition of the river's load, so forests and houses in sandy regions are sometimes buried, to be uncovered again perhaps by a change in the load carried by the wind.

179. **Sand Dunes.** — Sand-laden wind generally deposits its burden in mounds and ridges called *sand dunes* (page 302). When once a deposition pile begins, it acts as a

barrier to the wind and thus causes its own further growth. In great deserts where the wind is generally from one direction these sand dunes sometimes grow to a height of several hundred feet, but usually they are not more than 20 or 30 feet high.

They generally have a gentle slope on the windward side and a steep slope on the leeward side. The sand is

A Forest on Cape Cod.
The trees are being engulfed in wind-blown sand.

continually being swept up the windward side over the crest, thus causing the dune to move forward in the direction in which the prevailing wind blows. (Fig. 117.)

Dunes make travel difficult, as both in climbing and descending the traveler sinks into the yielding sand. Almost no plant life can find lodgment in these shifting sand piles, so the wind continually finds loose sand on which to act, and a dune country is always a region of shifting sands. As the dunes move in the direction of the prevailing wind they sometimes invade a fertile country, so that it becomes necessary if possible to find a way to check their movement. This has been done in some places by planting certain kinds of grasses capable of growing in the sand and thus protecting the sand particles from the action of the wind.

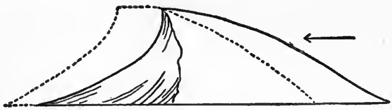


Fig. 117.

Sand dunes are found along almost all low sandy coasts, and they render difficult the building and maintenance of roads and railroads to many beach towns.

Summary. — Besides the sculpturing of waves and rivers, two other agents of erosion are *glaciers* and *winds*. Alpine glaciers are formed by huge masses of ice and snow crowding into mountain valleys where the snow never melts entirely. Glaciers are intersected by great cracks called *crevasses* and they carry accumulations of débris called *moraines*. Icebergs are the ends of glaciers which have broken off.

QUARRYING A SAND DUNE TO MAKE BRICK.

The northern part of America was once covered by a huge glacier at a time which we call the *Glacial Period*. This glaciation has had a great effect upon the region covered. Glaciers smooth out irregularities in the surface, grind rocks, transport soil and bowlders, dam lakes, force rivers to seek new channels and on account of this create waterfalls. Thus the glaciers of the Glacial Period have had a great influence upon the conditions of life.

The *winds* not only blow the clouds about over the land, but they bear dust and sand with which they sculpture and erode rocks and cliffs. They also build up sand dunes and by moving them over the surface of the land sometimes destroy forests and fields.

Questions

How are glaciers formed? Where are they found? What do they do?

How large and how thick is the Greenland icefield?

How are icebergs formed? Why are they dangerous?

Describe the different kinds of deposits and formations due to glaciers.

How are glacial lakes such as Lake Agassiz formed? Why are they fertile when drained?

Some waterfalls are due to glaciation. Why?

What was the extent of the North American ice sheet during the Glacial Period?

What has been the effect of the glacial period upon plants, animals and man?

In what ways has the wind modified the surface of the earth?

How are sand dunes formed? Why are they destructive to plant life?

CHAPTER XII

LOW AREAS OF THE EARTH

180. Level Areas. — At different places on the earth's surface there are broad extents of nearly level land. Here the drainage is often poorly developed, and there are slight depressions often of considerable area. After a rainfall the

A Level, Poorly Drained Area.
Such an area is called *young*.

shallow water stands in these depressions until it evaporates or sinks into the ground. In the parts where the drainage has been developed, the streams flow with slow currents in channels of little depth.

When excavations are made, the rock beneath the soil is often found in horizontal or almost horizontal layers. Where the elevation of these areas is considerable, the streams may have deep gorges and the surface may be well dissected. Where these level areas are low, they are called *plains*, and where high, especially if surrounded by steeply descending sides, they are called *plateaus*. A good example of the low, level area is the plain of northern Russia and of the high area, the Arizona Plateau through which flows the famous Colorado River.

181. Coastal Plains. — **Experiment 130.** — Fill a tall glass jar nearly full of water. Pour into this very slowly a mixture of sand and finely pulverized clay. Note the effect upon the color of the water. Allow the water to stand for several days and then examine the deposition on the bottom of the jar. Are the sand and clay now mixed as they were when poured into the jar? What effect has the water had upon the mixture?

We have already seen that the surface of the earth is not stable, but is subject to movements. If the land bordering a coast rises or the bottom of the ocean is depressed, it causes the water to withdraw from the land, and a strip of what was formerly sea bottom is changed into dry land.

This new area is composed of clays, sands and gravels, often containing shells similar to those found on the neighboring shores. The surface is comparatively flat, but slightly irregular, and the drainage lines have not as yet been established. The water that falls here which neither evaporates nor sinks into the soil runs into the slight depressions and makes shallow lakes. When these become full, the water finds an outlet into a lower region until at last it works its way to the sea.

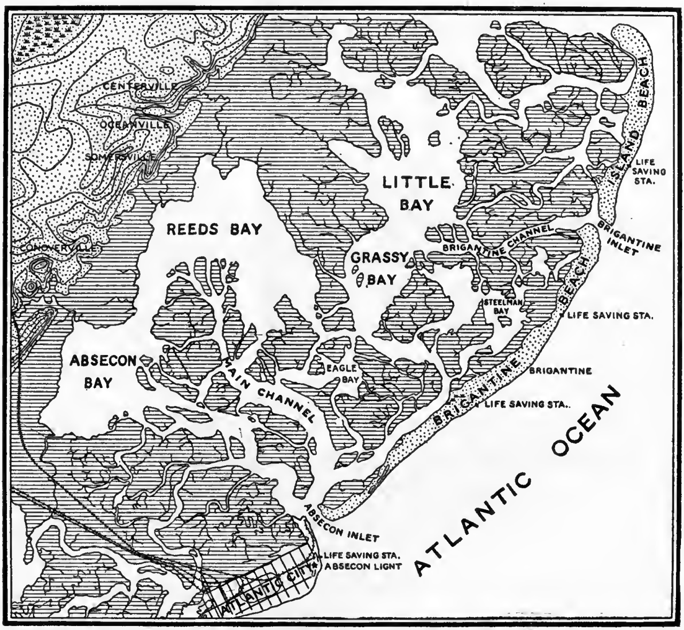
These outlet streams gradually establish themselves and form a continuous line of streams and pools reaching to the sea, with broad, poorly drained areas lying between. The streams at once begin to cut down their beds and the pools to fill up with the silt washed into them, until at last all the pools are drained and a network of streams carries the run-off into the sea.

Usually the dry land of the coastal plain has appeared very gradually, with long periods when there was no gain in its extent. Sometimes the waste brought to the ocean was of a different kind from what it was at other times. Thus the character and condition of the material composing the plain vary considerably, but all the strata are usually inclined slightly toward the sea. The boundaries of the different kinds of hard and soft material composing the plain are approximately parallel to the old shore line. The plain will thus become a *belted plain.*

As streams wear back faster in the soft than in the hard material, the side streams become longer in the soft layers than in the hard, and in time streams of considerable length are found running in a direction nearly parallel to the old coast. These have their outlets through streams which run down from the old land across the plain, so that the general appearance of the drainage is something like a lengthwise cross section through the trunk and limbs of an oak.

When mixtures of different materials are deposited in water, the coarsest sinks first and the finest last (Exp. 130). We should thus expect that of the material brought down by the river the coarser layers would lie back from the coast. This is often true, although there is frequently uncovered near the border of the old land back from the coast a belt of easily eroded material, and a lowland of erosion is formed in this by the streams. The Delaware River from Trenton to Wilmington and the Alabama River between Montgomery and Selma flow through such lowlands. These regions are called *inner lowlands* and possess a fertile, fine-textured soil, generally the best to be found in the coastal plain area.

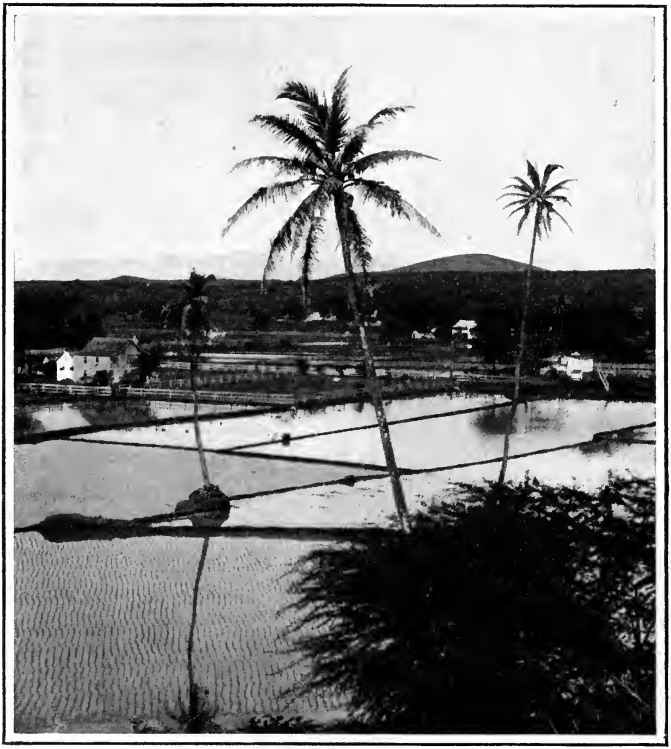
This inner lowland is bordered on the landward side by the old land, usually composed of firmly compacted rocks which often contain valuable minerals and building stones. On the seaward side it is bordered by the rather abruptly ascending edge of the coarse material of the plain which has not yet been removed. From the top of this ridge there is a gradual slope toward the sea. As the region back toward the old land is higher, and has been above the sea



THE COAST NEAR ATLANTIC CITY.
Showing marshes, lagoons and sand reefs.

and exposed to erosion longer, it is much more dissected than the surface nearer the sea and is much more irregular and hilly.

A *coastal plain* is a gradually emerged sea bottom, and so has shallow water extending out for a considerable distance from its edge. Along the shore are marshes and lagoons bordered on their seaward side by sand reefs, where the winds have piled up the sand brought in by waves. In some places these sand reefs are so situated that they are valuable for habitation, as at Atlantic City,



RICE SWAMP AT THE BORDER OF A NARROW COASTAL PLAIN.

New Jersey, where a large summer resort has grown up, or along the coast farther south, where a sparse population finds its home on the broader reef.

A coastal plain increasing in width toward the south extends from New York to the Gulf. The western coast of Europe has a considerable plain of this kind. The Netherlands are situated on land which has been either reclaimed from the sea naturally in recent geological time or artificially by man in recent historical time. In the southern part this reclamation is largely due to the sediment brought down by the Rhine.

Sometimes the materials of a coastal plain are found far inland in places which are now separated from the sea by mountain ranges, as near Lake Ontario. But the method of formation was the same, only thousands upon thousands of years have passed since these rocks were exposed, and vast geological changes have taken place in that time. Such areas as these are sometimes called *ancient coastal plains.*

In the western part of the United States the coastal plain is not as well developed as on the Atlantic border. But the region about Los Angeles is a coastal plain, and almost all the characteristics of the broad eastern plain can be seen in traveling from the ocean to the coast mountains.

CRUDE TURPENTINE STILL.
In the pine belt of the North Carolina coastal plain.

182. Industries on Coastal Plains. — The valuable minerals of the earth are usually found in the older rocks, so there is no mining on a coastal plain, and because the rivers are shallow and fall over no ledges as they flow across these plains, no great water power for manufacturing can be developed. The sluggish streams are often dammed and small water powers developed, but there is not the fall necessary for large factories, except sometimes in the hilly region back near the old land where the rivers have developed rather deep and narrow valleys, and mill ponds of considerable size may be made.

As the different kinds of soil lie in belts, agriculture will vary with the belts. In warm climates rice can be raised along the shore where the land is marshy. On the sandy land most profitable truck farming is possible if the transportation facilities are good. In many places in the southern states these sandy areas support fine forests of pine (page 198) which are most valuable for the production of turpentine, tar and lumber. Where the soil is not too sandy, cotton is raised in abundance. The materials for making glass, pottery and brick are widespread over coastal plains.

COTTON.
A most valuable product of the southern coastal plain.

The cities on coastal plains are usually found either (1) near the coast, where the rivers have formed harbors and so have made ocean commerce possible, or (2) at the head of navigation in the rivers where water transportation begins, or (3) still farther up the river at the fall line, where manufacturing on a large scale is possible.

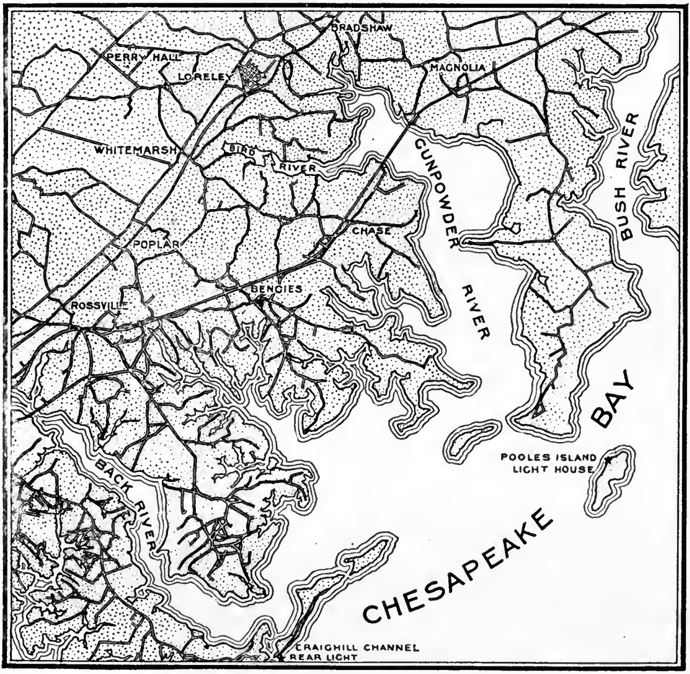
The *fall line* is the point on a river where its bed passes from the harder rock of the old land to the softer material of the coastal plain. The softer material is worn away more easily than the hard material, and falls or rapids are produced suitable for water power. A glance at a map of the southeastern United States will show that the princi-

PINEAPPLES.
A valuable crop of the southern coastal plain.

pal cities lie in lines nearly parallel to the coast. Of those near the coast are Norfolk, Wilmington, Charleston, Savannah, Jacksonville; at the fall line, Trenton, Philadelphia, Richmond, Columbia and Augusta.

Coastal plains furnish a most suitable place for the boring of artesian wells. As the strata are diversified in structure and all dip gently toward the sea, porous strata inclosed above and below by impervious strata are readily found. When the upper of these are tapped, water is forced by hydraulic pressure to a height nearly equal to the highest point reached by the upper stratum. Much of the drinking water on coastal plains is obtained in this way.

183. Embayed Plains. — If a coastal plain is submerged after it has been somewhat eroded, the water backs up into the stream valleys and forms *reëntrant bays.* The little side streams which enter into the main streams near



A SUBMERGED COASTAL PLAIN.

the coast no longer flow into these streams but into the bays. If the country is somewhat thoroughly dissected near the coast, there will be many small bays. The interstream areas will project out like long fingers with water between them.

The effect of a submerged and eroded coastal plain is seen in the Delaware and Chesapeake bay region. Here the old river courses have been submerged, and the land between the rivers extends into the ocean in narrow, rather flat strips with many little inlets along the sides. Easy water communication is here possible to a considerable distance inland and to almost every part of the land surface near the coast.

When the country was first settled, these water courses were most advantageous to the settlers, as the produce of the farms could be transported to sea-going ships with comparatively little difficulty, much more easily than would have been the case if it had been necessary to carry it by land. There was little need of building roads, as each farmer had a protected water highway to his door. Thus a part of this region was known as "Tide-water Virginia."

184. Lake Plains. — Lakes which receive the drainage from the land gradually have their floors smoothed over by the sediment which the streams bring to them and the waves and currents spread out. The lake itself is thus filled, or in time the outlet wears back so as to drain the lake. Thus a plain is left, the elevation of which is determined by the elevation of the old lake bed.

During the Glacial Period lakes were held in at some places by huge dams of ice and at other places by accumulations of sand or gravel brought down by the glaciers and deposited so as to obstruct the valleys. The ice has now disappeared and the gravelly material has often been easily eroded, so that lake plains are not uncommon in the northern United States. As the soil of these plains is fine and easily cultivated, they furnish excellent farm lands.

As already stated, a plain of this kind, remarkable for its fertility and extent, is drained by the Red River of the North and comprises the eastern part of North Dakota and about half of the Province of Manitoba. A somewhat similar plain is found in northern New York, bordering Lake Ontario. This was formed at the time when the outlet of the lake was the Mohawk River, the present outlet then being obstructed by ice. The ice dam has since

LAKE PLAIN.

The ice dam in this lake has recently receded.

melted, the lake has been lowered, and a part of its old bed has been exposed.

A change in the amount of rainfall may cause the formation of a lake plain. If not as much water is furnished to the lake as evaporates, the lake dries up and exposes its bed as a flat plain with perhaps a small remnant of the former lake still existing at the lowest part. Such is the region around Great Salt Lake, Utah.

185. River Plains. — Sometimes a river widens its valley enough so that it swings slowly from one side to the other, and, at high water, floods the valley for a considerable distance on either side of its course. A low, flat plain is thus developed, sometimes terminating near the mouth of the river in a delta.

These plains are very fertile and are usually called "bottom lands" by the farmers. They are often unhealthy because of floods and poor drainage. Where the water in the river rises rapidly and to a considerable height, it is dangerous to inhabit these plains. Thus it is necessary to build strong levees along the river bank, as in the case of the lower Mississippi and some of its tributaries. But

"Bottom Lands."

sometimes these plains are so fertile that they are densely populated, as the plain of the Ganges.

186. Prairies of the United States. — North of the Ohio River and extending westward beyond the Mississippi is a region of rolling land with a deep, rich soil. Early in the last century it began to be rapidly populated on account of its great agricultural advantages. Owing partly to the fineness of the soil, but mostly to the frequent burning over of the region by the Indians, the area was destitute of trees except in some places along the river courses.

Thus the emigrant did not need to go to the trouble and delay of clearing the forests before beginning to farm. Cultivation could begin in earnest with the first spring, and, as a rule, rich harvests could be obtained. The soil here is transported soil; it is deep and unlike that of the underlying rock. In some places it is rather stony and in others very fine and without stones. It is so deep that the underlying rock is only seen in deep cuts.

This soil was probably deposited by the great continental glaciers which once covered the region and was

ALFALFA CUTTING ON THE FERTILE PRAIRIES.

spread out either by the action of the slowly moving ice or by the water from the melting ice. This water flowed over the surface in shallow débris-laden streams, bearing their silt into the still waters of transient ice-dammed lakes. Whatever the original surface of the region, at present it is an irregularly filled plain due to the ancient ice sheet. As the soil is composed of pulverized rock not previously exhausted by vegetable growth it is strong and enduring, so that this country has, since its settlement, been noted for its productivity.

187. The Great Plains of the United States. — West of the Mississippi River, and merging almost imperceptibly into the prairie region on the north and the coastal plain region on the south, there is a broad extent of territory usually called the *Great Plains.* This region consists of irregular intrenched valleys 50 to 100 feet deep. Sometimes there are hills and mountains, but viewed from an eminence the country appears flat.

The elevations are either flat topped hills, the strata of which are slightly inclined and correspond in position to those found in the plain beneath, or they are masses of igneous material which appear to have been thrust up through the rock surrounding them. In the former case the elevations are simply remnants of the layers of rocks which once extended over the country, but which have now been eroded away over the larger part of it; in the latter case they are the igneous masses which have withstood erosion. The Great Plains may thus be considered as an example of a plain of erosion.

A HIGH, DRY PLAIN.

Here, as in the prairie region, trees are wanting, but their absence is due rather to the lack of the necessary rainfall than to the reasons assigned for the former region. Although formerly considered almost a desert on account of its small rainfall, this region now supports vast herds of cattle, and by the aid of irrigation will soon possess great agricultural wealth.

188. Life on Plains. — The life conditions on plains are very different from those in places where the irregularities of the surface are great. The climate of plains is quite uniform and depends to a large extent upon their position on the earth's surface. Movement is as easy in one direction as in another, and the lines of travel tend to be

A Herd of Cattle on the Great Plains.

straight. There is usually no reason for an accumulation of population in any one place, so the population tends to be uniformly distributed.

As movement from place to place is easy, it is not difficult for the inhabitants of a plain to mass themselves together at one point. In case of invasion by a superior enemy there is no place for hiding or safe retreat, and subjection or extermination are the alternatives, unless the plain is so large that the enemy is unable to spread over it. In the case of animals this has been shown in the practical extermination of the American bison and antelope. In the case of men it was shown on the plains of Russia in the thirteenth century when the Tartars conquered the region and threatened to overrun Europe.

Another instance was that of the fatal invasion of Russia by Napoleon. The Russians, unable to find a strategic place to make a stand, retreated farther and farther into the plain. The depletion of Napoleon's army, due to the extent of territory which must be held in his rear, the distance from his base of supplies and the rigor of the Russian winter, forced him to begin that disastrous

HERD OF BISON.

retreat, the fatal results of which probably led to his final overthrow.

The effect of plains on the distribution of population is shown in the early settlements on the coastal plain territory south of Philadelphia. Here there were almost no towns containing as many as twenty houses until the colonies had been settled for nearly two hundred years, and even now cities of considerable size are rare, but on the more rugged lands of the north the tendency to build towns began at the beginning of settlement.

189. Plains in History. — Plains have always played an important part in history. Here armies can march and countermarch with comparative ease. Large bodies of men can easily be assembled. Military stores can be readily collected and all the operations of war carried on without natural obstructions. Thus it happens that certain plains have been the seats of almost innumerable wars. The great plain of the Tigris and Euphrates was the gathering ground and battlefield of vast ancient monarchies. The plains of the Po have been the arena in which embattled Europe has settled some of its deadliest strifes, while the level lands of Belgium have been dyed again and again with the blood of thousands and thousands of Europe's bravest sons.

Part of the Plain of Waterloo, Belgium.

Summary. — Level areas are called *plains* when low, *plateaus* when high. When a coast has been elevated and part of the continental shelf becomes exposed, this is called a *coastal plain*, as the east coast of the United States from New York to the Gulf of Mexico.

Coastal plains have little mining and manufacturing; their agricultural products vary. Their large cities lie either at tide water or at the *fall line* of the rivers. The best drinking water on coastal plains usually comes from artesian wells.

Besides coastal plains there are *lake plains*, like those of northern New York and eastern North Dakota, and river plains, of which the Mississippi is the best example. The *prairies* have a dry, rich, treeless, fertile soil, a result of ancient glaciation. The *great plains* of the United States have an irregular surface usually barren of trees.

Questions

How does the drainage of a coastal plain develop?

What kind of a shore line will a coastal plain have?

What are the usual industries of a coastal plain?

Where are the largest cities on a coastal plain situated?

Describe the kind of coast line that results from the depression of a dissected coastal plain.

In what way are lake plains formed?

How are river plains formed?

What natural conditions made its possible for the pioneer settlers to become quickly prosperous on the prairies?

How have plains affected the welfare of their inhabitants?

How have plains influenced history?

CHAPTER XIII

THE HIGH AREAS OF THE EARTH

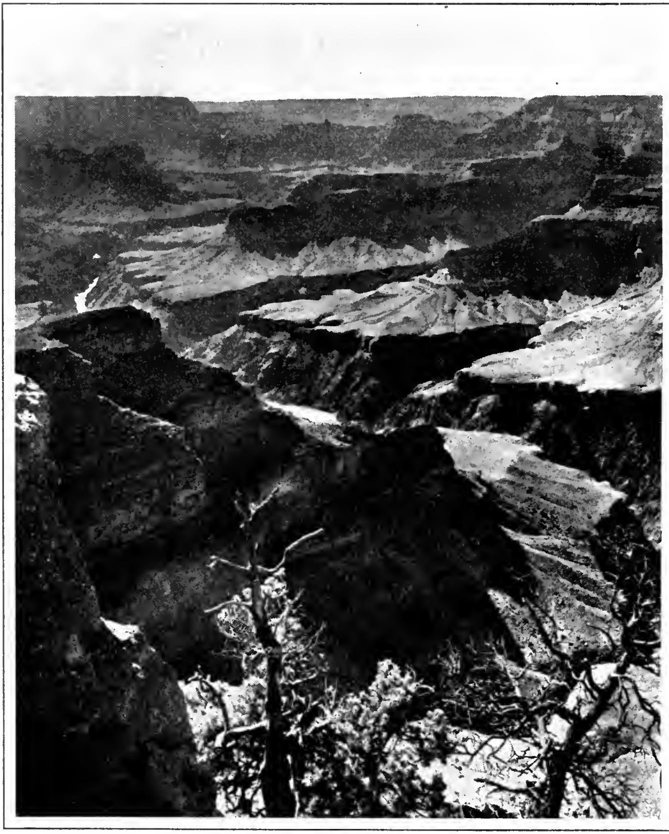
190. Young Plateaus. — Sometimes large areas of horizontal rock are elevated high above the sea, forming lofty plains whose surfaces are often irregular, owing to previous erosion. Such areas are called *plateaus*. The descent from a plateau to the lower land is usually steep. Areas of this kind, where streams are present, suffer rapid and deep erosion, since the grades of the streams are steep because of the elevation.

If there is not much rain there will be few streams, and these will have deep and steep-sided troughs. Such troughs render the area very difficult to cross. The valleys are too narrow for habitation or for building roads, and the deep troughs of the streams are too wide to bridge. Thus the uplands are isolated.

If these high areas are in a warm latitude, they are desirable for habitation on account of their cool climate, due to the elevation; but if in temperate latitudes, their bleak surfaces are too cold.

As the river troughs wear back, the harder rocks stand out like huge benches winding along the course of the rivers. From the different benches slopes formed from the crumbling of the softer strata slant backward. Thus the general outline of the stream sides will be something like that of a flight of stairs upon which a carpet has been loosely laid.

An excellent example of a region of this kind which has been eroded by a strong river gaining its water from a distant region is that of the Colorado Cañon Plateau. Here is found the grandest example of erosion on the face



COLORADO PLATEAU.
The river has cut a deep cañon through the plateau.

of the earth. The rocks are of various colors, and the gorge is nearly a mile deep and in places some fifteen miles in width. Words are inadequate to express the grandeur of the panorama spread out before one who is permitted to see this gigantic exhibition of the results of erosion. Wonderful, grand, sublime, are mere sounds which lose themselves in the ears of one who looks out upon this overpowering display of Nature's handiwork.

The region is very dry, and the river receives few and short branches for many miles of its course. The valley is widening much more slowly than it would if this were a land of considerable rainfall, and as yet the river fills the entire bottom of the gorge. The valley is in the early stages of its development and has just begun the vast work of wearing down the region. The side streams are small and the interstream spaces broad.

191. **Dissected Plateaus.**—If a plateau has been elevated for considerable time in a region of abundant rainfall, the streams extend their courses in networks, thoroughly dissecting the area and leaving between their courses only narrow remnants of the upland. The valleys are still deep, but the intervening uplands are of small extent. Traveling over the region in any direction except along the stream courses is a continual process of climbing out of and into valleys.

There is very little level space that can be used for cultivation, and on account of the steepness of the slopes it is very hard to build roads. The river valleys are so narrow that unless the roads are perched high up on the sides, they are liable to be swept away at the time of flood. Farming in these regions is very discouraging because of the difficulty of transporting crops and of finding anything but a steep side hill on which to grow them.

Railroads can get through only by following the principal valleys, and here, on account of the narrowness, the engineering of the roads is difficult. Unless the region is rich in minerals, it can support only a small population,

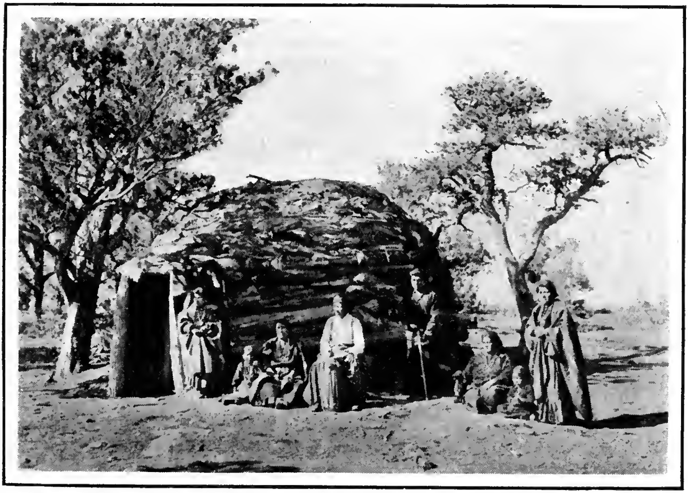
THE ENCHANTED MESA.
With old Indian village in the foreground.

and that will of necessity be poor. As soon as the forests are cut off, the soil rapidly washes down the hillsides and leaves naught but bare surfaces. Regions of this kind

A BUTTE.

are found in the Allegheny and Cumberland plateaus, extending from New York to Alabama.

192. Old Plateaus. — If a plateau remains elevated for a great length of time, the dissecting rivers are able to widen their valleys and wear away all the interstream spaces, except where these are very broad. Thus the rivers bring

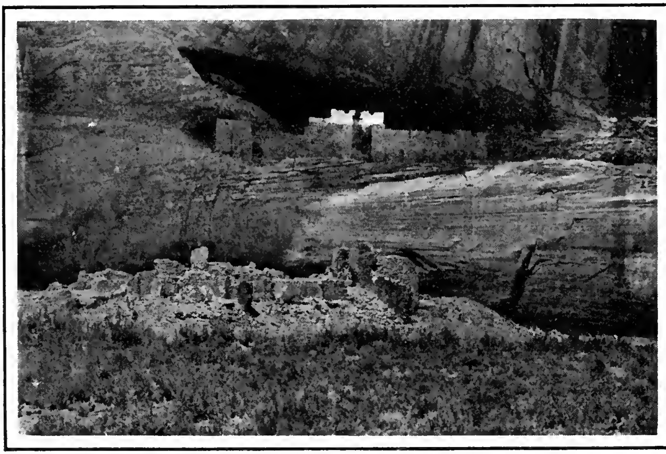


AN INDIAN HOGAN.

the surface down to a comparatively low level, with here and there a remnant which has not been worn away, but which shows in its steep sides the edges of the rock layers which formerly spread over the whole region. If these residual masses are large, they are called by the Spanish name *mesas*, meaning tables, and if small, *buttes*, from the French word which means *landmarks*.

Some of these mesas are so high and so steep that it is impossible to climb them, and others are simply low, flat-topped hills. A traveler in New Mexico and Arizona will see many of these mesas, which, like the lonely Indian huts or *hogans*, are but scattered remnants of what was formerly widespread.

On old plateaus travel is easy. There are no deep valleys, and one can easily pass around the mesas, which only add charm to what would otherwise be a most monotonous landscape. When these mesas are high, they are sometimes occupied by a few Indian tribes who have fled to

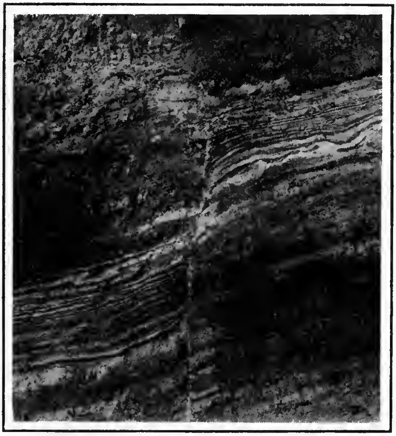


CLIFF DWELLINGS.
A protected retreat in a mesa.

them for protection, as the medieval barons when hard pressed fled to their isolated castles.

193. Broken Plateaus. — The force which has uplifted the plateaus is not always uniform enough in its action to lift large areas without fracturing the rock layers. Thus plateaus are found which have the rock layers broken and displaced. The layers on one side of the break may stand thousands of feet higher than those on the other side.

This is seen in the region of the Grand Cañon of the Colorado, where the Kaibab Plateau stands about 2000 feet above the Colorado Plateau and steep cliffs bound it on both its east and west sides. These *fault cliffs*, as they are called, are found at several other places in this region, showing that the whole area was much broken when it was uplifted. The Kaibab Plateau itself is so much higher than the plateaus on either side that it intercepts sufficient rainfall to support forests, whereas the plateaus about it are almost barren of trees.



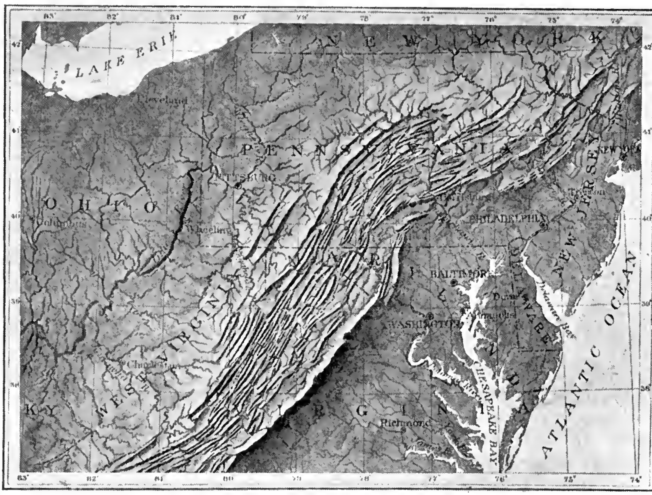
A FAULT.

In the walls of the Colorado Cañon some of these great breakage lines can be traced and the same strata seen to be thousands of feet higher on one side of the line than on the other. In front of these breakage cliffs or fault cliffs, accumulations of débris extend along the entire distance, showing that since the uplift there has been time for much erosion even in this dry region. The Colorado River passes over these great faults regardless of their existence. The cañons in the region seem not to have been influenced by the faulting. Probably it took place too slowly.

194. **Hills and Mountains.** — Irregular elevations of the earth's surface are called *hills*, or *mountains* when they are of considerable height. In the general use of these terms there is no exact line of separation. Elevations which in mountain regions would be called hills would in a flat region be called mountains. As a rule, elevations are not termed *mountains* unless they are at least 2000 feet high. But if

the general elevation of the country is great, as in the lofty regions of the Rockies, an elevation to be termed a *mountain* must rise to a striking height above the generally elevated surface, which is itself nearly everywhere more than 4000 feet above the sea.

195. Structure of Mountains. — Mountains are the results of deformations in the earth's crust, due to causes not fully understood and the study of which is a part of geology.



APPALACHIAN PLATEAU.
A range of old mountains greatly reduced in height.

The crust of the earth has been folded, pushed up, crumpled and in many ways distorted so that some portions have been elevated to a considerable height above sea level. Where these elevated portions have not remained long enough to be worn down, they form mountains.

All lofty mountains have been elevated in comparatively recent geological time, but this of course means millions of years ago. If mountains now lofty were geologically old, they would long ago have been worn down. The older mountains of the earth are all comparatively low, not because they were never elevated as high as the lofty mountains of to-day, but because their greater age has longer subjected them to erosion and thus reduced their height.

It is difficult to classify the different kinds of mountains, for very few of them are simple in their structure, but certain kinds of mountain forms are easily distinguished.

196. Block Mountains. — **Experiment 131.** — Take three pieces of smooth, straight-edged boards, two of which are about 15 × 55 cm. on a side and the other 8 × 55. Place these flat on a table with the smaller board in the middle and the longer edges close together. Sift corn meal, fine coal dust, powdered pumice, plaster of Paris and fine sawdust in even layers over the boards. Now lift carefully the inner edge of one of the wider boards and slip under it a narrow strip of wood 1 or 2 cm. thick. The layers of material spread over the boards will be broken and slant back from the line of breakage with their edges exposed along this line. Do the same with the wide board on the other side. The conditions shown will be similar to those exhibited in block mountains.

In southern Oregon and extending southward are found long, narrow mountain ridges, having a steep cliff on one side and a gentle slope on the other. Between these ridges are flat, troughlike depressions in which small lakes are sometimes found. The ridges are formed of thick layers of rock inclined at the same angle as the long slope of the ridge. The short slope of the ridge exposes the edges of these layers which have been broken across.

The débris slopes at the foot of the steep cliffs in some cases are slightly broken across in a direction parallel to the cliff. The steep cliffs sometimes face each other with a somewhat flat depression between, and sometimes the cliff on one ridge faces the long slope of the next. Some of the ridges are more gullied than others, showing longer exposure to erosion.

These ridges are due to strains which have broken the rock layers and elevated those on one side of the fracture above those on the other side, so that a steep fracture cliff has been formed with the rock layers slanting backward from its elevated edge. (Fig. 118.) Mountains of this kind are called *block mountains*. As is seen from the fracturing of the débris slopes, the movement of elevation is not yet completed.

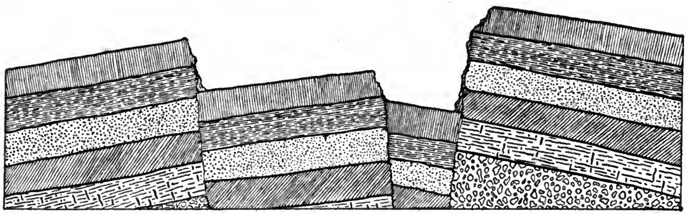


Fig. 118.

As some of the ridges are more gullied than others, it appears that the fracturing did not take place all at one time, but that the more gullied ridges were formed first. Earthquakes are not uncommon in this region. These are caused by a small slipping along the fault line.

In Oregon these ridges are little eroded. They are simple in structure and young in age. The longer streams flow down the gentle slopes parallel to the surface of the rock layers and the shorter streams along the steeper slopes across the edges of the layers.

197. Folded Mountains. — Experiment 132. — To the long edge of a piece of board about 10 cm. wide and 20 cm. long tack securely one of the shorter edges of a piece of rather thick rubber dam about 20 × 25 cm. Tack the opposite edge to a strip of board about 2 cm. wide and 20 cm. long. Place the rubber dam thus arranged on a smooth table and secure the wide board firmly to the table by a clamp or nail.

Taking hold of the strip, stretch the rubber dam as much as it will readily stand. Fasten the strip so as to hold the rubber dam in this stretched position.

Sift fine sawdust, plaster of Paris, fine coal dust, ground pumice, corn meal, or any other distinctly colored substances in even layers over the stretched rubber dam. Slightly dampen the layers. Releasing the strip, allow the rubber dam to contract very slowly. When it has fully contracted, cut carefully through the layers of material with a thin knife and remove that which is on one side of the cut. The layers will have been folded into irregular undulating folds, thus simulating *folded mountains*.

Where layers of rock are subjected to slow, uniform and tremendous lateral pressure, they may form undulat-

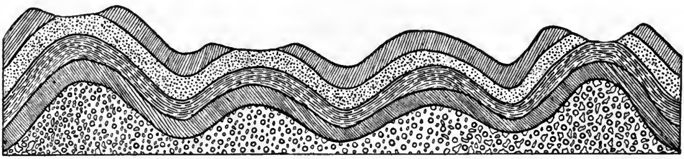


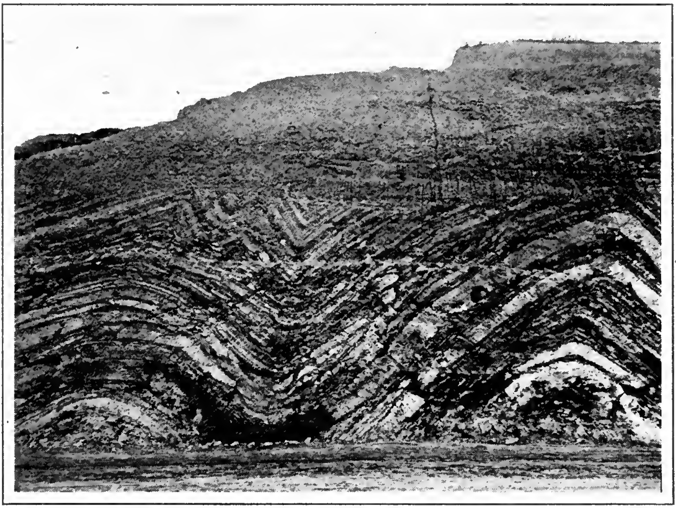
Fig. 119.

ing folds with little fracturing. (Fig. 119.) The contracting of the interior of the earth, due to cooling, has sometimes brought to bear such pressure, and in a few cases undulating folds have been produced.

The best example of this folding is that of the Jura Mountains, between Switzerland and France. Here the almost regular folding of the strata can be seen wherever the streams have cut across the mountains. The mountains are so young that there has been little carving by erosion and the downfolds still form the valleys and the upfolds the ridges.

The rock layers composing these folds contain marine fossils, showing that they were once horizontal and must have been formed in the sea. The longer streams run down the troughs of the folds, but in some places, often where the folds are least high, streams cut across them and pass from one trough to another. Along these transverse stream courses are usually built the roads that cross the ridges.

Sometimes the tops of the ridges have been sufficiently worn away or are broad enough to form considerable flat areas, where little villages are situated. But most of the population is found along the longitudinal valleys, especially where there are cross valleys. Some of the cross streams seem to have no connection with sags in the folds, but appear to have cut their valleys through the folds as fast as they rose, thus indicating that the rate of folding was slow.



FOLDED STRATA.

198. Massive Mountains. — The mountains already studied are all comparatively low. Probably none of them rises to a height exceeding 6000 feet. They are simple in form and outline, and although pleasing features in the landscape, are a bit monotonous. *Massive mountains*, on the contrary, are varied in form, lofty in height and are among the grandest and most inspiring of Nature's marvels.

In all ages mountains have been an inspiration to man's nobler thoughts and higher aspirations. With their heads piercing the azure vault of heaven and towering with

MASSIVE MOUNTAINS.
The high Sierras.

gigantic mass above the lower world, they force man to look up, and in the contemplation of their nobility to forget his meaner self. Like everything else which holds enduring admiration, these are the result of strain and stress and never ceasing battle with the forces of destruction.

The structure of massive mountains is complex in the extreme. Rock layers are often folded, twisted and contorted (Fig. 120) beyond all recognition of their initial condition. Their uplift has been no simple process, each age has added its peculiar impulse to their growth. As the forces of elevation have been lifting them up, those of degradation have been cutting them down. Their broad brows have been carved into peaks and pinnacles, and gorges and caverns have been cut into their flanks.

The different rock masses which enter into their structure have each assumed its own peculiar lineaments under the carving of the wind, rain, streams, avalanches and glaciers, and thus the variegated beauty of the whole mass has been produced. The central part of massive mountains is composed of igneous rocks, but on the sides over-

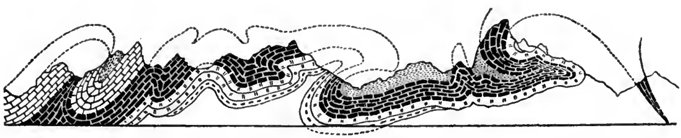


Fig. 120.

lying these, sedimentary rocks are found. The Rockies, the Alps and the Himalaya Mountains are of this kind.

199. Mountains that no longer Exist. — The mountains which are now such prominent features of the earth's surface are neither all the same age nor are they the only representatives of this kind of land forms that have ever existed. All the kinds of mountains thus far considered are young in geological age, although some are older than others.

All parts of the earth's surface are being gradually worn down by the action of water, but the higher portions are worn more rapidly than those lower, as here the forces of denudation act more intensely. Thus if mountains stop growing, they decrease in height until finally they are too small to be called mountains. Their rocks will be crumpled and folded, and all the characteristics of mountain form will be present except the elevation.

The slant of the rock layers may be such as to indicate a great elevation in former times, but now only the roots of the mountains are left and the region is of very moderate elevation. Regions of this kind are found in many parts of the earth.

In the Appalachian highlands of Pennsylvania the rocks show that they were once folded into ridges and troughs something like those of the Jura. But now the arches have been worn away, and the existing ridges are due to the resistance which the harder layers offer to erosion. These ridges are as likely to occur where formerly the troughs of the folds were as in what were the crests.

BEN NEVIS.
A mountain much worn down but still high.

The configuration of the country is not at all as it was when the rocks were folded. The elevation then was much greater than the highest ridges at present. If the beds should be reconstructed as they now lie, they would indicate a height much greater than the mountains ever had at any time. This indicates that these mountains have been lifted up and worn down more than once.

Another region in which the mountains have been reduced to inconspicuous heights is the Laurentian Plateau, the area around Hudson Bay. These mountains were very ancient and were worn down long, long ago. In some regions like southern New England, as the mountain structure has been worn down, it has left here and there a residual height like Mt. Monadnock which has not been fully reduced.

Although the general features of such a country are those of hills and valleys and it has little of the appearance of a plain as one passes over it, yet it will be found that the uplands have a general uniformity of elevation. Such an area is called a *peneplain*. The residual mountains

THE MATTERHORN.

which rise above the general level of the country and of which Monadnock is a sample have been named *monadnocks*. This is simply a name for a mountain left above a region which has been cut down by erosion to an irregular plain.

200. Mountain Peaks. — In mountain regions the features which are often most impressive are the serrated peaks which rise above the main mass of the mountains. The shapes of these peaks vary greatly in different mountain regions and tend to give individuality to the mountains.

The peaks have been formed by erosion, and their peculiarities are due to the different kinds and positions of the rocks from which they have been carved.

The younger mountains which have not been subjected to erosion for a long time do not show the peak and ridge structure. Their personal characteristics have not had time enough yet to assert themselves. All these peaks are the result, not only of original uplift, but of subsequent carving.

THE TETON RANGE.

201. Mountain Ranges. — As a rule mountains are found in *ranges*. The mountains in the range are by no means all the same elevation, nor is the range necessarily continuous, there being often gaps along its course. Neither were all ranges in a mountain region elevated at the same time. Those which make up the mountain region of the western United States differ much in the time of their elevation.

202. Earthquakes. — In mountain regions which are young or still growing, earthquakes are not uncommon. These are due to breaks or slips of a few inches or a few feet in the rock structure. From the place at which the break or slip takes place the motion is transmitted through the rock mass to the surface, where it causes sudden and often tremendous shocks. These slippings may occur occasionally for ages along the same fault line. Sometimes they are intense enough to cause great damage; at other times only a slight tremor is felt.

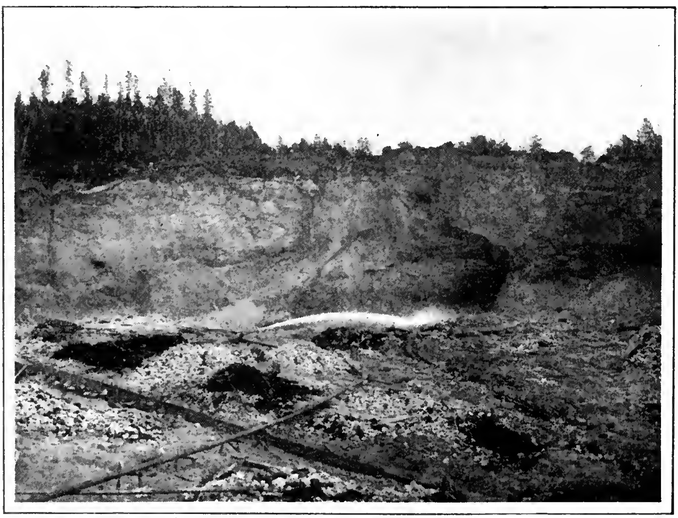
Fault Line of an Earthquake.

The rapidity of the transmission of the shock differs with the kind of material through which it is transmitted, varying from a few hundred feet to several thousand feet per second. The nearer a place is to the break or slip the greater is the intensity of the shock. Sometimes the crack or fault along which the movement occurs reaches to the surface and makes the displacement apparent.

Fence Broken by Slipping of the Earth along a Fault Line.

If an earthquake originates under the sea, a great wave may be developed which rushes inland from the coast, causing great destruction. One of the most fearful of these waves occurred at Lisbon, Portugal, in

THE RESULT OF AN EARTHQUAKE.



PLACER MINING IN THE SIERRAS.
The sand is washed from the gold by huge streams of water.

1755, sweeping away thousands of people who had rushed into an open part of the city to get away from the falling buildings caused by the earthquake shock.

Sometimes earthquakes are followed by terrible fires which cannot be extinguished on account of the disarrangement of the water supply. This was the case in the San Francisco earthquake.

203. Products of Mountain Regions. — When rocks are folded and crushed, in forming mountains, heat is generated, and heated water under pressure acts upon the components of the rocks and dissolves some of their minerals, which accumulate in cracks and crevices called *veins*. When the overlying beds have been worn away, these mineral veins, formed deep below the surface, are exposed and can be mined. Mountains are therefore the great mining regions.

Deep Down in the Calumet and Hecla Mine.
The world's greatest copper mine.

In this country mining is a most important industry in the Sierra Nevada Mountains and in the Appalachian region. In one are found great quantities of copper, silver and gold, and in the other iron and coal. In the old Laurentian Mountain region, near the Great Lakes, much copper is found. The Alps and the Pyrenees are among those mountains that have few minerals.

If mountains are not too high, they are also regions of forests and furnish great quantities of lumber. The surface is so rough that agriculture is not easily carried on, but they have great areas of pasture which often support large herds of cattle, sheep, and goats.

204. Effect of Mountains on Climate. — All over the world where people have the money and the leisure they are accustomed to go either to the mountains or the seashore

TOP OF PIKE'S PEAK IN SUMMER.
Notice the snow and the rocks broken up by the freezing water.

in summer in order to get where it is cooler. They might for the same purpose travel northward in the northern hemisphere, but they would need to go many times as far to get the same fall of temperature.

In summer one must ascend a mountain on an average about 300 feet vertically to get a mean fall of 1° F., whereas one must travel over 60 miles north to get the same change. In winter one must ascend farther on the mountain and travel not so far north, to get a change of a degree. As one ascends a mountain it grows colder and colder. In ascending a high mountain in the tropics one passes through all the changes in climate which one would pass in going from the equator toward the poles.

As already stated, high mountains also affect the climate of the country near them. The windward side of mountains is moist, since the moisture in the air is condensed in rising over them. On the lee side the country is dry, as the air which moves over it has already been deprived of its moisture.

POPOCATEPETL.
A snow-covered mountain in the tropics.

The country on the lee side will also be subject to hot, dry winds like the chinook winds of the eastern Rockies and the foehn in Switzerland. As the moist winds pass over the mountains their moisture is condensed. This raises their temperature so that it is above what it would normally be at the altitude reached. As they come down on the lee side of the mountain, the air is compressed and thus heated so that on this side it is considerably warmer at the same altitude than on the windward side. Thus high mountains affect not only the rainfall, but the temperature changes of the region round about.

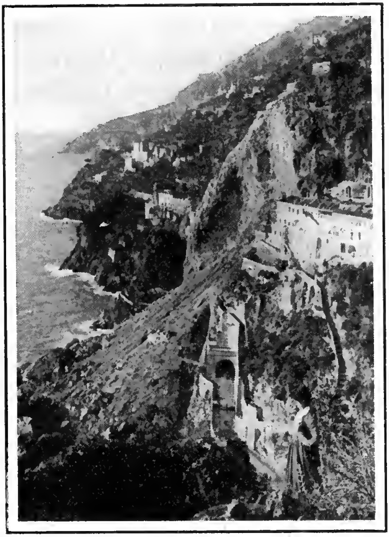
205. **Avalanches.** — In mountain regions where the inclination of the surface is steep, the loose material is liable to slide down the mountain sides, especially when it becomes moist because of long rains, or of the thawing of the frozen ground. As the material slides, the quantity increases,

LANDSLIDE.
Covering one of the main roads of Norway.

and momentum or force of movement is gained until a vast mass sweeps with almost irresistible force down the side, wrenching away trees, bowlders and whatever lies in its path. On reaching the valley the débris is piled in irregular mounds.

The scars of these avalanches are seen on the sides of almost all high mountains. In mountain regions which are inhabited, avalanches are frequently very destructive of life and property. In the Alps large forests are often maintained above villages to check the avalanches if possible and thus to protect the villages.

206. Mountain Animals and Plants. — As the temperature of mountains varies greatly from bottom to top, so the animals and plants must vary. Near the foot of the mountain the plants will be similar to those of the surrounding country, but these will soon disappear as the slope is ascended, since the temperature will have decreased, and their place will be filled by those capable of withstanding greater cold. If the mountains are sufficiently high, the tops will be bare or covered with ice and snow.



LANDSLIDE AT AMALFI.
This destroyed a part of the famous monastery.

The animals of mountains vary somewhat as do the plants, but since animals have the power of movement, their distribution will not be so uniform. They may ascend the mountain during the summer and retreat down the slope when the weather becomes severe. Animals driven from the plains by other animals or by man often find a place of safety in mountain regions.

The buffalo of the western United States found their only place of safety, until protected by stringent laws, in the mountainous region of the Yellowstone. The last small herd of caribou made their final stand in central

Maine on the heights of Mt. Katahdin; the deer which once roamed widely over New York State now are restricted to the Adirondack Mountains. In these mountainous retreats pursuit is difficult, and they can persist for a long time after being exterminated elsewhere.

Rocky Mountain Goats.

Some animals, such as the chamois of the Alps and the mountain goat of the Rockies, are particularly adapted to mountain life and find a congenial habitat nowhere else.

207. Mountain Peoples. — Mountains offer a retreat to persecuted people as well as to animals. Here are often found the races which once inhabited the surrounding plains, but which have been driven from them by conquerors. The people of Wales and the Scotch highlanders are probably descendants from more ancient inhabitants of the island than those in control to-day. The Pyrenees, the Caucasus and the Himalaya Mountains each contain tribes which were driven from the lower plains, but have been able in these retreats to withstand invaders who were too powerful for them in their former homes.

Flocks and herds frequently make up the greatest wealth of mountain peoples. Indeed in these regions it is common to reckon a man's wealth by the number of cows he can keep. In summer the cattle are driven to the higher slopes of the mountains, called *alps* in Switzerland and *saeters* in Norway. In winter they are brought down to the valleys, where the little villages are, and where every available foot of land has been utilized to produce hay for their feeding during the long winter months. Life is hard and meager, and industry, foresight and thrift are necessary.

As mountain valleys are separated from each other by ridges which for a considerable part of the year are almost impassable, the inhabitants are divided into groups whose world consists largely of the small valley in which

A MOUNTAIN SHEPHERD WITH HIS FLOCK.

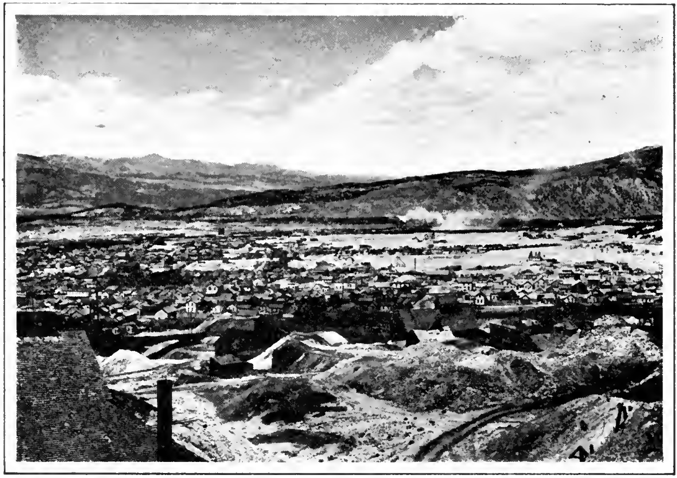
they live. Their customs and manners of dress become in time somewhat different from those of the valleys about them. In Norway many of the different valleys have developed various unique and beautiful costumes. Only in recent years, since travel has become more common, have these been laid aside for the humdrum, characterless costumes of the rest of Europe and of the United States. In some of the Scotch Highlands the natives still cling to their ancient dress.

Old-fashioned customs still maintain their hold in mountain regions long after they have been discarded in the surrounding country where intercommunication is easier. In the southern Appalachian Mountains many of the customs of the early pioneers are still common. Homespun clothing is still manufactured, and hog and hominy are the principal diet.

A Near View of the Jungfrau.
Such scenes as this produce the wealth of Switzerland.

In mountain regions, such as the northern Appalachians and Alps, where travel has been made comparatively easy, caring for the summer tourist has become the most important business. Here the old-fashioned customs have been laid aside and the boarding-house and hotel industry has largely supplanted all others. Such mountain regions have become a playground for the rest of the world, and the bracing air and cool climate are as great revenue producers as are fine farming lands and water powers.

In mountain regions rich in ores, mining naturally becomes the chief industry, and here, if there were any secluded native inhabitants, these have been replaced by the energetic miners from distant places. The deep and remote valleys and mountain sides have become the homes of mining camps and cities. Railroads have been built to these, overcoming almost impassable obstructions, and



CRIPPLE CREEK.
The largest mining camp in the world.

ore crushing and smelting works supply the places of the mills and factories of the manufacturing cities. When the ore fails, the army of workers moves on, and the city, once thriving and booming, becomes suddenly simply an aggregation of empty dwellings.

208. Effect of Mountains on History. — Not only have mountains been retreats for the vanquished, but they have been barriers against further conquest by the conquerors. It is very difficult for an army to traverse a mountain range. For a long time the Alps hemmed in the power of Rome. One of the greatest exploits of Hannibal and later of Napoleon was the passage of these same mountains.

In our own country the Appalachian Mountains acted for a long time as an impassable barrier to the expansion of the Thirteen Colonies. The trails across them were so long and difficult that it was many years before the fertile plains on their western side became populated. The Mohawk valley opened a comparatively easy route at the north, but the Cumberland trail at the south was long, circuitous and full of places suitable for Indian ambuscade.

The little mountain country of Switzerland is a buffer state for the rest of Europe. Afghanistan, rough, mountainous and desert, is a buffer state for Asia.

Mountains are often used as boundaries to countries, as in the case of the Pyrenees between France and Spain and the Carpathian Mountains between Austria-Hungary and Roumania. In early times it was thought sufficient to indicate the crest of the mountains as the boundary line, but soon it was found that what was to be called the crest was so open to controversy that definite lines, accurately determined from point to point, had to be substituted.

Sometimes the determination of what shall be called the crest line has given rise to bitter international disputes, as was the case recently between Chile and Argentina. It may happen that mountain boundaries are so broad and complicated that a little country inserts itself along the boundary of two powerful nations and is able to protect itself from being absorbed by either. The little country of Andorra, containing only 150 square miles, situated in a lofty valley on the southern slope of the Pyrenees, with a population not exceeding 10,000, has remained independent for nearly a thousand years in spite of its powerful neighbors.

Summary. — The high parts of the earth are *plateaus* and *mountains*. Some plateaus are *dissected* by the troughs of rivers that run through them and some are *broken* by faults. When plateaus are *old* and worn down they usually show remnants of their former surface in *buttes* and *mesas*.

Mountains are elevations higher than hills. *Block* mountains are formed by breaks in the rock layers of the earth; *folded* mountains are due to folds caused by lateral pressure. *Massive* mountains are complex in structure and their causes are various. The peaks of mountains are formed by erosion. Many mountains are found in ranges.

Mountains have a great effect upon climate. The windward side of mountains is usually wet and the leeward side dry. The wind, rain, and snow cause avalanches, which often do great harm to the plants and animals of the mountains and valleys.

Mountains have also a great effect upon history. Not only do they form excellent boundaries between nations and states, but they offer protection to weak animals which are unable to withstand their stronger neighbors in the unprotected conditions of the plains.

Questions

Describe the characteristics of a young plateau.

Why do not dissected plateaus attract a dense population?

What are the characteristic features of an old plateau?

Where in the United States are broken plateaus found?

Why are there no lofty old mountains?

How are block mountains formed? Where are mountains of this kind found? How are folded mountains formed? Where is a fine example of such mountains to be seen?

What are the characteristics of massive mountains?

What happens to mountains if they are exposed to erosion for a very long time? Where in the United States are such mountains found?

What are the causes which produce mountain peaks?

How are earthquakes caused?

What are the principal industries in mountain regions?

How do mountains affect climate?

What influence have mountains had upon plants and animals?

What influence do mountains have upon their human inhabitants?

What has been the effect of mountains upon history?

CHAPTER XIV

VOLCANOES

209. Subsurface Earth. — Many excavations and borings have been made deep into the earth's surface, and it has been found that the temperature increases with the depth. The rate of increase is not the same in different places, nor

MOUNT SHASTA.
An extinct volcano.

is the increase always uniform in the same place. The average of a number of deep excavations in different parts of the earth gives a rise of 1° F. for each 70 or 80 feet of descent.

The greater the pressure to which rocks are subjected the more difficult it is to melt them. If it were not for this, the solid part of the earth could not be more than 40 or 50 miles thick, as the interior heat would melt rocks under ordinary pressure. But the earth is too rigid for its interior to be otherwise than solid. So great is the pressure to which it is subjected that probably none of the material deep down in the interior of the earth is in a molten condition.

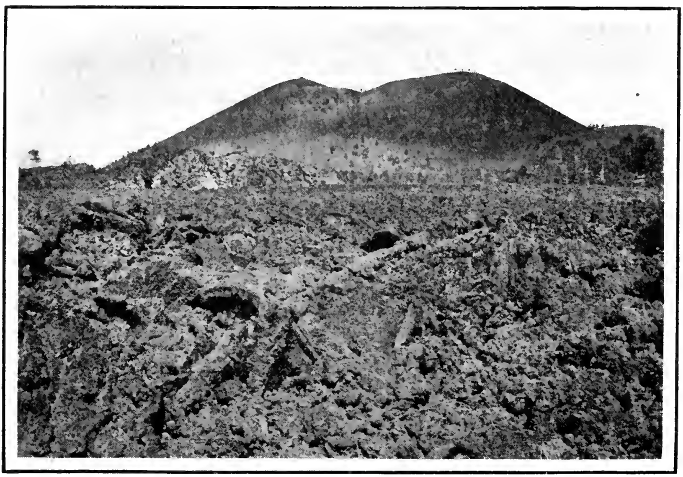
If the pressure near the surface should be decreased, or if the normal amount of heat at any place should be increased, the material might become fused, and under certain conditions might find its way to the surface. We know that heated material from below does rise toward the surface and intrude itself into the surface rocks and in some places pour forth over the surface.

What causes the uprising and outpouring of this molten material from below the surface of the earth, and how and why it reaches the surface are questions which as yet are unanswerable. But as soon as this igneous material comes within the range of observation, its properties and actions can readily be studied. The following descriptions of some well-known typical volcanoes show some of the results of subsurface activity.

210. Monte Nuovo. — In 1538, on the shore of the Bay of Naples near Baiæ, that once famous resort of the Roman nobles, after a period of severe earthquake shocks there suddenly occurred a tremendous eruption. From within the earth emerged a mass of molten material blown into fragments by the explosion of the included gases. Within a few days there was formed Monte Nuovo, a hill 440 feet high and half a mile in diameter, having in the top a cup-shaped depression or crater over 400 feet deep.

So great was the explosive force of this eruption that none of the ejected material was poured out in the form of a liquid. The whole hill is made up of dust, small stones and porous blocks of rock which resemble the slag of a blast furnace. The small fragments in such eruptions are called *ash* or *cinders*. In a week the eruption was over, and nothing of the kind has since occurred in the region.

When visited by the writer a few years ago, the bottom of the crater was a level field planted to corn. The whole process of formation of this volcanic cone was observed and recorded by residents of the region. Other similar eruptions have been observed, but perhaps this is the best known. We have here what may well be called a young volcano. The cone to-day is almost perfect in form.



CINDER CONE NEAR MOUNT LASSEN.

In northern California, near Mt. Lassen, which has itself recently become active, another almost perfect cone of this kind is found, which was probably formed much more recently than Monte Nuovo. From this cone both cinders and liquid material or *lava* were ejected.

211. **Vesuvius.** — When the Roman nobles were building their magnificent villas and baths along the shore of the Bay of Naples, the scenic beauty of the region was greatly increased by a mountain in the shape of a truncated cone, which rose from the plain a few miles back from the shore. Its sides, nearly to the summit, were covered with beautiful fields.

In the top of the mountain was a deep depression some three miles in diameter, partly filled with water and almost

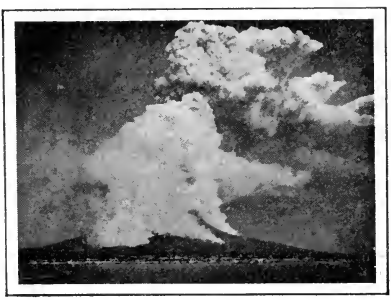
VESUVIUS AND NAPLES.

entirely surrounded by precipitous rock cliffs. There were no signs of internal disturbance. Around the mountain were scattered prosperous cities, the soil was fertile, the vegetation luxuriant. To this natural fortress Spartacus, the gladiator, retreated when he first began to defy the power of Rome.

In 63 A.D. the region about the mountain was shaken by a severe earthquake which did much damage. This was followed by other earthquakes during a period of sixteen years. In August, 79, the whole region was frightfully shaken, and the previously quiet mountain began to belch forth volcanic dust, cinders and stones, so that for miles around the sun was obscured, and a pall of utter darkness shrouded the country, lighted at intervals by terrific flashes of lightning.

A large part of the ancient crater, now known as Monte Somma, was blown away, and the villas and towns near the mountain were covered with the ash and cinders ejected. So deep were many of these buried that their sites were utterly forgotten. Pompeii and Herculaneum, after lying buried and almost forgotten for hundreds of years, have been recently partially uncovered.

These fossil cities show the people of to-day how the ancient Romans lived and built. The topography of the country and the coast line were greatly changed by this eruption. Pompeii formerly was a sea coast city at the mouth of a river. It is now a mile or more from the sea and at a considerable distance from the river.



MOUNT VESUVIUS.
Showing the famous eruption of 1872.

From the date of its first historic eruption until the present time Vesuvius has had active periods and periods when quiet or dormant. Sometimes the activity is mild, and at other times tremendously violent. At times the material ejected is fragmental and at other times streams of molten lava pour down its sides. Its ever changing cone, unlike that of Monte Nuovo, is composed partly of ash and partly of consolidated lavas. Even as late as 1907 a tremendous outpouring of ash took place which devastated a considerable area.

Mount Pelee and the Ruins of St. Pierre.

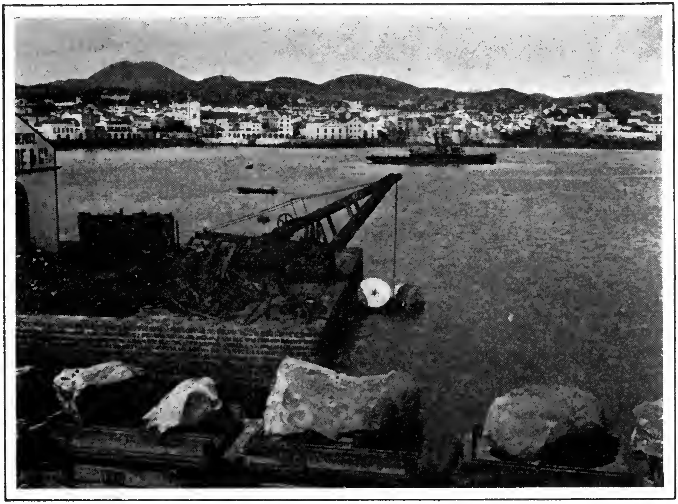
212. Mount Pelee. — At the north end of the island of Martinique in the West Indies rose a conical-shaped mountain. In a hollow bowl-like depression at the top lay a beautiful little lake some 450 feet in circumference. The mountain and lake were pleasure resorts for the people of the city of St. Pierre. According to legend this mountain had been violently eruptive, but in historic time there had been no indication of this except one night in 1851 when the volcano had grumbled and a slight fall of volcanic ash was found in the morning over some of the surrounding region.

On April 25, 1902, people began to see smoke rising from the vicinity of the mountain and from this time on till the final catastrophe smoke and steam came out in small quantities. By May 6 the volcano was in full eruption. On the morning of May 6 the cable operator at St. Pierre cabled, "Red-hot stones are falling here, don't know how long I can hold out." This was the last dispatch sent over the cable.

About 8 o'clock on the morning of the 8th a great cloud of incandescent ash and steam erupted, swept rapidly down the mountain toward St. Pierre and in less than three minutes killed 30,000 people, set the city on fire and destroyed 17 ships at anchor in the harbor. Thus within two weeks from the time of the first warning a rich and densely populated region was made a desolate, lifeless, fire-swept desert.

213. The Azores. — About 800 miles west of Portugal rises from the depths of the Atlantic a group of nine islands, the *Azores*. They have an area of about 1000 square miles, and the soil is very fertile. The islands are mountainous, one of the mountains rising to between 7000 and 8000 feet above the sea. Like other lofty islands of the deep ocean these are volcanic. Although at present not actively eruptive they abound in hot springs and have frequent earthquakes.

Volcanic cones are abundantly scattered over the islands, and comparatively fresh lava flows are not wanting. In recent times small islands have arisen in the group and eruptions have taken place. There are no other islands



SAN MIGUEL HARBOR IN THE AZORES.
Notice the volcanic cones in the distance.

near them. Their formation is due entirely to volcanic forces. Islands of this kind and coral islands are the only projections rising to the surface from the deep ocean floor.

214. Volcanoes of the United States. — In the Cordilleran region of the United States, west of the meridian of Denver, there are a score or more of lofty peaks which show conclusive evidence of volcanic origin. Until the summer of 1914 when Mt. Lassen suddenly began to erupt, none of these had been active since white men became familiar with the region. Some of the cones have been so recently formed that the forces of erosion have not had time to wear them away extensively. Thus they are almost perfect in shape like Mt. Shasta. Others, like Mt.

Mount Lassen in Eruption.

This volcano, after being dormant for centuries, suddenly renewed its activity in 1914.

Hood, have been deeply eroded, but not sufficiently to obliterate the conical outline.

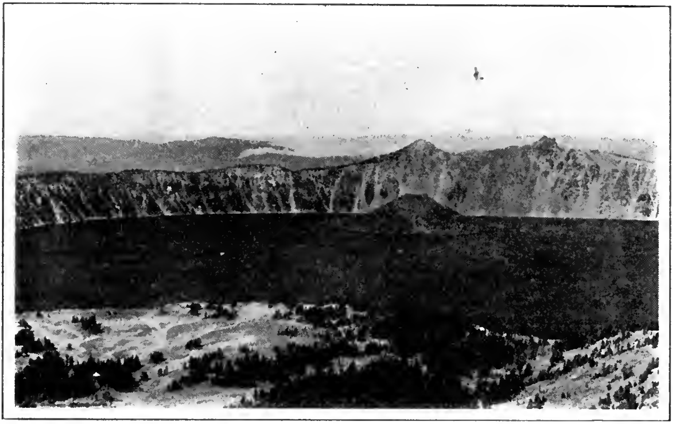
In the region around Mt. Taylor erosion has progressed so far that only the roots of the volcanoes still remain, the cones having been entirely worn away and only the central plug of lava left, forming what is called a *volcanic neck*. In the Aleutian Islands are numerous volcanoes which are still active, and in Hawaii are some of the greatest volcanoes on the earth.

MOUNT HOOD.
A beautiful old volcanic cone.

In Crater Lake we have a volcano whose normal development has been interrupted by an accident, its summit

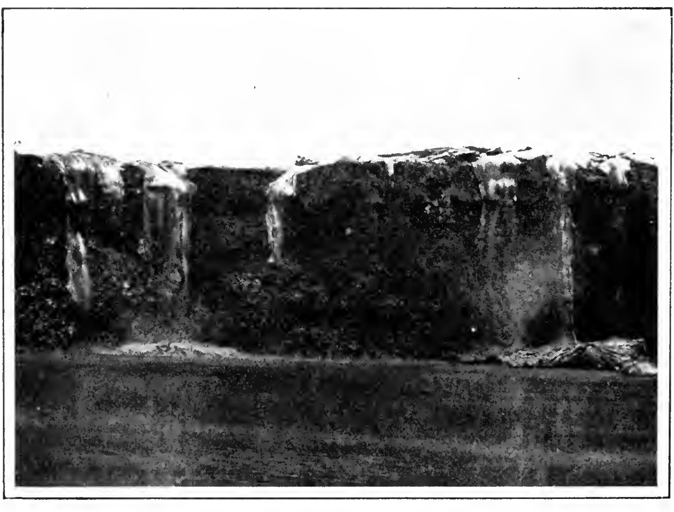
VOLCANIC NECKS NEAR MOUNT TAYLOR.

having fallen in, leaving a circular depression in the top of the mountain surrounded by steep walls and now nearly



CRATER LAKE.

filled with water. Except for the water filling, this decapitated volcano or *caldera* quite closely resembles the



LAVA FLOW IN THE HAWAIIAN ISLANDS.
Liquid lava flowing over a cliff.

probable condition of Vesuvius before the eruption of 79 A.D.

A HAWAIIAN CRATER.

215. Life History of a Volcano. — A volcano is simply a place in the earth's surface where molten rock or fragmental material from within the earth is extruded. If the extrusion of the lava is accompanied by gaseous explosions, it will be blown into fragments which will fall around the vent and build up a steep-sided cone, like that of Monte Nuovo. If the eruption is less violent, lava may flow from the crater or pour from openings formed in its sides.

As the same volcano usually ejects both the fragmental and molten material, volcanic cones are generally complex in their composition. Sometimes, however, cones are found which are composed entirely of one sort of material. Those which are largely or entirely formed of lava have a much gentler slope than the others. Such are the great Hawaiian cones.

Some volcanoes, like Stromboli, are in constant eruption; others, like Etna, vary their eruptions with irregular periods of rest, while still others remain quiet for very long periods and then suddenly break forth with terrific force, as did Vesuvius in 79. As a rule, but not always,

Cross Section of a Lava Flow.

eruptions are preceded and accompanied by earthquakes. Just why volcanoes erupt is unknown.

After a volcanic cone has come into being it is subject to the action of the erosive forces, and unless its material is renewed by fresh outpourings it will in time be worn down. Unlike other kinds of mountains it is also liable to disruption by explosions from within.

216. Distribution of Volcanoes.—The number of active volcanoes on the earth is about 300. Most of them are situated on the borders of the continents, on islands near the continents, or else they form islands in the deep sea. Soundings show that there are many peaks in the sea which have not reached the surface; these are probably volcanic. Few volcanoes are far from the sea although there is an active crater in Africa several hundred miles from the Indian Ocean.

Extinct cones are sometimes found far in the interior of continents, as the Spanish Peaks of Colorado, which are more than 800 miles from the present coast. Many of the once active deep-sea cones have now become extinct, and their gently sloping shores have been cut back into

THE CITY OF ST. HELENA.

cliffs which rise abruptly from the sea. One of these, St. Helena, rising from the depths of the Atlantic Ocean and bounded by precipitous cliffs, is noted as being the place of exile of the Emperor Napoleon I of France.

Summary. — Volcanoes are openings in the earth's crust through which portions of melted earth material pour forth. This material may be *ash* and cinders or it may be molten *lava*.

Some of the most interesting or best-known volcanoes are in Italy. Monte Nuovo, the New Mountain near Naples, is so called because it came into being in a few days. Vesuvius, which dominates all views of Naples, is perhaps the world's most famous volcano. Mount Pelee in Martinique had perhaps the most disastrous and spectacular eruption in all history. The Azores islands are all volcanic in their formation, and Hawaii has some of the world's greatest volcanoes.

The United States has a number of volcanic peaks, like Mt. Shasta and Mt. Hood, but until the recent eruption of Mt. Lassen, it had no active volcano.

Questions

What is the condition of the earth's interior?
Describe the eruption and present condition of Monte Nuovo.
What has been the history of Vesuvius?
What is Mount Pelee's story?
How were the Azores formed?
What volcanoes are there in the United States?
Give the life history of a volcano.
Where are volcanoes found?

APPENDIX

217. Determination of Latitude. — In Fig. 121 consider the sun as vertically above the point where our meridian crosses the equator and the lines *AB* and *ED* as representing rays from the sun. The line *FI* tangent at the point *A* will represent a level surface at that point. Draw the line *CH* through the point *A*. It will be at right angles to the tangent line *FI*. The latitude of the point *A* is measured by the angle *ECA*, as this angle measures the number of degrees of latitude between the point *E*, which is on the equator, and the point *A*.

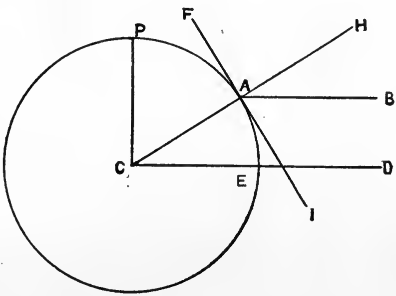


Fig. 121.

It can be proved by geometry that the angle *HAB* is equal to the angle *HCE*, since if the sun is vertical, the line *CED* is a straight line. The angle *HAB* is equal to a right angle, or 90° minus the angle *BAI*. As the angle *BAI* can be easily found by measuring the elevation of the sun above a horizontal plane, it is not a difficult thing to find the latitude of a place when the sun is vertical at the equator.

As the sun is vertical at the equator but twice in a year, on March 21 and September 23, this method can be used without modification only on those days; but since the angle of the sun above or below the plane of the equator is given in the Nautical Almanac for every day in the year, by adding this angle to the angle *BAI* when the sun is above the equator, and subtracting it when the sun is below the equator, the latitude of a place can be found for any day.

On board ship, every fair day, the officers will be seen just before noon coming on deck with their *sextants* to take the elevation of the sun. They find the elevation several times until they are sure that the sun has reached its highest point, and at this moment they call for the time to be taken on the chronometer; for when the sun reaches its highest point, it is noon for that place. Thus by making use of this one observation they are enabled, with the help of the chronometer, to find both their latitude and their longitude, or their exact position on the earth.

218. Topographical Maps. — Maps which attempt to show the surface features of the earth are called *topographical maps.* There are several ways in which we may try to show on a map the irregularities of the surface. One of these is *shading*, that is, making the hills and ridges light, while the valleys are shaded dark. A somewhat similar way is to draw short broken lines in the direction of the slopes. This gives a more accurate representation of the steepness of the descents, since the lines are made short and heavy when the slope is steep and longer and lighter when it is gradual. Such maps are called *hachure maps.*

The commonest way in this country is to draw lines connecting places of equal elevation. These lines wander in and out of the valleys and around the hills, but always pass through places which are of the same altitude. The distances apart of the lines vary continually, but the elevations never. From these maps the height of any place can be determined with great accuracy, for its height will be indicated by the line passing through it or near it. These maps are called *contour maps*.

219. Contour Maps. — Although it is easy to find the elevations of places on a contour map, it is hard to get a clear idea of what a contour map really expresses. The best way to gain an appreciation of a contour map is to get a map of the region in which you live, take it into the field, and study map and region together. Another excellent way is to make a contour map of a model. When once you have made a map of this kind, you will readily understand all other similar maps.

We must remember that a contour is the projection on a flat surface of a line which passes through places of equal elevation. It shows where the margin of water would come if the place in question were submerged to a given depth. No two contours can possibly cross each other, as no place can have two elevations. No contours can ever end except at the edge of the map, for a sheet of water must have a continuous boundary and only where the map terminates can the line representing the edge of the water appear to end.

Experiment 133. — Provide each pupil with a contour map representing the home locality if possible; if not, use the contour map facing page 345. Let the teacher or different pupils pick out places and ask some one to give their elevations. In this way you will get an idea of how elevations can be determined by use of a contour map. Notice the different topographical symbols used on the map.

220. Maps of Curved Surfaces. Projections. — The accurate mapping of small areas offers no great difficulty because these are practically flat, but when an attempt is made to represent a curved surface upon a flat surface, difficulties present themselves which are insurmountable. If the rind of an orange is taken off, it cannot be made to lie flat, and if crushed into this shape, it will break into pieces and only partly cover the surface over which it spreads. The same is true of any curved surface. Thus the continents of the earth, if they were flattened out, would of necessity be broken into fragments. If they could not themselves be made to occupy a flat surface, then no accurate map of them can be made on such a surface.

Although there are several ways of representing a curved surface upon a flat surface, yet no method has been found which is perfectly satisfactory. If the areas are in the right proportions, the outlines are not; and when the outlines are right, the areas are not. These different ways of mapping the surface of the earth are called *projections*. As a large part of our knowledge of the earth's surface is obtained from maps, it is very essential to have some idea of how these maps are made and wherein the essential error of each consists. The two important kinds of projection are the *cylindrical* and the *stereographic*.

221. Cylindrical Projection. — In this projection it is considered that a cylinder is wrapped around the globe touching at the equator. The points on the globe are projected on to the cylinder by lines drawn *from the center of the globe* through each point to the surface of the cylinder. Thus the meridians become straight lines always the same distance apart; and the parallels of latitude are also straight lines, but their distances apart will increase with the latitude. The poles themselves, being in the diameter of the cylinder, lie at an infinite distance from the equator.

When such a cylinder is unrolled it forms a skeleton map on which can be plotted places whose latitude and longitude are known. The directions north and south will be up and down the map, and east and west to the right and left. This cylindrical projection causes a degree of latitude to vary from about $\frac{1}{360}$ of the earth's circumference at the equator to infinity at the poles; and a degree of longitude, which near the poles has almost no length, is made to have a length everywhere equal to that of a degree on the equator. Thus passing from the equator toward the poles, the areas of surfaces on the earth are increased when represented on this projection, but the increase east and west and the increase north and south are not equal. This causes the shape of the portions of the earth farthest from the equator to be much distorted.

The *Mercator projection* is the most commonly used of all projections. It is a simple modification of the cylindrical, in which the exaggeration north and south is made equal to that east and west. In this projection the polar regions are greatly enlarged. This explains why Greenland, which on the globe is of comparatively small size, when seen on the ordinary map of the world is half the size of North America. The great advantage of this projection is that the meridians and parallels are both represented by straight lines. A navigator can thus at any time find his course by drawing a straight line joining the places between which he is sailing. This is why most nautical charts are constructed on this projection. But to geographers this projection is not of as great value as some others since the shapes of the land masses are so much distorted.

222. Stereographic Projection. — Of the hemispherical projections probably the best for study is the stereographic. This, or a slight modification of it, is the projection upon which are constructed the hemispherical maps usually seen. In it a plane is considered as held tangent at a certain point on the globe and from a point on the globe directly opposite the point of tangency, lines are drawn to the plane through the intersections of the parallels of latitude and longitude. Through these projected intersections the meridians and parallels of latitude are drawn.

In this projection, places near the point of tangency have their outlines correctly reproduced, but the farther away a place is from this point, the greater the distortion. This distortion, however, is never as great as that at the north and south in the cylindrical or Mercator projections. In the stereographic projection, however, the directions north and south and east and west must be traced on a curved line, thus making it much more difficult to tell at a glance the direction of one place from another. It is not possible on this projection to show more than one half the earth's surface on a single map.

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1. The experimental evidence precedes the chemical theory.

2. The historical order is followed as far as possible in developing the theory.

3. The practical aspects of the science are emphasized.

In selecting their material the authors have been governed wholly by what they consider its intrinsic value to the elementary student, without reference to its traditional place in a text-book.

To give the pupil some idea of the great commercial importance of chemistry a number of typical manufacturing processes have been described and illustrated. When a substance is manufactured in several ways the authors have given the process most extensively used in this country. The commercial production of copper, aluminum, iron, and carborundum has been described somewhat in detail, as these are notable examples of modern chemical processes.

An important feature is the brief summary and the test exercises given at the end of each chapter.

Laboratory Exercises to Accompany First Principles of Chemistry

By the authors of the First Principles of Chemistry. 12mo, flexible cloth, 147 pages. Price, 50 cents.

IN this manual are included seventy-one experiments, divided into three groups. Group A consists of forty-four experiments which all students should perform. Group B contains quantitative experiments, and Group C includes several extremely interesting experiments dealing with the practical applications of Chemistry.

Household Chemistry for Girls

By J. MAUD BLANCHARD, High School, Los Angeles, California
12mo, cloth, 108 pages. Price, 50 cents.

THE author's purpose is to outline a strong course in chemistry, especially suited to girls of high school age. Though the ultimate aim is the training of intelligent homemakers, it is a manual of chemistry, *not* of domestic science. It is therefore suitable for a purely academic high school, no less than for a polytechnic high school, where a rigorous course in household chemistry forms a necessary foundation for the work in domestic science. The choice of subjects is based in a general way on the following scheme: —

What we breathe.
What we drink and use for cleaning.
What we use for fuels and illuminants.
Chemical nature of common substances.
Foods and food values.
Adulterants and simple methods for their detection.
Textiles — care of textiles, removal of stains, etc.

The second half of the book, beginning with Experiment 28, is devoted to qualitative experiments in organic chemistry, as delicate quantitative experimentation is beyond the ability of high school pupils. Supplementary reading is of course advisable in this connection; with this in view, a full list of library text-books is given, and definite references to these accompany the experiments.

High School Physics

By Professor HENRY S. CARHART, of the University of Michigan, and H. N. CHUTE, of the Ann Arbor High School. New Edition, thoroughly revised. 12mo, cloth, 444 pages. Price, $1.25.

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Text-Book of Cooking for Secondary Schools

By CARLOTTA C. GREER, East Technical High School, Cleveland.
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Part I is a guide to teach pupils to cook. The pupils follow established recipes and are taught to consider the processes of cooking as experiments in scientific study. Added to recipes and directions are suggestions to aid the pupil to appreciate the significance of each step and to understand the change that is taking place in the substances he is using. In the reviews the pupil is helped to work out his own scheme for preparing a meal.

Part II adds to the planning and cooking of meals a practical method of calculating food values. Special attention is given to cooking and serving without a maid.

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The entire book has been worked out and tested in the classroom of one of the largest vocational schools in America.

Descriptive Inorganic General Chemistry

A text-book for colleges, by the late Professor PAUL C. FREER. Revised edition. 8vo, cloth, 559 pages. Price, $3.00.

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