THE

YOUNG FOLKS' ASTRONOMY

BY

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PREFACE.

THE commendation which the astronomical articles in the Young Folks' Cyclopædia of Common Things have received from parents and teachers has led to the preparation of this little volume, in the hope that it will fill a want long felt in homes and schools. There can be little question of the propriety of early grounding a child in an elementary knowledge of the astronomical features of the earth on which he lives and of the universe of which it forms a part; yet it is almost impossible to find a text-book in which either the language or the ideas are within an ordinary child's comprehension, most of the books miscalled astronomy "primers" being fitted only for those who already possess some knowledge of the science and of its correlated subjects. In the present work the topic is treated in the most elementary way, the child being first taught that the earth is a heavenly body which moves in the heavens in the same way as the moon, and which would look from the moon at night much as the moon looks to us. From this

his mind is gradually led up to a contemplation of the other heavenly phenomena, such as the movements of the bodies of the solar system, and what results from them; then of the fixed stars and the constellations, and lastly of some of the practical uses of astronomy, such as the measurement of time and the calendar. Abstruse calculations and the use of expressions requiring a knowledge of mathematics have been avoided, and even numbers denoting celestial distances so great as to mean nothing to a child, have been made intelligible by comparison with some known measure of length on the earth. The language used is simple, technical phrases have been explained, and pictorial illustrations introduced wherever they tend to make the text clearer and more intelligible.

It is perhaps not improper to add that the work was submitted, before printing, to the criticism of two eminent teachers, who approved of its general method and expressed a belief that it is well adapted for teaching.

J. D. C., Jr.

New York, May, 1881.

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THE

YOUNG FOLKS' ASTRONOMY.

LESSON I.

ASTRONOMY AND WHAT IT TEACHES.

Astronomy is the science which tells about the heavenly bodies and their movements. To understand what it teaches it is first necessary to know what the heavenly bodies are.

Every child is astonished on being told for the first time that the stars are not small lights, but are large bodies—nearly all of them much larger than our whole world, and that many of them are much like our world, and perhaps are covered like it with living things. He is still more astonished when he is told that our world, or the earth on which we live, is a round ball made up of much the same matter as the stars. Yet we know that these things are true, because they have been proved to be so in ways which will be told about in other parts of this book. We know that the stars and our earth are large round bodies, which are always moving in the heavens, and for this reason they, together with the sun and the moon, are called

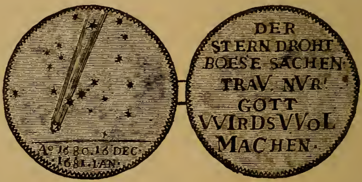
1. The Earth as seen from the Moon.

the heavenly bodies. It may be at first hard to think of the earth, which looks flat to us, as a heavenly body like the sun, the moon, and the stars, which appear to float in the heavens upheld by nothing; but it will not seem so strange when it is shown, as it soon will be, that our earth moves through the heavens touching nothing but the air around it. If it were possible to see the earth from the moon, it would look to us much like the moon, only it would be larger and the dark and light parts would show different shapes from those which we see on the moon's surface. In the picture (1), which shows one side of the earth as it would look from the moon, the light parts are Europe, Asia, and Africa, and the dark parts the ocean.

Astronomy is one of the most important and most useful of studies. By means of it we can measure time correctly, and tell beforehand what the movements of the heavenly bodies will be. We are thus enabled to make almanacs which give the times of the rising and setting of the sun and the moon, the rising and falling of the tides, and other useful information.

By means of astronomy also we know much about the earth which could not otherwise be known, and are able to make maps on which are correctly shown the situations of its lands and seas, and of towns, rivers, and mountains. For as different stars must be seen from different places on the earth, if an astronomer were carried blindfolded to the most distant part of the earth, and placed with his instruments on a rock in the middle of the ocean, he could tell, in a few minutes, by studying the stars, exactly where he was. Thus the sailor knows from the stars where his ship is, and is enabled to steer his way safely across the great oceans.

Astronomy too has made men braver and better than they were in old times. When the causes of the movements of the heavenly



2. Medal of the Great Comet of 1680. [Newcomb and Holden's Astronomy.]

bodies were not understood, men worshiped the sun as a god, and were filled with awe and dread when it was darkened, for they believed that their god was angry with them; and when they saw a comet flaming in the sky, they thought it to be the forerunner of war, sickness, or famine. In 1680 a very bright comet appeared, and the people in Europe were so frightened at it that a medal like the picture (2) was struck in Germany to quiet their fears. The inscription on the back is, in English: "The star threatens evil things; trust only! God will turn them to good." Happily we are free from such silly notions, for our knowledge of astronomy has taught us that each one of the heavenly bodies forms a part of a great system called the universe, which is governed by laws that never change.

RECITATION FOR LESSON I.

What does astronomy tell about?

The heavenly bodies and their movements.

What are the heavenly bodies?

The earth, the sun, the moon, and the stars.

What does astronomy enable us to do?

To measure time correctly, and to tell in advance the movements of the heavenly bodies.

Of what use are these things to us?

They enable us to make almanacs and maps.

What are almanacs good for?

They give us the time of the rising and setting of the sun and the moon, the rising and falling of the tides, and other useful information.

How does astronomy aid us in making maps?

It enables us to lay down correctly on them the situations of lands and seas, and of towns, rivers, and mountains.

How does astronomy aid the sailor?

By studying the stars he can tell exactly in what part of the sea his ship is, and can thus find his way safely across the great oceans.

How does a knowledge of astronomy make men better and braver than they were in old times?

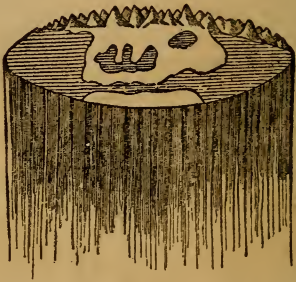
It teaches them the causes of the movements of the heavenly bodies, so that they no longer fear them.

LESSON II.

WHAT THE ANCIENTS KNEW ABOUT THE EARTH.

People have not always known as much as we do about the earth. In the earliest ages of which history tells, there were learned men who taught that it is round, but this was by no means generally believed. Little was known in ancient times of the surface of the earth. America and Australia had not been discovered, and even the greater parts of Europe, Asia, and Africa had not been explored. As far as travelers had gone, whether on land or sea, more land and more water were seen beyond, and so it came to be the belief of almost every one that the earth was nearly flat, that it was surrounded by the waters of the ocean, and that the heavens hung over it like a dome. Some thought that this great island floated in the water, some that it had long roots which stretched downward without end (3), and others that it was held up by many strong columns or pillars (4).

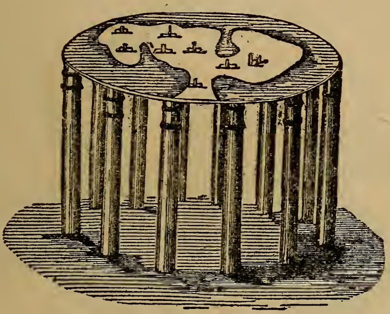
The ancient Hindoos, or people of India, had still more singular notions about the earth. They believed that it was shaped like a hemisphere (Greek *hemi*, half, and *sphaira*, sphere)—that is, like the half of a sphere or globe—and that it rested with its round side upward, as shown in the picture (5), on the



3. Ancient Idea of the Earth with Roots.

heads of four elephants standing on an immense turtle, which floated on the sea.

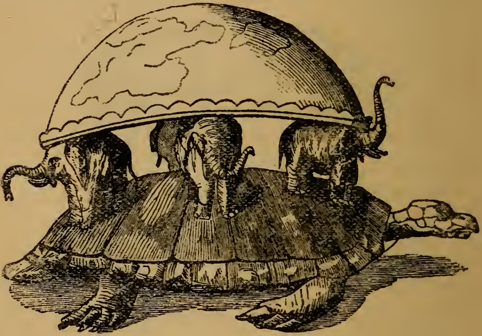
The ancients had many ways of explaining the rising and setting of the sun. Some thought it to be a great ball of fire which was put out by the waters of the ocean when it set and which was lighted again when it rose in the morning after passing through the waters beneath the earth; others thought that it passed through a tunnel under the earth; and still others, who believed that the earth was held up on columns, thought that the sun went between them. All these things seem very laughable to us, who know that the earth is really round like a ball, and that



4. Ancient Idea of the Earth on Columns.

it is not held up by any solid thing, but floats in the heavens, just as the moon does; but we must remember that it has taken thousands of years to find out all that we know about it.

We must remember, too, that the earth, at first sight, really appears to be flat, and that the heavens look like a dome above us. This is the same wherever on the surface of the earth we may happen to be. If we are in a hilly country, we see all around us hills whose tops the heavens appear to touch; and if we walk to the top of the hills, more hills are generally seen beyond, with the dome of the heavens reaching down to them. If we stand



5. The Hindoo Idea of the Earth.

in the middle of a flat country, we still see the heavens shutting in the land on all sides, and meeting it in a line which is broken only by the hills, trees, or houses which may be in sight; and it is the same at sea, where there are no hills, trees, nor houses to shut out the view—the waters stretching out like a great plain meet the sky all around. The line where the earth and the sky appear to meet, whether on land or water, is called the horizon (Greek, limit or bounding line).

RECITATION FOR LESSON II.

Did the ancients know as much about the surface of the earth as we do?

No; they knew nothing of America and of Australia, and very little even of Europe, Asia, and Africa.

What did they think of the shape of the earth?

Most people believed that it was a nearly flat island, with the heavens hanging over it like a great dome.

How did they think the earth was held up?

Some thought that it floated in the water, some that it had long roots, and others that it was held up by many strong columns.

Did not the Hindoos have a different notion about it?

Yes; they believed that it was shaped like a hemisphere, and that it rested on the heads of four elephants standing on a great turtle, which floated on the sea.

What do you understand a hemisphere to be?

The half of a sphere or globe.

How did the ancients explain the rising and the setting of the sun?

Some thought it was a great ball of fire which was put out by the waters of the ocean when it set, and lighted again when it rose out of the waters in the morning; some thought it passed under the earth through a tunnel; and those who believed that the earth was held up by columns thought it went between them.

Does not the earth really appear to be flat?

Yes; wherever we go, on land or sea, it looks like a great plain broken by hills and valleys, with the sky stretching over it like a dome.

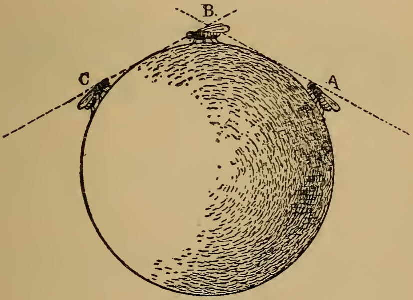
What do we call the line all around us where the earth and the sky appear to meet?

The horizon, which means the limit or bounding line.

LESSON III.

HOW WE KNOW THAT THE EARTH IS ROUND.

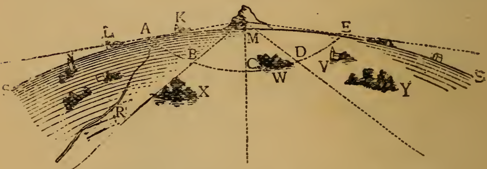
Wherever we happen to be, we always see the horizon around us; and if we go in any direction from a place, things not seen



6. The Flies' Horizon.

before come into view in the distance, while the horizon always appears to be just as far off. This is because the earth is round, and as we travel nearer and nearer to things they appear to rise up from below the horizon over its rounded edge.

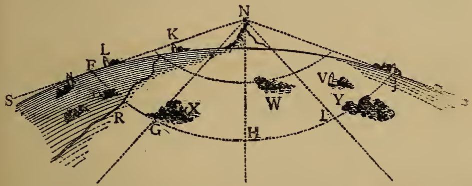
This will be best understood by looking at the picture (6) of the two flies on an orange. Suppose first that one fly is standing still on the side of the orange at *A*, and another on the other side at *C*. The one at *A* cannot see the one at *C*, on account of the roundness of the orange (earth), which shuts out the view; but if *A* should travel up to *B*, it could then



7. The Horizon seen from the foot of a Mountain.

look over the rounded edge and see the one at *C*.

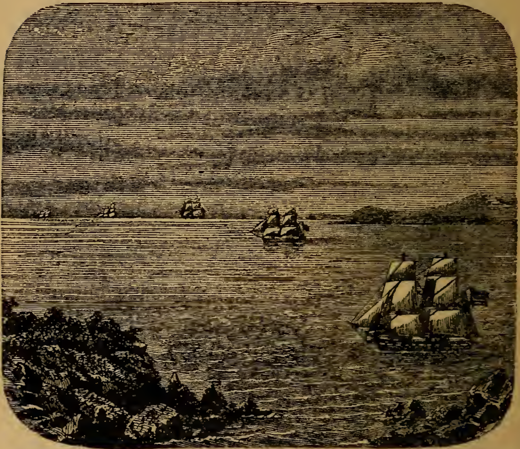
The two pictures (7 and 8) show how one can see further over the edge of the earth from the top of a mountain than from its base. The curved figure *SS* (7) is a part of the rounded surface of the earth, on which is seen a mountain, *M;* houses *K*, *L*, and *V;* woods, *W*, *X*, and *Y;* and a river, *R*. If we were standing near the foot of the mountain at *M*, we could see on our right only to *A*, and on our left only to *E*, because all things further away than those points would be below the round edge of the earth, and only the sky would appear beyond. In front we could see to *B*, *C*, and *D*, and if the mountain were not there we could see the same distance behind. The dotted line *ABCDE* then would be our horizon, or the line where earth and sky appear to meet.



8. The Horizon seen from the top of a Mountain.

But if we go up the mountain and stand on the top of it at *N* (8), we can then see much further than before, and our horizon will be at *FGHIJ*, instead of at *ABCDE*. From our first position we could see only the house *K* and the top of the house *L*, and a part of the wood *W*; but from the mountain we can see not only these, but the rest of the wood *W*, all the wood *X*, and part of that at

Y, a larger part of the river *R*, and the houses at *L* and *V*. The rest of the wood *Y* and the other parts below the line *FGHIJ* will still be out of sight, because they are below the



9. Ships Above and Below the Horizon.

rounded edge of the earth; but if we could go higher than the top of the mountain, we could see still further, for the higher we are above the surface of the earth the further over the edge we can look.

That the earth is round is shown on the sea still better than on the land, because there are no hills, trees, and houses to shut out the view. If we watch ships in the distance just coming into view, we shall see first the tops of the masts, then the sails will come into sight little by little, and lastly the hull will come up over the edge. In the picture (9) are shown several ships, some in full view, and some just going down or coming up over the edge of the earth. In the same way, if we watch a ship sailing away from us, we shall see the hull first go out of sight, and then the masts and the sails go down little by little until at last all will disappear. If the sea were flat the whole of the ship would stay in sight, and all would gradually grow dimmer and dimmer until it faded entirely from view.

But the best proof that the earth is round is that men have traveled round it. About three hundred and fifty years ago (1519), a Portuguese named Magalhaens, or Magellan, in the service of the King of Spain, sailed in search of the Moluccas, or Spice Islands. After passing through the strait at the south end of South America, called after him the Strait of Magellan, he sailed westward across the Pacific Ocean until he came to the Philippine Islands. He was killed on one of these islands in a fight with the natives, but his ship, the Vitoria (Victory), kept on going west, and in three years after leaving Spain returned there (1522), having sailed entirely around the earth.

Since then this voyage has been made a great many times, and as it now takes, by the aid of railroads and steamships, only about three months to go round the earth, many people make the trip for pleasure. This proves that the earth is round and not flat, for by traveling in a straight line always in one direction we finally come back to the place we started from, just as a fly creeps round an orange; but if the earth were flat, the further we traveled in a straight line the further we should be from the point we started from.

But, it may be asked, could not one travel round the earth if it were oval or egg-shaped? Yes; but we know that it is not very oval, but more round like a ball, because its shadow is round. The shadow of a thing is always like the thing itself; for instance, if you hold up a square thing, like a book or sheet of paper, between a lamp and the wall, it will cast a square shadow on the wall; an oval thing, like an egg, will cast an oval shadow; and a round thing, like an orange or a ball, a round shadow. Now, there are certain times, which will be told about by and by, when the shadow of the earth can be seen, and it is always nearly round; and from this we conclude that the earth itself is nearly round as an orange is.

RECITATION FOR LESSON III.

Why is it, when we go in any direction from a place, that things not seen before appear to rise up into view in the distance?

Because as we travel nearer and nearer to them they come into view over the rounded edge of the earth.

Why can we see more from the top of a mountain than from its foot?

Because the higher we get, the further over the rounded edge of the earth we can see.

How does the sailing of a ship prove that the earth is round?

When a ship is coming in from sea, the tops of the masts are first seen, and last of all the hull comes up into sight.

Why does not the hull come into view at the same time with the masts?

Because when the tops of the masts are

first seen, the hull is below the rounded edge of the earth.

Would it not look the same if the sea were flat?

No; if the surface were flat, the whole of the ship would come into view at once.

What still better proof is there that the earth is round?

That men have gone entirely around it by traveling always in one direction.

Could they not do this if the earth were egg-shaped?

Yes; but we know that it is not egg-shaped, because we can sometimes see its shadow; and it is nearly round like the shadow of a sphere or ball.

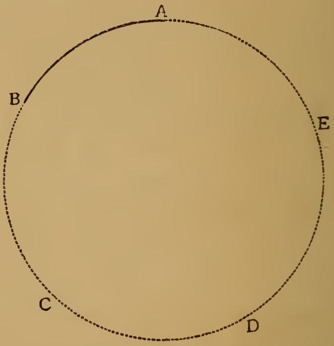
LESSON IV.

ABOUT THE SIZE OF THE EARTH.

It may be thought that though the earth's roundness seems to be proved, it is hardly fair to call it round like an orange, because an orange is smooth, while the surface of the earth is very rough and uneven in places. But the earth is just as smooth for its size as an orange is, for the hills and mountains on its surface are no larger in proportion than the rough places on the skin of the orange. Indeed, the earth is much smoother for its size than an orange, because if the orange were made as large as the earth, and the roughnesses on its skin were made large in proportion, they would be very much higher and rougher than the highest mountains on the earth.

There are higher mountains on the moon than on the earth, in proportion to its size, yet the moon looks to us like a round, smooth, bright ball, with some dark patches on it; and if we could get as far away from the earth as we are from the moon, it also would look much the same to us, for we would not be able to see its roughnesses.

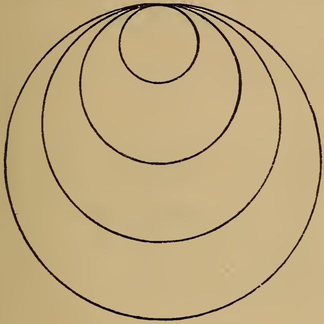
If the mountains on the earth are, then, so small in proportion to its size, the earth must be very large. That it is so is proved by the fact that its surface, which we know is round-



10. Showing that a Curve is part of a Circle.

ed, appears flat to us. If we stand in the middle of a great plain, or on a ship at sea, we cannot see any curve, though we can look many miles in every direction. From this it is clear that the curve must be very slight, and the circle of which the curve forms a part very large.

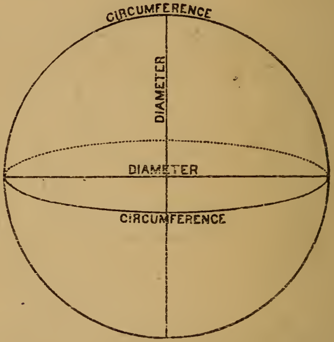
This will be understood better by laying a piece of hoop on the ground, and marking the curve around until the two ends meet. In the picture (10), *AB* is a piece of hoop, large enough to show the curve, and *CDE* is the curve continued all the way round. We



11. Showing that the flatter the Curve is, the larger must be the Circle of which it is a part.

shall easily see from this that a curve is only a part of a circle, and the next picture (11) will show us that the flatter the curve is, the larger must be the circle of which it is a part.

Now, the curve of the earth's surface is so nearly flat that we who stand on the surface cannot see that it is round at all; if it were continued, therefore, round the earth until the two ends met, it would form a very large circle. In fact, we know exactly the size of this circle, for it has been very carefully measured; it is nearly twenty-five thousand (25,000) miles. It may be hard at first



12. Circumference and Diameter.

to understand how great a distance this is, but perhaps we may get some idea of it when we think that if we should walk ten miles every day it would take us nearly seven years to go round the earth.

If, again, a straight line should be drawn from the surface of the earth through its centre to the surface on the other side, it would measure about eight thousand (8,000) miles. A measurement thus made through the earth is called its diameter; and a measurement made round the earth in a great circle is called its circumference.

RECITATION FOR LESSON IV

Some parts of the earth's surface are very rougn and uneven: is it proper to call the earth at those parts round?

Yes; because the earth is so very large that the highest mountains on its surface are not so large in proportion as the rough places on the skin of an orange.

How would the earth look from the moon?

Like a round, smooth ball, with some dark patches on it, much the same as the moon looks to us.

How do you know that the earth is very large?

Because its surface, which is curved or rounded, is so large that it looks flat to us.

How has the size of the earth been found out?

By measuring a part of the curve, and then by continuing the curve round until the two ends met and formed a circle round the earth.

What is the length of this circle?

Nearly 25,000 miles.

What is such a measurement made round the earth or round any other circle called?

Its circumference.

What is the length of a straight line drawn through the centre of the earth, from one side to the other?

About 8,000 miles.

What is such a measurement made through the earth or any other round thing called?

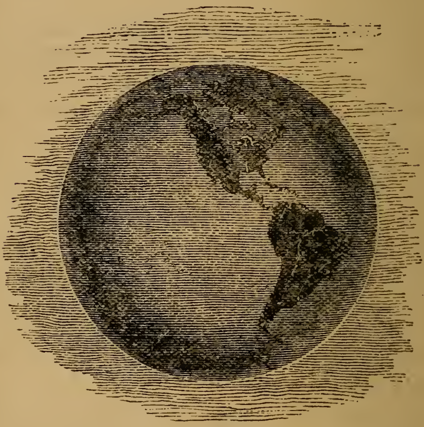
Its diameter.

LESSON V.

THE EARTH IN THE HEAVENS.

We have thus learned that the earth is a globe or sphere, and that it is very large; we have now to find out what holds it up in the heavens. But is it necessary to suppose that it is held up by anything? We see the sun, the moon, and the stars above us, with nothing solid to hold them up; and why should not the earth hang in the heavens like them, touching nothing and upheld by nothing which can be seen. Indeed, we know that this is so, for wherever we go on any part of the surface of the earth we always see the heavens above, with nothing solid between them and the earth.

It must be clearly understood that the heavens mean something more than the air in which we see the clouds float. The air, which covers the earth like an envelope on every side, and which, when taken together, is called the atmosphere (Greek, *atmos*, air, and *sphaira*, a sphere), does not reach up very high. Air thick enough to breathe lies only two or three miles deep on the surface of the earth, and above that it grows thinner and thinner until it seems to fade into nothing. But beyond that, reaching away millions on millions of miles through space, stretch the



13. The Earth in the Heavens.

heavens, in which are the sun, the moon, and the stars.

The air or atmosphere, then, is a kind of shell, which covers the whole surface of the earth, as seen in the picture 13, where it is shown many times thicker in proportion than it really is. Some think that it is only about fifty miles thick, which is really very little, when compared with the thickness of the earth; and it is scarcely anything when compared with the great heavens; yet it is this little shell of air around us which makes the heavens look to us like a dome. In clear days this vault looks blue, because the air, which appears to us to be clear, is slightly blue when taken in large masses; and in misty weather it looks whitish or grayish, according to the clouds floating in the air. In the night, when the atmosphere is clear, the sky does not look to us so much like a dome, and we can see the stars shining so far away in the black heavens that they look like twinkling specks of light.

It has been said that wherever we go on any part of the surface of the earth we always see the heavens above us. One may exclaim, How can the heavens be *above* a person standing on the opposite side of the earth from us! Would it not be more proper to say *below?* No; it would not be proper to say below, because the heavens would appear to him on his side of the earth just as they do to us on our side, and we are as much upside down to him as he is to us. Since the earth is a globe, the words *up* and *down* cannot be used to mean the same real direction to persons on all sides of it. The term *up* means simply *from* the earth's centre, while

14. Men on different sides of the Earth.

down means *toward* the earth's centre. A person in China, which is on the opposite side of the earth from us, would use the word up just as we do here, and to mean the same thing, but his *up* would be in a direction just opposite to ours. So to every one on the earth, no matter on what side of it he may be, *up* means from the centre of the earth toward the heavens, and *down* means toward the centre of the earth; and the heavens are always above and the earth always below him. The reason of this is hard to understand, but it will be made clearer further on.

RECITATION FOR LESSON V.

What holds the earth up in the heavens?

It is not held up by any solid thing, but floats in space like the sun, moon, and stars.

How do you know this?

Because wherever we go on the earth's surface we always see the heavens above us, with nothing solid between them and the earth.

When you speak of the heavens, do you mean the air or atmosphere?

No; the atmosphere does not reach up very high, and forms only a very small part of the great heavens, in which are the sun, the moon, and the stars.

What causes the heavens to look in the day-time like a great blue dome reaching down to the earth on all sides?

The atmosphere, because the air is blue.

Do the heavens look the same in the night-time?

No; when the heavens are black at night they do not look so much like a dome.

You speak of the heavens above us; if you were on the opposite side of the earth would you say the heavens below us?

No; because the heavens would look the same there as they do here.

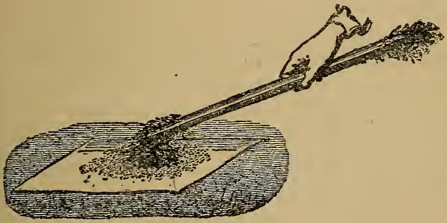
How can you explain this?

As the earth is a globe, the words *above* and *below*, or *up* and *down* cannot mean the same real direction to persons on all sides of it. Above and up mean simply from the earth's centre, and below and down toward the earth's centre.

LESSON VI.

THE ATTRACTION OF GRAVITATION.

When we hold a stone in our hand it feels heavy, and we say that it has weight; if we drop it, it falls to the ground, and we say that it falls because it has weight. This is true, but what is this which we call weight? Why are things heavy?



15. Iron-filings drawn by a magnet.

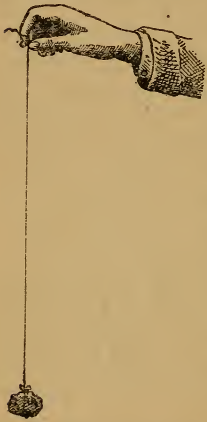
If a magnet be held near to a mass of iron filings, the little pieces of iron will be attracted or drawn toward it and will collect in a cluster on its end. We cannot see anything between the magnet and the iron filings to make them go to it, yet we can see that they are drawn to it by some force which though invisible is strong. If, now, a small magnet be held near a large mass of iron, the magnet will be drawn to the iron just as the iron filings were drawn to the magnet. The iron is really drawn by the magnet as much as the magnet is drawn by the iron, but the iron being so much the larger overcomes the magnet and makes it come to it.

Every thing on the earth attracts or draws toward itself every other thing, much as the magnet draws the iron filings to itself; but as the larger the thing is the more it attracts, and as the earth itself is much larger than anything on it, it attracts or draws toward itself everything on it with so great a force that it will not let most little things go toward each other. We cannot see anything between the earth and the things which are drawn toward it any more than we can between the magnet and the iron filings, but the attraction is just as real in the earth as in the magnet. It is, however, a different kind of attraction from that of the magnet, for the magnet draws the iron filings more than the earth does, as it keeps them from going to the earth; but this is true of iron only, all other things being attracted more by the earth.

Thus the earth is always drawing everything to itself. The force with which it does this is called gravitation, or the attraction of gravitation, which causes what we commonly call weight; and when we say that a thing is heavy, we mean simply that it has gravity, or is drawn toward the earth by the force of gravitation. Now, some things are attracted toward the earth much more strongly than other things; and when a thing is drawn strongly we say it is heavy, and when it is drawn with but little force we say it is light.

If it were not for the attraction of gravitation we should have no seas, lakes, nor rivers, for all the water on the earth is kept in its place by this force. The atmosphere, too, is held around the earth by the same force, else it would all fly away and become scattered throughout the heavens.

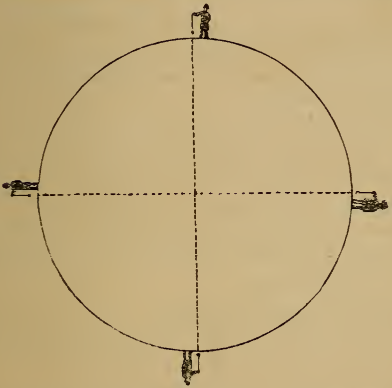
When we drop a stone it falls in a straight line to the earth. The direction of this line can easily be seen by tying a string to a stone and raising the stone up a little; the stone (16) is drawn downward by the attraction of gravitation, and this draws the string into a straight line, which, if it could be continued down through the earth would pass directly through its centre. This would be the same, no matter on what part of the earth's surface we might stand. In the picture (17) are shown four persons standing on different sides of the earth, each one holding such a string in his hand; it will be seen that the dotted lines drawn straight from each string meet in the centre. So all things which fall anywhere on the earth always go toward the same point—that is, toward the centre of the earth.



16. Showing that a Stone falls in a straight line to the Earth.

You can now understand why *down* always means toward the centre of the earth, and *up*, on any part of the surface of the earth, always means toward the heavens; and also why persons on the opposite side of the earth from us do not fall off, but live there as easily as we do on our side; their natural position is just the same as ours, with the feet upon the earth and the head toward the heavens, and they are held in their places just as we are in ours, by the attraction of gravitation, which draws everything toward the centre of the earth.

The attraction of gravitation was first found



17. Showing that the line made by anything in falling, would go, if continued, to the centre of the Earth.

out by Sir Isaac Newton, a famous Englishman. While sitting in his garden one day, he saw an apple fall from a tree. This set him to thinking what made it fall, and he soon made up his mind that all things on the earth are drawn alike toward the centre of the earth; and by making many experiments he found out that this is true.

RECITATION FOR LESSON VI.

If a magnet be held near some iron filings, what will happen?

The pieces of iron will be attracted or drawn to the magnet.

If a small magnet be held near a large mass of iron, what will happen?

The magnet will be drawn to the iron.

What do you learn from this?

That the larger draws the smaller to itself.

Is this true of other things on the earth?

Yes; all things on the earth are attracted or drawn toward each other, but by another kind of attraction.

Are they all attracted equally?

No; the larger the thing is the more it attracts or draws things toward itself.

What attracts more than anything else?

The earth, because it is much larger than anything on it.

What is this force which draws things to the earth called?

The attraction of gravitation.

What is meant when a thing is said to be heavy?

It is meant that it has gravity, or is drawn toward the earth by the force of gravitation.

What would happen to things on the earth if there were no gravitation?

Seas, rivers, and lakes would not stay in their places, and the air would fly away and be scattered through the heavens.

When we drop anything, in what direction does it fall?

Toward the centre of the earth.

Is this the same everywhere on the earth's surface?

Yes; because the attraction of gravitation draws everything on the earth toward its centre.

Who first found out the attraction of gravitation?

Sir Isaac Newton.

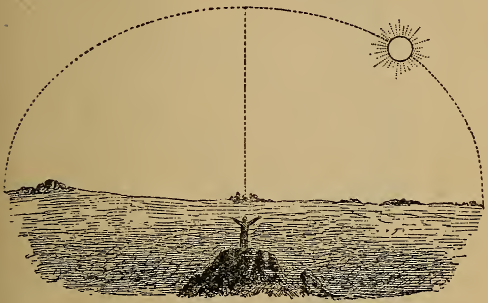
LESSON VII.

THE EARTH TURNS ROUND.

We have thus learned that the earth is a great globe which floats in the heavens; we have now to find out whether it moves or is at rest.

When we watch the other heavenly bodies they appear to move around the earth, which seems to us to be at rest. The sun appears to rise in the east in the morning, pass through the heavens over our heads, and set in the west in the evening. The moon appears to follow the same course; and if we watch the stars on a clear night, we shall see those in the east rising up little by little above the edge of the earth, and those in the west gradually sinking down below the horizon. Thus, while the earth seems to be still, all the heavenly bodies above, the sun, the moon, and the stars alike, appear to be moving through the heavens from east to west in curves or rounded paths, which, if continued all round the earth, as we marked round the curve of the piece of hoop (10), would form circles. This is what is called the apparent movement of the heavenly bodies, because they appear to move round the earth in these paths.

There are two ways of explaining this: first, we may explain it as the ancients did, by saying that the earth stands still, while the



18. The apparent movement of the Sun.

sun and the stars move round it in circles; and second, by saying that the earth itself is all the while turning round.

We now know that the first cannot be true. If it were true, the sun and the stars would really move round us, as they appear to do, once every twenty-four hours. But the sun is many hundred thousand times larger than the earth, and many of the stars are as large, and probably larger than the sun, as will be told about hereafter; and it seems absurd to think that these immense globes should turn around our earth, which, though it seems large to us, is really very small when compared with the other heavenly bodies. The sun, too, as you will learn by and by, is many million miles away from the earth, and the stars are so much further away that we can not even count the distance. Now, the further they are away from the earth the larger must be the circles in which they move round it, and the faster they must go to get round it in the twenty-four hours. If we suppose them to move round the earth, we must believe that they travel through the heavens at a speed so great that our minds can scarcely think of it. But it does not seem reasonable to believe this.

Suppose, now, that the earth turns round in a way opposite to that in which the other heavenly bodies appear to move—that is, from west to east. The apparent movements of the heavenly bodies can then be easily explained: the sun will then appear to rise in the east and to set in the west, as if it really moved round the earth, and the stars will look as if they followed the same course.

Let us try to make this plainer. Set a lamp upon the table to represent the sun. Stick a knitting-needle through the centre of

19. The motion of the Earth shown with an orange.

an orange, and call it the earth. If we hold it as shown in the picture, and turn it round and round by twisting the needle moving the orange always from left to right, the light of the lamp will shine on every side of it in turn, moving round it from right to left, or the opposite way from that in which the orange turns. Stick a pin in one side of the orange and suppose it to be a man standing on any part of the earth; then turn the orange round until the light of the lamp strikes it; this will be sunrise at that place on the earth, and if you keep on turning, by and by the pin will come into shadow again, which will be sunset at that place. The man (pin) on the earth (orange) will really move round with it, while the sun (lamp) stands still, but the sun will look to him exactly as if it moved, and he will seem to himself to stand still.

Thus we, who are upon the earth, are all the while moving round with it, and the sun and the stars come into our view and then pass out of it as we spin round. Our movement being from west to east, things appear to move in the opposite direction, because as the eastern edge of the earth goes down they come into sight above it, and we then keep on moving by them until the western edge of the earth shuts them out of our view.

RECITATION FOR LESSON VII.

When we see the sun rise in the east, pass through the heavens over our heads, and set in the west how does it appear to us?

As if the earth stood still, and the sun moved every day around it.

How do the moon and the stars appear to move?

In the same way, in circles or rounded paths round the earth.

What are these movements called?

The apparent movements of the heavenly bodies, because they really appear to move thus round the earth.

How can these apparent movements be explained?

In two ways: first, by saying that the earth stands still, while the sun and the stars move round it; second, by saying that the earth itself turns round.

Which is the true way?

We know that the sun and the stars do not really move round the earth; therefore the earth must turn round.

In what way must the earth turn round to cause the apparent movements of the heavenly bodies?

From west to east, or the opposite way from which they appear to move.

How will this explain the apparent movements of the heavenly bodies?

As the eastern edge of the earth goes down as it turns around, the other heavenly bodies come into sight above it, and as the earth keeps on moving they appear to cross the heavens above our heads until the western edge shuts them out of sight.

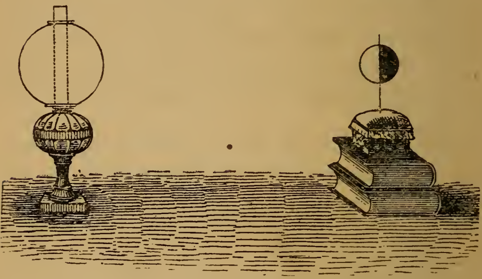
LESSON VIII.

THE EARTH TURNS ROUND ONCE A DAY.

The earth, then, is all the time spinning round like a top, and the sun and the stars appear to us to move only because we on the earth are moving ourselves, just as the telegraph poles, the fences, and the trees appear to move when we are riding past them in the cars.

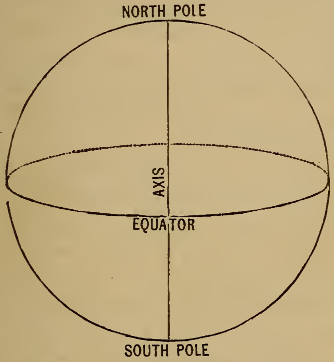
To form a still clearer idea of the movement of the earth, let us return again to the lamp and orange (which we have used to represent the sun and the earth). It will be handier to set up the orange in a pin-cushion, as shown in the picture (20). Twist the needle so as to make the orange turn round slowly in the direction from left to right. The orange will thus turn round the needle just as a wheel turns round on its axle. The straight line which the needle makes through the centre of the orange we will call the axis (Latin, *axis*, an axle-tree) of the orange, because it is the axle or line around which it turns; and the two ends of the axis, or the points where the needle goes into and comes out of the orange, we will call the poles (Latin, *polus*, the end of an axis). Draw a circle round the middle of the orange, at an equal distance in every part from the two poles, and call it the equator (Latin, *æquus*, equal), because it divides the orange into two equal parts.

Now let us apply this to the earth. Of



20. Lamp and Orange.

course the earth has no real axis, but as it always spins round in just the same way, we imagine a line for it to turn on, and call it the earth's axis. The two points where this imaginary line or axis touches the surface of the earth we call the poles, the upper one being named the North Pole and the lower one the South Pole. Nor is there any circle around the earth like that which we have drawn round the orange, but we imagine one at an equal distance between the North Pole and the South Pole, and call it the Equator, because it divides the earth into two equal parts. As the whole earth is a sphere (Greek,



21. The Earth—its Axis, Poles, and Equator.

sphaira) or globe, we call the upper half, or part between the Equator and the North Pole, the Northern Hemisphere (half-sphere), and the lower half, or part between the Equator and the South Pole, the Southern Hemisphere.

To go back to the orange again: set a lamp in the middle of the table to represent the sun, and place the orange and cushion on one side of it. It will be seen that while the side of the orange toward the lamp is lighted up, the other side is in shadow. Stick a pin into the middle of the light side and turn the orange slowly round by twisting the needle; the pin head will pass out of the light into the shadow, go through the shadow, enter the light again, and, by the time that the orange has turned completely round once, the pin head will have reached the place where it started from.

What do we learn from this? We have said that the earth turns round on its axis as the orange does round the knitting-needle. Now, just as the pin head on the orange passes from the light of the lamp into the shadow and then into the light again, in only one turn of the orange, so a like point on the surface of the earth passes out of the light of the sun through the darkness, and round into the sunlight again in exactly one turn. But we know that it takes just twenty-four hours for such a point to go from the light round into the light again (or rather, as the sun does not always rise at the same time, let us say from the noon of one day to the noon of another); therefore we know that it takes the earth twenty-four hours to turn round. In fact, the earth turns on its axis once every day; and as the day is made up of day and night, each side of the earth is brought round into the sunlight once each day, and is cast into shadow once each day. This turning of the earth on its axis is called its rotation.

RECITATION FOR LESSON VIII.

What is the axis of the earth?

The line through the centre of the earth around which it turns.

Is there really such a line through the earth?

No; we only imagine one for the earth to turn around on.

What do we call the two points on the surface of the earth at the ends of this imaginary line or axis?

The poles of the earth.

What are the names of the two poles?

The upper one is named the North Pole, and the lower one the South Pole.

What is the Equator?

A line drawn round the middle of the earth at equal distances from the two poles.

Is there really such a line round the earth?

No; we only imagine one to divide the earth into two equal parts.

What are these two parts called?

The upper half, or part between the Equator and the North Pole, is called the Northern Hemisphere; and the lower one, or part between the Equator and the South Pole, the Southern Hemisphere.

How fast does the earth turn round on its axis?

It goes round once every twenty-four hours

What is this movement of the earth called?

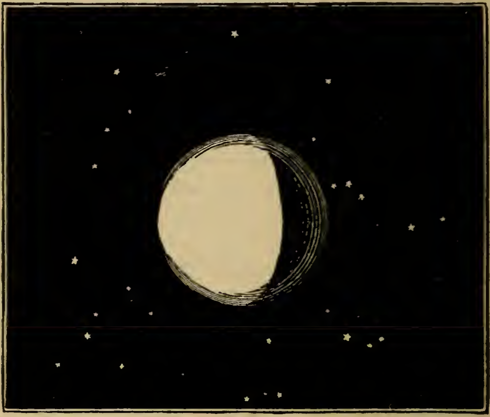
Its rotation.

LESSON IX.

THE TURNING OF THE EARTH CAUSES DAY AND NIGHT.

The earth, then, turns round on its axis once in every twenty-four hours, while the sun is all the time shining steadily in the heavens; and it is this rotation which causes the difference between light and darkness on the earth, which we commonly call day and night. If the earth did not move at all, one-half of it—the side toward the sun—would always be flooded with light, while the side furthest from the sun would always be in darkness. It would therefore be continual day on one side and continual night on the other. But as it does turn round on its axis, it makes the changes of day and night, it being day on our side of the earth when it is night on the other, and night on our side when it is day on the other.

We can now understand the real meaning of morning, noon, and night, of daybreak and twilight, of sunrise and sunset. Suppose that we are standing at some point on the earth's surface—at Washington, for instance—and that it is nearly daybreak. As the earth is turning round on its axis all the time from west to east, its eastern edge is going down and bringing into view new parts of the



22. The Earth in the Heavens lighted on one side by the Sun.

heavens, while its rising western edge is shutting out little by little the heavens on the other side. If the sky is clear we shall soon see a faint dusky light, called twilight, in the east, and we know that the eastern edge of the earth is coming near where the sun shines.

This is the dawn or daybreak, the first appearance of the light of day. This light gets brighter little by little and by and by we see a rosy tint, which, as the edge of the earth comes nearer to the sun, grows more and more yellow until it becomes of the color of fire; soon the edge of the sun comes into view and we call it sunrise. This is the name given to the first sight of the sun in ancient times, when people thought that the sun really rose in the east, moved across the heavens, and set in the west, while the earth stood still; and we still keep the same name, though we do not understand it to mean what the ancients did.

As the earth turns more and more toward the east, the sun appears to rise higher and higher, going toward the west until it gets over our heads. We then say that it is noon or midday, and the time between sunrise and noon we call the morning or forenoon.

After midday the turning or rotation of the earth gradually brings its western edge nearer and nearer to the sun, which is thus made to look as if it moved toward the west; and by and by it appears to us to go down behind the western horizon. The time between midday and sunset we call afternoon, and after sunset we call it evening until night sets in. In most of the Southern states the people seldom say afternoon, but call it evening after twelve o'clock in the day; but this is not the usage in other places.

After the sun has gone out of sight the sky and clouds near the horizon are generally colored with orange, red, and golden tints much like those of morning; but these gradually fade away as the western edge of the earth rises higher and higher, until at last only a gray dusky twilight is left, like that before the dawn. After this comes the night, and if there is no moon, the side of the earth on which we are remains in darkness until it rolls round into the sunlight once more.

While we are in darkness the opposite side of the earth is in sunshine. When it is midnight at Washington it is midday in the centre of China; and when the sun is rising at Washington it is just setting there.

RECITATION FOR LESSON IX.

What causes day and night on the earth?

The rotation or turning round of the earth.

How do you explain this?

When the side of the earth on which we are has rolled round into the light of the sun, it is day with us and night on the other side of the earth; and when the earth has rolled round so far that the sun cannot shine on our side, it is night with us and day on the opposite side of the earth.

What would happen if the earth did not move at all?

It would be always day on one side of the earth and always night on the other.

What is the real meaning of sunrise?

It means that the earth has turned far enough in its rotation to bring the sun into view above its eastern edge.

What is noon or midday?

The time when the earth has turned round far enough to bring the sun over our heads.

What is the meaning of sunset?

It means that the earth has turned round far enough to hide the sun from view below its western edge.

What is twilight?

The faint dusky light seen before sunrise and after sunset.

LESSON X.

THE EARTH MOVES ROUND THE SUN.

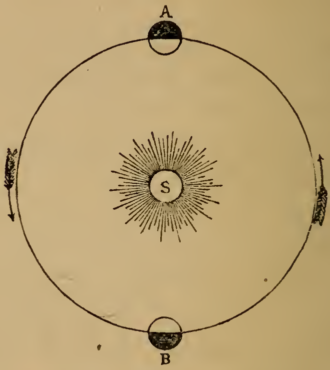
We have thus learned that the earth is all the time turning round on its axis, and that it is this motion which causes day and night. Let us see if this rotation will explain all the movements the heavenly bodies appear to make. As the earth always turns round in the same way, without changing, and as the stars are fixed in the heavens, we ought always to see the same set of stars at the same time—that is, the stars which appear at evening, at midnight, and at sunrise of to-day should appear in exactly the same positions at evening, midnight, and sunrise of every other day throughout the year.

But is it true that the stars always look the same to us at the same time? No; if we study the heavens carefully every night we shall see that the stars are getting further and further toward the west all the time, while new ones are coming into view in the east. In the course of six months they will have become so changed that those which we see at midnight in summer will be different from those which we saw in the heavens at midnight in the winter; but in six months more the same stars first seen will appear again, and the heavens will look just as they did a year before.

If we watch the sun also, we shall see that it appears to have a slightly different position each day in the heavens, being one day at its rising near one star and the next day near another; but when a year has passed away we shall find it again in about the same position in which we first saw it.

The ancients explained these apparent movements of the sun and the stars by saying that they moved in circles round the earth; but we know that they are caused by the movement of the earth round the sun, in a circle, once every year. The earth, then, has two movements: it spins round on its own axis once every day, and it rolls round the sun, somewhat as a ball would roll round a race-track, in a great circle once in about every three hundred and sixty-five (365) days, or a year.

It may at first be difficult to understand how the earth can have these two motions at the same time; but they are very well shown by a spinning-top. It spins round itself very fast, and at the same time moves more slowly round in a circle, thus having two movements at once. It is the same with the earth: it spins round on its axis three hun-



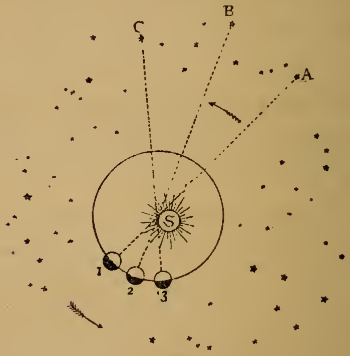
23. Showing the apparent movement of the Stars.

dred and sixty-five times while moving round the sun once.

It is easy now to understand why the stars appear to move toward the west a little every night, and why the sun appears to change its place among the stars. In the picture (23), S is the sun, and A B are different positions of the earth as it moves round the sun. Of course, it is day on the light side of the earth toward the sun, and night on the dark side furthest from the sun. When the earth is at A, a person on the dark side will see at midnight the stars opposite to the sun. As the earth moves onward in its path round the sun, the stars will appear to move, little by little, in the other direction, until, when it gets to B, on the other side of the sun, which will be in just six months, an entirely new set of stars will light the heavens; and in six months more, when the earth gets round to A again, the stars first seen will again come into view.

In the next picture (24) is shown the apparent movement of the sun in the heavens, caused by the real movement of the earth round the sun. When the earth is at the point marked 1, a person on the light side, or side toward the sun, will see the sun in the direction of the star A; but when the earth gets to the point marked 2, the sun will appear to be in the direction of the star B; when at 3, in the direction of C; and so on all round the heavens, the sun appearing in a different place among the stars each day. If you walk around the lamp, and suppose the objects on the wall to be stars, you will see how the lamp appears against different ones from different positions. It is just this way that the sun appears against different stars as we go round it with the earth.

The great pathway in which the earth travels round the sun is called the orbit of



24. Showing the apparent movement of the Sun.

the earth, the word orbit being made from a Latin word meaning a circle. Of course, there is no real path through the heavens, but as the earth always moves in about the same line round the sun, we imagine such a pathway. We are accustomed to call this orbit a circle, but it is not exactly a circle; for it is a little longer than it is wide, being thus a kind of oval, which we call an ellipse. The sun is not exactly in the centre of the earth's orbit, but a little nearer one end than the other.

This annual movement of the earth in its orbit is called the revolution of the earth around the sun.

RECITATION FOR LESSON X.

Does the rotation of the earth on its axis explain all the movements of the heavenly bodies?

No; if the earth always turned round in one place, without changing, the stars seen on any night would appear the same on every other night of the year.

Do they always appear the same?

No; they are continually changing, so that the stars seen in winter are somewhat different from those seen in summer.

But are not the stars seen in one summer the same as those seen in another summer?

Yes; when summer comes round again, the same stars are again seen.

Does the sun ever appear to change its place in the heavens?

Yes; it appears to change its place a little every day, but when the year has passed, it is again in the same position in which it was first seen.

What is the cause of these apparent motions of the stars and the sun?

They are caused by the movement of the earth around the sun once every year.

Has the earth, then, two movements?

Yes; while turning on its axis it is all the while rolling in a great circle round the sun.

What is this circle called?

The orbit of the earth.

What is the movement of the earth in its orbit called?

The earth's revolution round the sun.

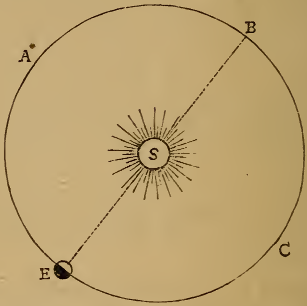
LESSON XI.

THE EARTH'S ORBIT.

The last chapter teaches us that the earth has two motions; one, a spinning motion, in which it turns round on its axis once in twenty-four hours, or a day; the other, a forward motion, in which it moves in its orbit round the sun once in three hundred and sixty-five days, or a year. We have also learned that the first movement makes our day and the changes of day and night; we have now to find out what is caused by the second movement.

To do this we must first learn a little more about the orbit of the earth. The distance of the earth from the sun is so immense that it is almost impossible for us to form any idea of it. Astronomers tell us that it is about ninety-two million (92,000,000) miles, but this long row of figures means very little for us. Perhaps we may form some idea of it when we think that it is three thousand six hundred and eighty (3,680) times the distance round the earth. We have learned before that it takes about three months, traveling on steamships and railway cars, to go round the earth; if we should travel at the same rate toward the sun, it would take us nearly a thousand (920) years to reach it.

It will be seen by the picture (25) that the distance of the earth from the sun at any point



25. Earth's orbit, ABCE; diameter of orbit, EB; Sun, S.

in its orbit is only half that of the diameter or breadth of the orbit—that is, the distance from E to S is half that from E to B; the orbit of the earth must be therefore one hundred and eighty-four million (184,000,000) miles wide. Now, the circumference of the orbit—that is, its length or measure round it —is more than three times as much as its diameter, or five hundred and seventy-seven million (577,000,000) miles. But great as is this distance—so great that our minds can scarcely take it in—the earth travels over it every year. To do this, it has to move nearly eleven hundred (1,097) miles every minute, which is more than a thousand times faster than the speed of the swiftest railway train.

It may be hard to understand how the earth can travel at this great speed through the heavens without our feeling any motion,—indeed, almost without our knowing it; but we must remember that we and everything else on the earth, even the air around it, are borne along at the same speed. Sometimes, when we are riding on the railway, the car moves so smoothly that we do not feel that we are going at all, and it is only when we look out of the window and see the trees, fences, and other things outside appear to go very rapidly in the other direction that we become conscious that we are traveling very fast. So the motion of the earth, though very fast, is so very smooth that we do not feel it, and only know it by seeing the sun and the stars move the other way.

In traveling round its orbit the earth moves always at the same speed, always smoothly, and always keeps in the same plane—that is, at the same level, just as a horse does in running round a very smooth, flat race-course. Imagine a great sheet of pasteboard to be spread out flat from the centre of the sun all round to the earth's orbit, so as to make an immense level surface, and call it the plane of the earth's orbit; this plane is the earth's race-course, for it is in it that the earth always travels in its yearly journey round the sun.

Let us now go back once more to the lamp and the orange and knitting-needle, shown in the picture on page 48. We learned from that, by turning the orange round slowly, that day and night are caused by the spinning round of the earth on its axis once every twenty-four hours. The axis of the earth is there represented as standing straight up and down; if it really stood in this way while the earth is going round in its orbit, the equator would always be in the plane of the earth's orbit, and the two poles of the earth would always be at the same distance from the sun. The rays of the sun would then fall equally on both poles, so that the whole half of the earth within a line drawn round it through each of the poles would be lighted up at once, while the other half would be in darkness.

The days and the nights would then be everywhere of equal length. But we know that they are not of equal length: in our summer the days are long and the nights are short, and in our winter the nights are long and the days are short.

RECITATION FOR LESSON XI.

Can you explain the two motions of the earth?

It turns round on its axis once every day, and rolls round the sun once every year.

How far is the earth from the sun?

About ninety-two million miles.

How long does it take to go round the earth by rail and steamer?

About three months.

How long would it take us to go to the sun if we could travel toward it at the same rate of speed?

Nearly a thousand years.

How much longer than the distance from the earth to the sun is the earth's orbit?

More than six times as long.

How fast must the earth travel to go over this immense distance every year?

More than a thousand times faster than the speed of the swiftest railway train.

Why is it that we do not feel any motion when the earth is traveling at this great speed through the heavens?

Because everything on the earth, even the air around it, is borne along at the same rate of speed.

What do you understand by the plane of the earth's orbit?

The great level field in which the earth moves round the sun.

If the axis of the earth stood straight up and down while it is moving in its orbit around the sun, what would happen?

The days and the nights would be everywhere of equal length.

Are the days and the nights always of equal length?

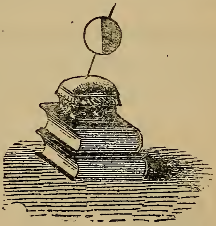
No; in our summer the days are long and the nights short, and in our winter the days are short and the nights long.

LESSON XII.

WHY THE DAYS AND NIGHTS ARE UNEQUAL.

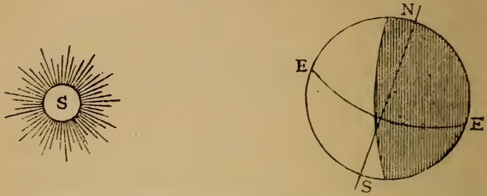
How then can we account for the difference in the lengths of the days and nights in different seasons?

Instead of setting the orange and needle straight up in the cushion, as in the picture on page 48, set it a little slanting, with the top of the needle tipped toward the right. In the four next pictures (27, 28, 29, and 30) the orange thus slanted is shown on four different sides of the lamp, the needle being kept at the same slant in each position. In the first position (27) the lamp being supposed to be at the place marked S, the upper end of the needle is farther away from the lamp than the lower end. If you now turn the orange round, by twisting the needle with your fingers you will see that the light does not



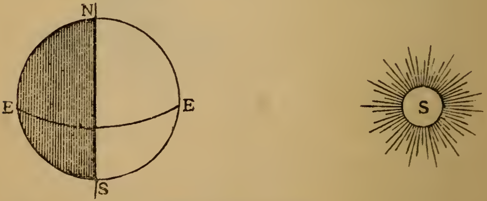
26. Orange with needle slanting.

shine at all on a part round the north pole, while it shines all the time round the south pole, and that all the parts on the line of the



27. First Position. N, North Pole; S, South Pole; EE, Equator.

equator are lightened and darkened equally. If the earth were always in this position toward the sun, it would be always night at



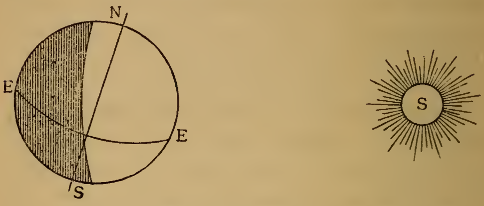
28. Second Position.

the north pole, and always day at the south pole.

Stick a pin in the orange about half way between the equator and the north pole. As the orange turns round you will see that the pin has a longer course to travel on the dark side than on the light side. In these parts, therefore, the nights are longer than the days. But if you stick the pin half way between the equator and the south pole, it will be much longer in the light than in the shadow in passing round the orange; the days, therefore, in these parts are longer than the nights when the earth is in this position.

Move the orange one quarter round the table, as in the next picture (28). You will see, although the needle is kept at the same slant as before, that the poles are now at the same distance from the lamp, and that the light shines equally on them. When the earth is in this position one half of it is in the sunlight, while the other half is in shade, and the days and nights are therefore equal everywhere.

Move the orange another quarter round the table, as in the third position (29). The north pole will now be nearer the lamp than the south pole, and the light will shine all the time round the north pole, while the south pole will be in shadow. When the earth is in this position, therefore, it will be always day at the north pole and always night at the south pole. The pin between the equator and the north pole will now be longer in pass-



29. Third Position.

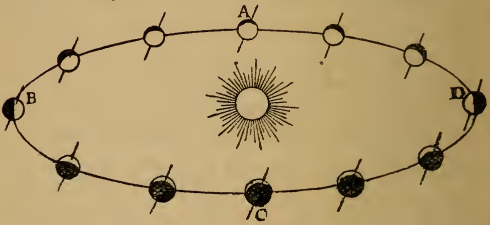
ing through the light side than through the dark side, and in the same parts on the earth the days will be longer than the nights.

30. Fourth Position.

Lastly, move the orange round another quarter; it will then be in the position shown in the fourth picture (30). The poles will now be again at equal distances from the lamp, so that the light will shine on both at the same time. When the earth is in this position, one half is again in the sunlight, while the other half is in the shadow; the days and nights, therefore, are everywhere equal.

It must not be thought, because we have shown four positions of the earth in its journey around the sun by placing the orange on four sides of the lamp, that the earth passes at once from one to another of these positions in traveling round its orbit; it moves from one to another gradually, passing through many other positions as it goes, so that the days and the nights lengthen and shorten little by little. Some of these other positions can be seen in the next picture (31), where the earth is shown at different places in its orbit. Of course in this picture the earth is drawn very much larger in proportion to the sun than it really is, because if it were made of its proper size it would be so small that we could scarcely see it. The axis of the earth, too, is made to extend from the poles, as the knitting needle does from the poles of the orange, so as to show the slant of the axis to the plane of the earth's orbit.

When the earth is at A (position 2 of orange), its axis, though slanting in one way, does not slant toward the sun, but is in all its parts at the same distance from it, so that it is shone upon just as if it stood straight up and down. Both poles are therefore touched by the sunlight, and night and day are equal in all parts of the earth. In passing from A to



31 Different Positions of the earth in its journey round the Sun.

B the north pole of the axis gradually gets nearer to the sun, while its south pole gets farther from it; and during all this time the north pole is in the light, while the south pole is in the dark: it is, therefore, at this time of the year always day at the north pole and always night at the south pole. On the equator the days and nights are of the same length, but in the Northern Hemisphere the days are longer than the nights, while in the Southern Hemisphere the nights are longer than the days. In moving from B to C the axis of the earth becomes less and less slanting toward the sun, until, when it reaches C, the two poles are again at equal distances from it, and the light just touches both again. During this time the north pole has continued in the light and the south pole in the dark, but in the Northern Hemisphere the days have been growing shorter and the nights longer, and in the Southern Hemisphere the nights have been growing shorter and the days longer, until at C both are again of equal length.

We thus see that it has been day at the north pole and night at the south pole during all the time in which the earth has been moving from A through B around to C. The day has therefore continued for six months at the north pole, and the night for six months at the south pole: at the equator the days and nights have all been of the same length, but at most places in the Northern Hemisphere the days have all been longer than the nights, and it has been summer, while at most places in the Southern Hemisphere the nights have all been longer than the days, and it has been winter.

While the earth is passing from C to D the north pole of its axis is gradually getting farther away from the sun, and the south pole nearer to it: the night is therefore just beginning at the north pole, and the day at the south pole; and as the north pole remains in shadow while the earth is moving round through D to A again, it follows that during all this time (six months) it is night and winter at the north pole, and day and summer at the south pole: at the equator the days and the nights have all been of the same length, but at most places in the Northern Hemisphere the nights have all been longer than the days, and it has been winter; while at most places in the Southern Hemisphere the days have all been longer than the nights, and it has been summer.

RECITATION FOR LESSON XII.

How does the axis of the earth stand in the plane of its orbit?

It slants a little toward the plane of its orbit.

Does it always keep in this position?

Yes; it always keeps the same slant while the earth rolls around the sun.

What is caused by this slanting of the earth's axis?

The days and nights are made of unequal length.

Why is this?

Because some parts of the earth are thus kept longer in the sunlight, while others are kept longer in the shadow.

How is it with the parts around the equator?

They are always equally in sunshine and in shadow, and the days and nights there are therefore always of equal length.

How long are the days and nights at the two poles?

Always six months each; and it is always day at the north pole when it is night at the south pole.

Are the two poles ever equally distant from the sun?

Yes; at two points in the earth's journey around the sun the poles are equally distant from it, and the days and nights are then equal all over the earth.

When it is night at the north pole, what is the difference between the days and nights in most other parts of the Northern Hemisphere?

The nights are longer than the days.

When it is day at the north pole, what is the difference between the days and nights in most other parts of the Northern Hemisphere?

The days are longer than the nights.

LESSON XIII.

THE CHANGES OF THE SEASONS.

Now, what have we learned in the last chapter?

First, that although the turning of the earth on its axis makes day and night, the difference in the length of the days and the nights is caused by the yearly movement of the earth round the sun and by the slant of its axis to the plane of its orbit.

Second, that there are two points in the earth's journey in its orbit round the sun where the slant of its axis makes no difference in the length of the days and nights, because its two poles are then at the same distance from the sun.

Third, that the days and nights are always of equal length on the line of the equator, in whatever position the earth may be in its orbit.

Fourth, that it is always day at the north pole and night at the south pole during the six months of the year when the north pole of the earth's axis is the nearer to the sun, and always night at the north pole and day at the south pole during the six months when the south pole of the earth's axis is the nearer to the sun.

Fifth, that at places between the equator and the poles the days and the nights are of unequal lengths whenever either of the poles is tipped toward the sun.

If you clearly understand these things, you can also understand how this difference between the length of the days and nights causes the changes of the seasons—spring, summer, autumn, and winter. Heat, like light, comes from the sun, and it is when we have the most light (in the day-time) that the earth becomes heated, and when there is the least light (in the night-time) that it becomes cooled. It becomes most heated then when the days are longest, and most cooled when they are shortest; and summer is the season of long days and winter the season of long nights, while spring and autumn are the seasons when the days and the nights are more nearly equal in length.

In the Northern Hemisphere, in which we live, the nights are longest in December; the earth there has less of the sun than at any other time of the year, and therefore becomes most cooled, and we call it winter. After that the days begin to grow a little longer, and the earth to get more sun, until in March the days and the nights become equal in length, and we call it spring. From this time the days grow longer little by little, so that the earth gets more light and heat, until June, the season of the longest days and the shortest nights, when we call it summer. From summer the days grow shorter and shorter until they become of the same length again with the nights, in September, when we call it autumn, and the nights then grow longer than the days until winter comes round again in December.

We have learned that when the nights are longest in the Northern Hemisphere the days are longest in the Southern Hemisphere; therefore when it is winter here it must be summer there. This will be understood more easily by looking at the picture on page 76. When the earth is at the point in its orbit marked D (about December 21), the south pole is nearest the sun: it is therefore summer in the Southern Hemisphere because the days are long and the nights are short, and winter in the Northern Hemisphere because the nights are long and the days are short. Winter continues in the Northern Hemisphere for three months while the earth is moving round toward the point marked A. When A is reached (about March 21) the days and nights are equal, and it is spring in the Northern Hemisphere and autumn in the Southern Hemisphere. Spring continues in the Northern Hemisphere for three months while the earth is moving round to B. When it reaches B (about June 21), the north pole is nearest the sun: it is therefore summer in the Northern Hemisphere, because the days are long and the nights are short, and winter in the Southern Hemisphere because the nights are long and the days are short. Summer continues in the Northern Hemisphere for three months while the earth is moving round toward C. When it reaches C (about September 21), the days and nights are again equal, and it is autumn in the Northern Hemisphere and spring in the Southern Hemisphere. Autumn then continues three months in the Northern Hemisphere, until the earth reaches D, when winter again begins.

The positions of the earth in its orbit marked A and C in the picture on page 76 are called the equinoxes—that is, the times of equal nights (and days), (Latin *æquus*, equal, and *nox*, night), A being with us the vernal (spring) equinox, because it is then spring in the Northern Hemisphere, and C the autumnal equinox, because it is then our autumn. The other two positions of the earth, B and D, are called the solstices (Latin *solstitium*, from *sol*, the sun, and *sistare*, to stand still), that is, the standing still of the sun, because the sun then appears to stand still for a few days; B being in the Northern Hemisphere the summer solstice and D the winter solstice.

RECITATION FOR LESSON XIII.

What is caused by the difference in the length of the days and the nights?

The changes of the seasons—spring, summer, autumn, and winter.

How do you explain this?

Heat as well as light comes from the sun; when the days are longest therefore the earth becomes most heated, and we then have summer; and when the nights are longest the earth becomes most cooled, and we then have winter.

What then are spring and autumn?

The seasons when the days and the nights are nearly equal in length.

When does winter begin in the Northern Hemisphere?

In December, because then the nights are longer than the days.

About what time are the nights longest?

About December 21.

Do they continue of the same length?

No; they grow a little shorter every day until March 21, when they are of about equal length with the days, and we then call it spring.

Do they remain long of equal length?

No; the days then grow a little longer until about June 21, when they reach their greatest length, and we call it summer. They then grow shorter all the while till September 21, when the days and nights are again of equal length, and we call it autumn.

How long do the nights then grow longer?

Until December, when winter comes round again.

When it is winter in the Northern Hemisphere, is it also winter in the Southern Hemisphere?

No; when it is winter here, it is summer there, and when it is spring here, it is autumn there.

LESSON XIV.

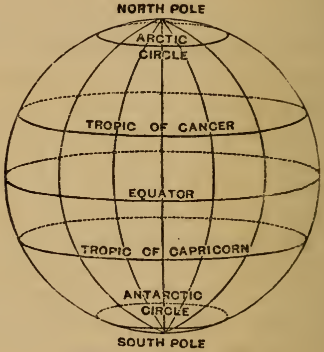
CLIMATE AND THE ZONES OF THE EARTH.

We have thus learned that the four seasons —spring, summer, autumn, and winter—are caused by the difference in the lengths of the days and nights, and that the seasons differ on opposite sides of the earth because when the days are long and the nights are short on one side, the nights are long and the days are short on the other. It is now easy to understand why it is winter in China when it is summer in the United States, and summer there when it is winter here; but we must not make the mistake of thinking that seasons like ours are found all over the world, for they belong only to those parts of the earth called the temperate zones.

We shall understand this better if we first learn something about climate. The sun does not shine alike on all parts of the earth; some parts therefore get much more heat than others, and thus it follows that while some countries have a warm climate, others have a cold climate. Let us set up the orange and knitting-needle once more in front of the lamp; we shall see that the light falls straight upon the middle part of the orange, that is, on the part around the equator, that it falls slanting on the parts half way between the equator and each of the poles, and still more slanting on the parts near the poles. It is the same with the earth; all its parts are warmed and lighted by the sun as it turns round, but not all equally; the parts around the equator get the direct heat of the sun's rays, as we do at noon, and are therefore the warmest parts of its surface, the heat lasting all the year round; while those at the poles get the rays very slanting, as we do at evening, and are therefore the coldest parts of the earth—the regions of everlasting snow and ice. Between these two are more temperate climates, where the heat and the cold are about equal, and where only the seasons change four times each year.

We thus divide the surface of the earth into several zones or belts, as shown in the picture (32), by drawing round it circles parallel to—that is, running the same way with—the equator. The two circles nearest the equator, one above and one below it, are called the tropics, the northern one being called the

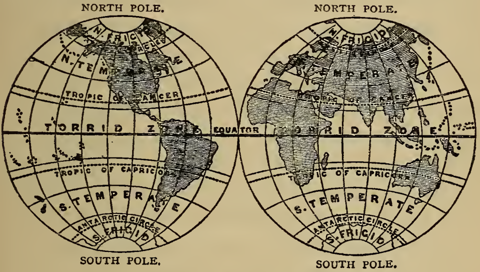
Tropic of Cancer, and the southern one the Tropic of Capricorn; the zone or belt between these circles is called the Torrid Zone, that is, the hot zone, because it is the place of the greatest heat. The sun shines directly upon it all the days of the year, so that it is



32. The Circles of the Earth.

hot continually, and has no change of seasons like ours.

The Polar Circles are circles drawn round each of the poles, at a certain distance from them. The one round the north pole is called the Arctic Circle, and the one round the south pole the Antarctic Circle. The zone between the Arctic Circle and the north pole is called the North Frigid or cold Zone, and the one between the Antarctic Circle and the south pole the South Frigid Zone. As the sun shines upon these zones during only a part of the year, and with very slanting rays, they are the coldest parts of the earth. They have not four seasons like ours, but winter



33. The Zones of the Earth.

lasts through nearly half the year, and summer through nearly the other half; but the sun's rays give but little heat, and the summer is scarcely warm enough to melt the snow. At the poles themselves the day lasts for six months, and is followed by a night of six months, so that the polar day and year are the same.

Between the tropics and the polar circles lie the temperate zones, or zones of moderate heat; the one between the Tropic of Cancer and the Arctic Circle being called the North Temperate Zone, and the one between the Tropic of Capricorn and the Antarctic Circle being called the South Temperate Zone. In these two zones the rays of the sun do not fall upon the earth so straight as they do in the torrid zone, and the heat is not so great as it is there; they also fall upon it less slanting than in the polar circles, and the cold is not so intense as there; their climate therefore is much more moderate than that of either of the other zones, and much better fitted for mankind; and it is only in them that regular changes in heat and cold enable us to divide the year into four seasons.

It must be borne in mind that these circles, by which we divide the surface of the earth into zones, are, like the equator, only imaginary lines, and that there are really no such divisions. It must also be clearly understood that the climate is not exactly the same in all parts of each of the zones; in the torrid zone, for instance, it is hotter near the equator than in the parts near the temperate zones, and that in either of the temperate zones the parts near the torrid zone are warmer, and the parts near the polar circles cooler than the middle parts. There are also other differences that cannot be explained here.

RECITATION FOR LESSON XIV.

Are seasons like ours found all over the earth?

No; they belong only to those parts of the earth called the temperate zones.

Does the sun shine alike on all parts of the earth?

No; its rays fall straight on the parts around the equator, and they therefore get its full heat and are the warmest parts on the earth's surface; but they fall very slanting on the parts around the poles, and those parts therefore get little heat and are the coldest parts on the earth's surface.

Are there not parts on the earth's surface where the heat and the cold are nearly equal?

Yes; the parts between the equator and the poles.

What are these differences in the heat of different parts of the earth called?

Climate.

How is the earth divided according to climate?

Into five zones or belts: the zone around the equator is called the Torrid Zone; that around the North Pole the North Frigid

Zone, and that between this and the Torrid Zone the North Temperate Zone; the zone around the South Pole is the South Frigid Zone, and that between it and the Torrid Zone the South Temperate Zone.

Is the climate in all parts of each of these zones exactly alike?

No; in the torrid zone the parts near the equator are much hotter than those near the temperate zones; and in the temperate zones the parts near the torrid zone are warmer and those near the frigid zones are cooler than the middle parts.

LESSON XV.

THE SUN.

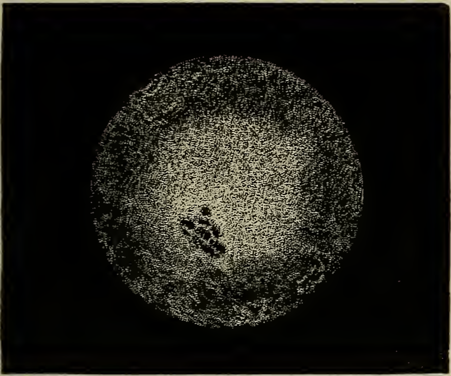
We have now learned that the earth is a globe which moves round the sun once every three hundred and sixty-five (365) days, and that it is this movement which makes our year; that it also spins round on its own axis once in twenty-four (24) hours, thus making our day, and that the division of the day into day and night on any part of the earth is caused by that part's coming into and going out of the sunlight. We have also seen that the difference in the length of the days and nights is caused by the slanting of the earth's axis, so that the sun shines longer on some parts than on others, and that this causes climate and the changes of the seasons.

Thus from the sun comes our heat and light. Without it the earth would be an icy desert, covered with eternal darkness, wholly unfit for the growth of plants and animals, and unsuited for the abode of man. What then is this sun, on which depends the very life of everything on our earth?

It is dangerous to look at the sun when it is shining brightly, either with the eye alone or through a telescope, as one may easily be blinded by it; but it may be looked at safely through a piece of glass smoked over a candle. It appears, when seen in this way, like a round bright object, and not very large—not much larger, indeed, than the full moon commonly looks; but we would make a mistake if we should judge of its size from its appearance alone, for the further away any object is, the smaller it looks to us. We have already learned (Lesson X.) that the sun is distant from the earth about ninety-two million (92,000,000) miles; it must then be of immense size to look even as large as it does from such a distance.

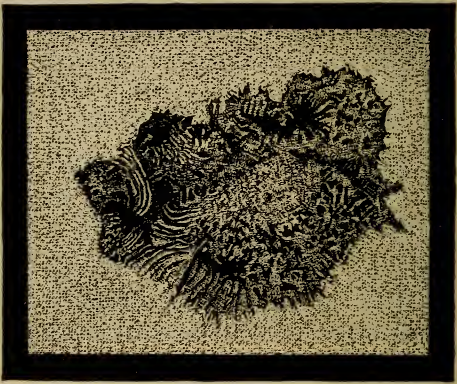
The earth, around which it takes us three months to travel by means of railways and steamships, seems very large to us; but if we should make one and a quarter millions of globes as large as it into one great ball, it would not be as large as the sun. Indeed, compared with the great sun, our earth is a very small thing in the universe.

When viewed with the eye alone the sun appears to be of nearly the same brightness in all parts, but when viewed through a telescope it is seen to be brighter in the centre than in the outer parts. Its surface has a mottled or blotchy appearance, as if strewn all over with something shaped like little grains, as shown in the picture (34), which is made from



34. Photograph of the Sun. [Newcomb and Holden's Astronomy.]

a photograph. Dark patches or spots are also seen on parts of its surface, sometimes singly and sometimes in groups, some of them small and some so large that several globes of the size of our earth would not cover one of them. When looked at through a very large telescope, these spots are seen to be not merely patches on the surface of the sun, but deep holes in it. They generally look darkish in the middle, with a ragged fringe or border of a lighter color, much like that shown in the picture (35). By carefully



35. A Sun Spot. [Newcomb and Holden's Astronomy.]

watching these spots, they have been found to move slowly from the east side of the sun's face toward the west side. After going out of sight on the west side, they have been seen to appear again on the east side, and to pass across the sun's face as before, going thus entirely round it in about twenty-five days. It is supposed from this that the sun is all the time moving round and carrying these spots with it, and that it therefore turns on its axis as the earth does, but much more slowly than the earth, going round only once in about twenty-five or twenty-six days.

When the sun is hidden from us by the moon in a total eclipse, as told about in Lesson XVIII., it presents a far grander appearance than it usually does. As soon as its face is hidden by the moon, a beautiful silvery or pearly light is seen glowing all round the globe of the moon, brightest next to the moon, and shading off little by little toward the outer edge. This is called the *corona* (Latin for crown), because it looks much like a crown of light. It is not always round, but is sometimes more nearly square, and sometimes has points like rays of light extending from it, as shown in the picture. Besides the corona, jets of reddish flame are seen to shoot out at different places around the moon's disk, like great tongues of fire. It was once thought by many that the corona and the jets of flame belonged to the moon, but it is now known that they are parts of the sun. We cannot tell exactly what causes the corona, but the

36. Corona of the Sun during the Eclipse of July 29, 1878.
[Newcomb and Holden's Astronomy.]

flame jets are supposed to be masses of burning gas which shoot up from a layer of burning gases by which the surface of the sun is surrounded. This layer is called the chromosphere or color sphere (Greek, *chroma*, color, and *sphaira*, sphere), because it colors in some degree the light of the sun. It cannot be seen with the naked eye, and seldom through a telescope. The chromosphere is made up chiefly of hydrogen gas, and is thought to be much like an ocean of fire, which is always in motion, like flames blown by the wind, and from which the fiercely blazing vapors frequently spout up hundreds of thousands of miles.

Under the chromosphere is the surface of the sun, which is the only part commonly seen. This, which looks to us like a shining globe, is called by astronomers the photosphere or light sphere (Greek *phos*, light, and *sphaira*, sphere), because from it comes the light of the sun. We do not know exactly how the great globe of the sun is made, but the best astronomers now think that the surface or photosphere is a solid or nearly solid crust, and that its inside is made up of gases packed very closely together, but which are kept from becoming liquid by the heat. This heat is so great that we have nothing on the earth to compare it with, metals and other minerals being turned into vapor by it as easily as water is turned into steam here. We know this by examining the light of the sun with the spectroscope, which shows that it is made up not only of burning hydrogen and oxygen, but also of the gases of iron, zinc, copper, nickel, cobalt, aluminum, sodium, magnesium, calcium, and other metals.

The sun, then, is an immense globe, made up mostly of highly heated gaseous matter, turning on its axis in the heavens, and giving off light and heat to all around it. The earth is at such an immense distance from it that it gets but very little of this light and heat, but even this little is often strong enough to be very uncomfortable. If we were much nearer to the sun, we would be blinded and scorched by its rays; and if we were much farther from it, we would have neither light nor heat enough for our comfort.

RECITATION FOR LESSON XV.

From whence comes our light and heat?

From the sun.

How large does the sun look when seen through smoked glass?

About as large as the full moon.

Can we judge of its size in this way?

No; because it is a great distance from us; and the farther a thing is away the smaller it looks.

How large is the sun compared with the earth?

It is more than one and a quarter million times as large as the earth.

How does the sun look through a telescope?

It looks brighter in the centre than in the outer parts, and appears to be strewn over with something like little grains.

What else can be seen?

Dark patches or spots, which are seen, when viewed through a very large telescope, to be holes in its surface.

How do these spots appear to move on the sun?

They appear to move across from the east to the west side, then go out of sight, and in time to come again on the east side and move across the sun's face as before.

How long does it take the spots to thus go round the sun?

About twenty-five days.

What do we conclude from this?

That the sun turns round on its axis once in about twenty-five days, carrying the spots with it.

What is seen when the sun's face is hidden by the moon in a total eclipse?

A crown of silvery light, called the corona, is seen all around the moon, and jets of reddish flame shoot out like tongues of fire.

What causes these appearances?

They come from the sun. We do not know exactly what causes the corona, but the flame jets are supposed to be burning gases which shoot up from the sun.

With what is the sun supposed to be covered?

With a layer of burning gases much like an ocean of fire, which is always in motion, and from which fiercely blazing vapors spout up hundreds of thousands of miles high.

What is this gaseous layer called?

The chromosphere.

What is the photosphere?

The surface of the great globe of the sun, which lies under the chromosphere.

Which is the part commonly seen?

The photosphere; the corona and the chromosphere can be seen only when the sun is hidden by the moon.

How do the best astronomers now think that the globe of the sun is made up?

They think that the photosphere is a solid or nearly solid crust, and that the inside of the sun is made up of gases packed very closely together.

Do we know what any of these gases are?

Yes; by examining the light of the sun, it has been found to consist of burning hydrogen and oxygen, and of the gases of many metals.

Do these burning gases give out great heat?

Yes; so great that if the earth were much nearer the sun, we should be blinded and scorched by its rays.

LESSON XVI.

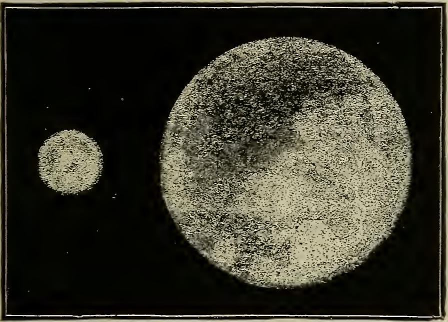
THE MOON AND ITS PHASES.

We have learned that the sun gives us light and heat. But, one may say, the moon gives us light by night; how then do we get all our light from the sun? It is true that we get some light from the moon, but it is not its own light; the moon gives no light of its own, but only reflects the light of the sun.

Every object which we see shone upon by light reflects or bends some of the rays of that light to our eyes, and enables us to see the object. Other rays fall on objects around us, and are in turn reflected to our eyes by those objects, so that we are enabled to see them also. So, although the moon has no light of its own, it reflects to us a part of the sun's rays, and these form in our eyes an image of the moon which we can see, and other rays from the moon falling on objects around us are again bent or reflected to our eyes so that we can see them also; and thus it is that everything which the moon lights on the earth is seen by us.

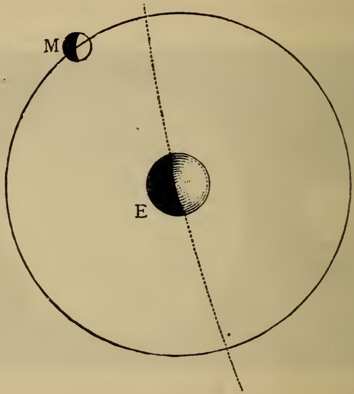
Why then is it, one may ask, that we do not always see the moon alike? The sun is always shining in the heavens, but sometimes the moon looks large and round to us, and sometimes small and narrow like a crescent, while at other times we cannot see it at all.

To understand this well we must first learn



37. The Moon and the Earth—comparative size.

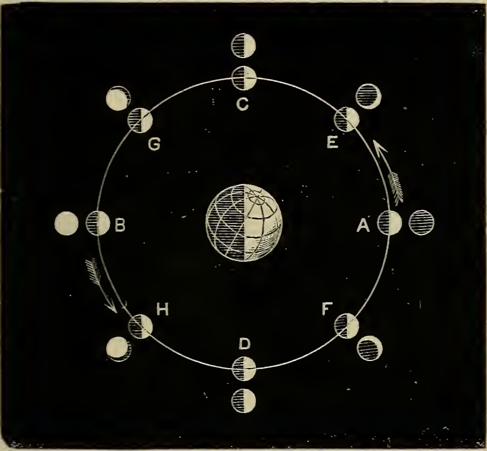
something more about the moon. Like the earth, the moon is a globe which floats in the heavens. It looks to us to be nearly as large as the sun, but it is really much smaller than the earth (it would take about fifty balls like the moon to make one globe of the size of the earth), and looks larger, only because it is near to us—that is, near compared with the distance of the sun. Its distance from the earth is about two hundred and forty thousand (240,000) miles, or about ten times the earth's circumference. So, if we could use the same



38. The Moon in its Orbit.

means of travel, it would take only about ten times as long to go to the moon as to go around the earth. This seems to us on the earth a great distance, but it is really very small when we think of the immense size of the universe and the distances of the other heavenly bodies, for the moon is much nearer to us than any other of them.

Now, we know, for reasons which cannot be explained here, that the moon is all the



39. The Moon and its Phases.

time moving round the earth, while the earth is moving round the sun. The orbit, or pathway, of the moon is nearly a circle, and it takes it about a month to travel round it once. It is shone upon by the sun during this time, but as it is a sphere or globe, only the half of it toward the sun is lighted up by the sun's rays, while the other half is in shadow. Sometimes we on the earth see the whole of the light side, sometimes only a part of it, and sometimes the dark side is toward us so that none of the sun's rays are reflected to us, and then we do not see it at all.

These different appearances of the light part of the moon, as it moves round the earth, are called its phases Greek, *phasis*, appearance. We shall understand them better from the picture (39), which shows the earth and the moon in eight different positions in its orbit around it. In this the earth is in the center, and *AECGBHDF* is the moon in different places in its orbit, with one-half of it lighted up by the sun, supposed to be at a very great distance away on the right. The outside globes show the way the moon in these different positions looks to us on the earth. When the moon is at *A*, between the earth and the sun, it is said to be in conjunction (Latin, *conjunctum*, joined or united), because the two appear to be joined together. When in conjunction, the light side of the moon is turned entirely away from the earth, and we cannot see it at all. It is then called new moon, for the moon is really there although not visible to us.

Soon after leaving the position at *A*, a part of the moon on the side toward the sun begins to be seen, like a narrow crescent, with the horns, turned from the sun, as in *E*. The crescent (Latin, *crescens*, growing, so called because it increases in size) grows wider as the moon travels on, until at *C* one-half of the lighted part—that is, one-quarter of the whole moon—can be seen from the earth, and the moon is then said to be in her first quarter.

More and more of the lighted side now becomes visible to us as the moon moves on, until at *G* we see more than half of the lighted side, and the moon is said to be gibbous (Latin, *gibbus*, hump-backed)—that is, swelled or rounded out. At *B*, when the moon is on the opposite side of the earth from the sun, it is said to be in opposition (Latin, *oppositum*, set or placed opposite). The whole of the lighted side is then seen, and we call it full moon.

In passing round the other side of her orbit the moon shows the same forms, only in the backward order; thus, at *H* she looks as she did at *G*, and is again called gibbous; at *D*, when she is said to be in her last quarter, she presents the same appearance that she did at *C*, and at *F* the same that she did at *E*, until, when she reaches *A* again, she is once more invisible to us, and we again have new moon. Some of the ancients had singular notions about the changes of the moon. The people of Hindoostan used to say that the moon was full of nectar, which the gods ate little by little, and that this was the cause of its growing smaller when it waned; and that the nectar grew again when the moon waxed or became large again. Some savage nations think that the moon breaks up into stars when it becomes small, and is made anew each month.

It must not be forgotten that the earth is all the time moving round the sun while the moon is moving round the earth, and that the moon itself is thus always traveling with the earth round the sun. It is therefore called the satellite (Latin, *satelles*, an attendant) or attendant of the earth, because it follows it around as a servant does his master.

It has been said that it takes the moon about a month to travel round the earth once. The real time between one new moon and the next is about twenty-nine and a half days.

RECITATION FOR LESSON XVI.

Whence does the moon get its light?

From the sun; the moon has no light of its own.

How are we enabled to see anything?

Everything we see shone upon by light reflects or bends a part of that light to our eyes; and this is what enables us to see the thing thus shone upon.

How does this explain the moonlight?

The sun shines upon the moon, and a part of the light which it gets is reflected to us so that we are able to see the moon and the things on the earth which it lights.

What is the moon?

A globe like the earth, but much smaller than it.

Why then does it look nearly as large as the sun?

Because it is very near to us, compared with the distance of the sun.

How far is it from the earth?

About two hundred and forty thousand miles.

How long would it take to go to the moon if we could use the same means of travel that we do on the earth?

About ten times as long as it would take to travel round the earth.

What motion has the moon?

It revolves in its orbit around the earth, just as the earth revolves around the sun.

How long is it in going round in its orbit?

About a month.

Why does not the moon always look the same to us?

Because only the half of it toward the sun is lighted by its rays; sometimes we see the whole of the light side, sometimes only a part of it, and sometimes, when the dark side is toward us, we do not see it at all.

What are the different appearances of the moon called?

Its phases.

What are the principal phases of the moon?

When the dark side is toward us it is called new moon; when a quarter of the bright side can be seen, it is said to be in its quarter; when three-fourths can be seen, it is called gibbous; and when the whole of its lighted side is toward us, it is called full moon.

When is the moon said to be in conjunction?

When it is between the earth and the sun.

What is new moon?

When the light side of the moon is turned from us so that we cannot see it at all.

When is the moon said to be in her first quarter?

When it first shows, after new moon, one-half of its lighted part.

When is the moon called gibbous?

When more than half of the bright side is shown, so that it appears to be rounded or swelled out.

What is full moon?

When all the bright side is shown to us.

When is the moon said to be in opposition?

When it is on the opposite side of the earth from the sun.

When is the moon said to be in her last quarter?

When it shows, just before new moon, one-half of its lighted part.

Why is the moon called the earth's satellite?

Because it follows the earth around the sun as a servant follows his master.

LESSON XVII.

WHAT THE MOON IS LIKE.

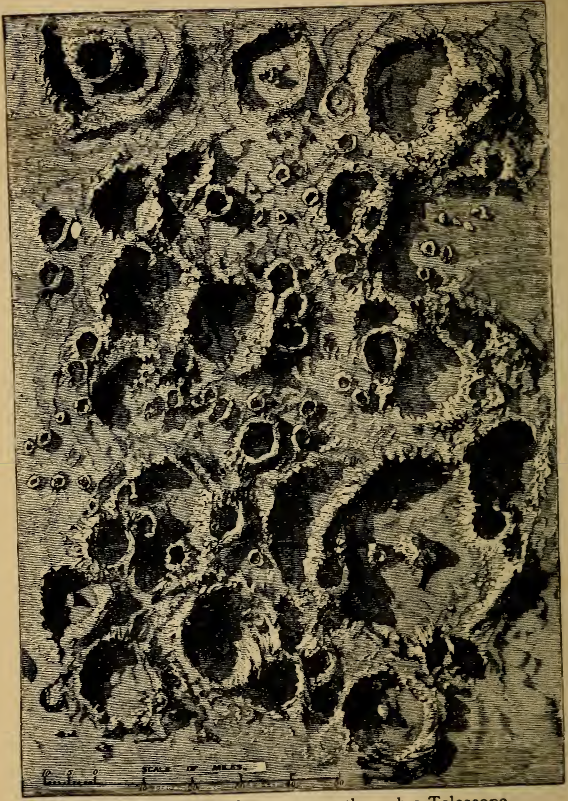
If we look with the unaided eye at the moon when it is full or nearly full, on a clear night, we shall see that some parts of its surface are darker than others, giving it a mottled appearance. These spots or blotches somewhat resemble the features of a human face, and probably gave rise to the story of the man in the moon. But when the moon is viewed through a telescope this appearance changes, and the surface is seen to be made up of mountains, valleys, and plains.

The moon has been studied very carefully by astronomers, and we have now good maps of its surface, on which the different parts are carefully set down and named. The darker patches were thought in former times to be seas, and on the maps they are still called seas, though they are now known to be plains of dry land. Most of their names are fanciful, such as Oceanus Procellarum (Ocean of Storms), Mare Tranquillitatis (Sea of Tranquillity), and Mare Imbrium (Rainy Sea).

These level regions cover about one-third of the part of the moon which we can see, for, as will be shown presently, we never see but one side of the moon. No seas, lakes, nor rivers are visible anywhere; indeed, so far as we know, there is no water at all in the moon and no atmosphere or layer of air around it. There can then be no clouds, dew, nor rain, and therefore no life, vegetable or animal, such as we know on the earth.

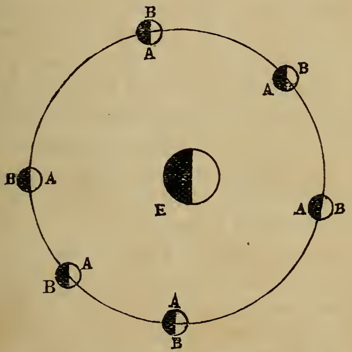
The surface, as seen through a strong telescope, looks like a desert waste, as rough and arid as a volcanic region on the earth, covered in parts with rugged mountains and craters. The moon mountains are different however, from those on the earth, being generally in the form of rings enclosing a plain, from which rise cone-like peaks of a lower height; and sometimes there is only a single round peak in such a plain. Many of the mountains look like the craters of dead volcanoes, but no living volcanoes have been found, although some astronomers have thought that they saw signs of life in some of them.

The picture (40) gives a general view of a part of the surface of the moon, as seen through a strong telescope, showing the ring mountains and, in some cases, the peaks within them.



40. The Moon's Surface, as seen through a Telescope.
[Newcomb and Holden's Astronomy.]

The height of many of the moon mountains has been measured as carefully as that of mountains on the earth, and some of them have been found to be nearly as high as the highest ones on the earth (25,000 to 30,000 feet, or more than five miles). They are, therefore, really higher in proportion, because the moon is so much smaller than the earth. All these



41. Showing that the Moon always has the same side toward the Earth. E, Earth; A, side of Moon always toward the Earth; B, side always from the Earth.

mountains, like the great plains, have been laid down in the maps and named, mostly after great philosophers and astronomers, such as Newton, Herschel, and Kepler.

In looking at the moon we always see the same spots in nearly the same places on its surface, and from this we know that it always presents the same face to us, and one side of it is never seen by us. If you walk round a table, always keeping your face toward the middle of the table, you yourself will turn completely round once in going round the table once; yet only one side of you will ever be toward the table. Now call yourself the moon and the table the earth, and you will easily understand how the moon can turn on its axis once while going round the earth once, and why it is that we never see but one side of it. For certain reasons, which will not now be explained, we really see a little more than half of the moon's surface, so that only about three sevenths of it is hidden from us.

The moon has therefore two motions: first, a motion round the earth, in which it presents to us its different phases, passing from new moon to full moon and back to new moon again in about twenty-nine and a half days; second, a motion round its axis, turning round once in just the same time. As the spinning round of the earth on its axis makes day and night on the earth, so the turning of the moon makes day and night in the moon; but while our day is only twenty-four hours long, the moon day lasts a month, each day and each night being nearly fifteen of our days in length. During the long day, with the sun always shining, the heat must be very great; and during the long night, when no sun warms it, the cold must be terrible. There is no twilight there before sunrise and after sunset, as on the earth, but day begins and night comes on almost at once.

RECITATION FOR LESSON XVII.

How does the moon look through a telescope?

Its surface is seen to be covered with mountains, valleys, and plains.

What were its plains once thought to be?

They were thought to be seas, and they are still called seas on maps of the moon, though they are now known to be only dry land.

Is there no water on the moon?

None can be seen by us, and no atmosphere or layer of air has been found around it.

What follows from this?

That there can be no clouds, dew, nor rain, and therefore no life such as we have on the earth.

What is the general appearance of the moon?

It looks like a desert waste, covered in parts with rugged mountains.

Are there any volcanoes to be seen?

Many of the mountains are hollow at the top like volcanoes, but no living volcanoes have been seen in the moon.

Have the heights of any of these mountains been measured?

Yes; and they are higher in proportion than mountains on the earth.

What other motion has the moon besides its motion around the earth?

It turns round once on its axis while going round the earth.

What happens from this?

That the same side is always toward us, and we therefore never see the other side of the moon.

Do we not really see a little more than half of it?

Yes, we see about four sevenths; so only three sevenths are hidden from us.

Is there any day and night on the moon?

Yes; but the day there is about a month long, each day and each night being nearly fifteen of our days in length.

Must it not also be hotter and colder there than on the earth?

Yes; during the long day the heat must be very great, and during the long night, when no sun warms it, the cold must be terrible.

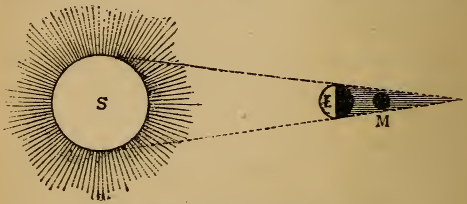
LESSON XVIII.

ECLIPSES OF THE MOON.

The earth, while revolving in its orbit around the sun, always casts a great shadow in the heavens on the opposite side from the sun; and when the moon, moving in its orbit around the earth, comes into this shadow we say that the moon is in eclipse.

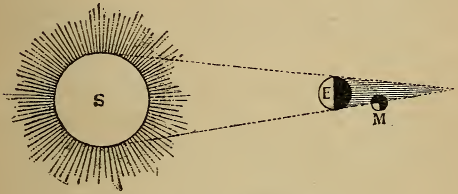
We shall understand this better if we return once more to our lamp and orange, the former of which, placed in the middle of the table, stands for the sun and the latter, near the edge of the table, for the earth. The lamp lights up only one side of the orange, leaving the other side in shadow. If you hold a sheet of paper behind the orange you will see that the shadow cast upon it is as round as the orange itself. Move the sheet of paper back from the orange little by little, and the shadow on the paper will become smaller and smaller until it finally ends. You will thus see that the shadow behind the orange is shaped like a cone—that is, large and round at one end and coming toward a point at the other, something like a sugar-loaf. Now hold a small plum hung on a string to represent the moon in the shadow, and it will be wholly cut off by the shadow of the orange from the light—that is, it will be in eclipse.

It is the same with the shadow of the earth. Since the sun is much larger than the earth, and the earth is round, the shadow of the earth must be like a cone, whose point is on the side opposite to that on which the sun



42. Total Eclipse of the Moon.

shines. The length of this shadow is more than three times the distance of the moon from the earth, and when the moon in passing in its orbit round the earth comes into it the rays of the sun are cut off from it, and as the moon has no light of its own, it is hidden in this shadow, or eclipsed. This can easily be seen in the picture (42), where S is the sun, E the earth, and M the moon; the moon, cut off from the sunlight by the shadow of the earth, is in eclipse. It will be remembered that when the moon is on the opposite side of the earth from the sun, so that the earth is between the two, the moon is said to be in opposition, and it is then full moon. This is the only time that an eclipse of the moon can take place, because the moon must have its bright side toward us to be eclipsed. Of course,



43. Partial Eclipse of the Moon.

when its dark side is toward us there is no moonlight to be eclipsed.

As the moon is in opposition once every month, it may seem to you that there ought to be an eclipse every month. This would be so if the moon passed exactly behind the earth, each time it goes round; but it sometimes passes a little above and sometimes a little below the cone of the earth's shadow, and then of course there is no eclipse. Sometimes it passes through the edge of the shadow, so that only part is cut off from the sunlight, and the eclipse is then said to be partial (43); but when the whole of the moon enters into the earth's shadow, the eclipse is said to be total. The length of a total eclipse differs according to the part of the shadow through which the moon passes. If it goes through the middle of the shadow, which is about three times as broad as the moon itself, it may be in eclispe nearly two hours; but the time is generally much less.

Although the eclipse is called total when the whole of the moon is in the earth's shadow, the moon is not always entirely hidden from view when eclipsed; for, though this sometimes happens, it is very rare. It usually appears, when in the middle of the shadow, of a dull copper-red hue, something like the color of the sun when looked at through smoked glass. When the eclipse is partial, only the part within the shadow is of this dark color.

Let us once more return to our lamp and orange. By holding the sheet of paper again so that the shadow of the orange will fall on it, we shall see that there is a kind of half-shadow all around the real shadow of the orange. There is a like half-shadow all round the cone-shaped shadow of the earth. This, which is called the *penumbra* (Latin *pene*, almost, and *umbra*, a shadow), is where only a part of the sun's rays are cut off by the earth. When the moon is in the penumbra it is only partly hidden, and is not of so dark a color as when in the shadow itself. Sometimes the moon passes partly within the penumbra without touching the true shadow at all; in such an eclipse it is not much darkened.

It is during a partial eclipse of the moon, that the shadow of the earth can be seen, and it is from this that we get one of the proofs that the earth is round like a globe or sphere (see Lesson 2). When the moon enters only partly into the shadow of the earth, the rounded edge of the shadow can be seen on the bright part of the moon; this edge, if continued round, would form a circle, and we thus get the shape of the shadow, just as we did when we held the sheet of paper behind the orange. As only a round thing casts a round shadow, we conclude that the earth must be round.

RECITATION FOR LESSON XVIII.

When is the moon said to be in eclipse?

When it is in the shadow of the earth.

What do you mean by the shadow of the earth?

The earth always casts a great shadow in the heavens on the opposite side from the sun.

What is the shape of this shadow?

Cone-shaped—that is, round and pointed at one end like a sugar-loaf.

Is it not very long?

Yes, it is more than three times as long as the distance from the earth to the moon.

When only can the moon be eclipsed?

When it is in opposition, when the earth is between it and the sun; because the moon must have its bright side toward us to be eclipsed.

As the moon is in opposition once every month, why is it not eclipsed every month?

Because the moon does not always pass exactly behind the earth each time it goes round; it sometimes passes a little above and sometimes a little below the earth's shadow, and then of course there can be no eclipse.

What is a partial eclipse of the moon?

When the moon passes through the edge of the shadow, so that only part of it is cut off from the sunlight.

What is a total eclipse of the moon?

When the whole of the moon enters into the earth's shadow.

Is the moon entirely hidden when in total eclipse?

Sometimes, but very rarely.

What does it usually look like when wholly in the earth's shadow?

It has a dull copper-red hue, like the color of the sun when seen through smoked glass.

What is the penumbra of the earth's shadow?

A kind of half-shadow all round the cone-shaped shadow of the earth.

How does the moon look when in the penumbra?

It is only partly hidden, and is not of so dark a color as when in the shadow itself.

When can we see the shadow of the edge of the earth on the moon?

When the moon is in partial eclipse.

What is the shape of this shadow?

Rounded so that if continued around it will form a circle.

What do we conclude from this?

That as the shadow of the earth is round, the earth itself must be round.

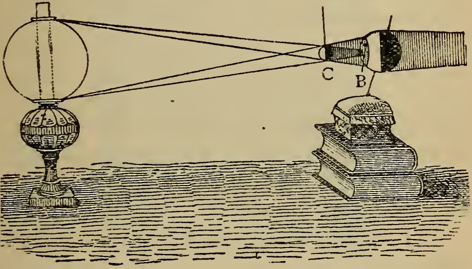
LESSON XIX.

ECLIPSES OF THE SUN.

We have seen, in the last chapter, that an eclipse of the moon can take place only when the moon is in opposition — that is, on the opposite side of the earth from the sun, when the earth is between it and the sun; we have now to learn that an eclipse of the sun can take place only when the moon is in conjunction — that is, at new moon, when the moon is between the sun and the earth. As an eclipse of the moon is caused by the shadow of the earth on the moon, so an eclipse of the sun is caused by the shadow of the moon falling on the earth.

We can easily see this by going back to our lamp and orange again. Tie a small ball, about as large as a plum, to a thread, to represent the moon, and hold it near the orange between the lamp and the orange (standing for the sun and the earth as before), as shown at C in the picture (44), so that its shadow will fall on the orange. If you could put your eye on the spot where the shadow falls, you would not be able to see the lamp, which would thus be totally eclipsed.

The moon, at certain times, casts just such a shadow on the earth as the plum casts on the orange; and to all who are within that shadow the sun will be in total eclipse. An eclipse of the moon is seen in all parts of the earth where it is night at the time and the



44. Eclipse of the Sun, shown with Lamp and Orange.

moon is above the horizon; but it is different with an eclipse of the sun. The shadow of the moon, like that of the earth, is cone-shaped, but as the moon is much smaller than the earth, its shadow is only large enough to cover a small part of the earth's surface. There is also a penumbra or half-shadow around the dark shadow of the moon, just as there is about the shadow of the earth. In the picture both the shadow and the penumbra are shown. The eclipse will be total only where the dark shadow falls; it will be partial at any place, such as B, within the penumbra, and there will be no eclipse at all in places outside of the penumbra. Total eclipses of the sun are therefore very rare at any one place on the earth's surface, but as astronomers are able to tell us where the shadow of the moon will fall, we can easily see one by going to the right place. There will be eight more total eclipses of the sun in this century, but none of them will be visible in the United States. The first one which will be seen in this country will take place May 28, 1900.

As the moon is not always at the same distance from the earth, it is sometimes so far away that its shadow cannot reach the earth's surface. There will then be no total eclipse of the sun at the place where the shadow would fall if it were long enough, for the moon will cover only the middle of the sun, leaving its edge visible all round it like a bright ring of light. Such an eclipse is called an annular eclipse — that is, a ring eclipse. The appearance of the sun during an annular eclipse is shown in the picture (45), where the round shadow of the moon is seen nearly covering the disk of the sun.

If the moon always passed exactly between the earth and the sun, there would be an eclipse of the sun every month at new moon; but it sometimes passes above and sometimes

45. Annular Eclipse of the Sun.

below a line between them, and when it does, there can be no eclipse. An eclipse of the sun is seldom total at any one place more than four or five minutes, and never more than eight minutes; but the entire eclipse, from the time the moon begins to cover the sun to the time it leaves it, may be two or three hours. There are more eclipses of the sun than of the moon, but as sun eclipses are seen on only a small part of the earth, while moon eclipses are visible over a whole hemisphere at a time, more of the latter than of the former are seen at any one place.

When there is a total eclipse of the sun night seems to fall in the day-time. Though the darkness is really less than when the full moon is shining, it appears to be much greater on account of the sudden change from daylight to darkness. A gloom spreads over everything, the darkness has a purple or violet tinge, and the air feels cool. Animals bleat and bellow, fowls and birds cease their songs and go to roost, and crickets begin to sing as if night had really come. When the sun is wholly hidden by the moon, the moon looks as if it were surrounded by a crown of silvery or pearly light. From this, which is called the corona (Latin for crown) and which, we have learned, is made by the light of the sun, reddish flames are often seen to dart out to a great distance, looking like tongues of fire.

In ancient times, before the cause of eclipses was known, people used to be greatly terrified when they took place. In some countries it was believed that a great dragon swallowed the sun, and drums and gongs were beaten, and all kinds of noises were made to drive the beast away, and this is done even now in Persia and China. In others, it was thought that war, famine, and sickness were caused by eclipses; and some people even saw in them the end of the world. But all such superstitions have now passed away, excepting among the ignorant, for we not only know the exact cause of eclipses, but we can even tell when eclipses will take place many years ahead of their time.

We can also tell the date of eclipses which took place thousands of years ago, and in this way some important dates in history have been found out. Thus Herodotus tells about an eclipse of the sun which took place when a battle was going on between the Lydians and the Medes. Herodotus does not give the date, and other writers give it different times between 583 B.C. and 626 B.C. But a British astronomer found out by calculating backward that the only eclipse of the sun between those dates at that place must have taken place May 28, 585 B.C., and so we know that the battle must have been fought on that day.

RECITATION FOR LESSON XIX.

When is the sun said to be in eclipse?

When its light is hidden from us by the moon.

When only can the sun be eclipsed?

When the moon is in conjunction—that is, between the sun and the earth.

Does the moon then cast a shadow like that of the earth?

Yes, it casts a cone-shaped shadow; but as the moon is much smaller than the earth, its shadow is much smaller.

Is it large enough to cover all the earth?

No; it is only large enough to cover a small part of the earth's surface at once, and only those who happen to be where the shadow falls will see the sun in eclipse.

Is it not different with an eclipse of the moon?

Yes, an eclipse of the moon is seen in all parts of the earth where it is night at the time and the moon is above the horizon.

Has the moon's shadow also a penumbra?

Yes, it has a half-shadow around it, just as the shadow of the earth has.

Where will an eclipse of the sun be total?

Only where the dark shadow of the moon falls.

Where will an eclipse of the sun be partial?

At any place within the penumbra.

Are not total eclipses of the sun very rare at any one place on the earth's surface?

Yes; but as astronomers are always able to tell where the shadow of the moon will fall, one can easily be seen by going to the right place.

What happens when the moon is so far away that the shadow of the moon does not reach the earth?

The moon will then cover only the middle of the sun, leaving its edge visible all round it like a bright ring of light.

What is such an eclipse called?

An annular eclipse—that is, a ring eclipse.

Why is there not an eclipse of the sun every month?

Because the moon does not always pass directly between the sun and the earth, but sometimes above and sometimes below a line between them.

How do the sun and moon look when the sun is in total eclipse?

The face of the sun is wholly hidden by the moon, which looks black; and all around the edge of the moon is seen a crown of light, called the corona, from which reddish flames are often seen to dart out like tongues of fire.

Is it not quite dark during a total eclipse?

Yes, it is almost as dark as night, and the air is quite cool.

LESSON XX.

THE SOLAR SYSTEM.

We have thus learned that the sun is the great centre around which the earth turns in its orbit.

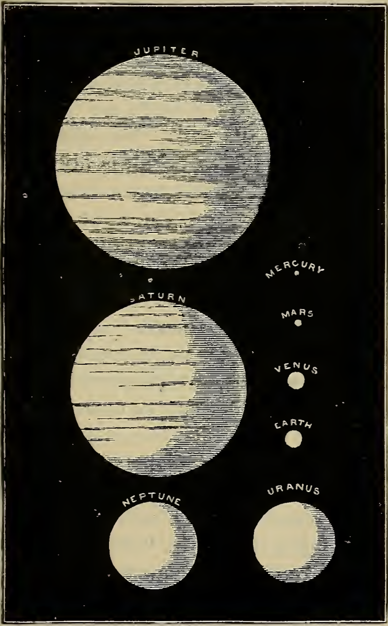
We have now to learn that the earth is only one of a family, of which the sun is the head, all the members of which move round the sun in like orbits, but at different distances from it. The earth and the other members of the sun's family are called planets or wanderers, the word planet being made from a Greek word meaning to wander. They were thus called by the ancients because they appear to wander in the heavens amongst the stars; and we still give them the name, although we know that they do not really wander, but move in regular orbits round the sun.

The family of the sun, consisting of the earth and the other planets, and a few other bodies, occupies a place alone by itself in the heavens, and is entirely separate from what we commonly call the stars. When we look up into the heavens at night we see what looks to be an immense dark vault spangled over with stars, among which move the moon and the planets which are in sight. Though some look larger and some smaller than others, they are all apparently at about the same distance from us, and planets and stars look nearly alike; but they really differ from each other in many things, and the stars look like the planets only because the stars are at an immense distance.

When looked at through a telescope the planets are seen to be globes or spheres, solid round bodies like the earth, while the stars still appear to be twinkling points of light, much as they do to the naked eye. The stars too never change their places in the heavens. You must not understand that they never move at all: what is meant is that they never change their places in regard to each other—that is, that they keep the same arrangement in the heavens all the time; while the planets, which are always moving in their orbits, are sometimes near one group of stars and sometimes near another. The stars too, as you will learn by and by, are hot bodies which shine by their own light, like the sun; while the planets, like the moon, are cool bodies, having no light of their own, but only reflecting the light of the sun.

Let us now leave the stars for a while and study the sun and the planets, which I have told you form a separate family by themselves and occupy a separate place in the heavens—wholly distinct from the rest of the heavens, as much so as the United States is from the other countries of the earth. This group, which we will call a family, because the sun is the great head on which all the others depend, is commonly known as the solar system—that is, the system or group of the sun.

Besides the earth, there are seven principal planets which move in orbits round the sun. They are named, after the gods of the ancients, Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. The first five have been known from the oldest times, and were so named by the ancients; but Uranus was not discovered until 1781 and Neptune until 1846. Mercury, Venus, and Mars are smaller than the earth, the others much larger. The first two, Mercury and Venus, are called interior (inside) planets because their orbits are inside that of the earth; and Mars, Jupiter, Saturn, Uranus, and Neptune are called exterior (outside) planets because their orbits are outside



46. Comparative sizes of the Planets.

that of the earth. Some idea of the different sizes of the planets, as compared with each other, may be formed from the picture (46), in which they are shown, as they would appear if they were all at the same distance from us.

The eight planets, then, are all the time moving round the sun in great circular paths called orbits, all of which are at different distances from the sun. We have already learned that the earth's orbit is about ninety-two million (92,000,000) miles from the sun, and we have tried to form some idea of this immense distance; but the distance of the orbits of some of the exterior planets is as much greater than this, as this is greater than the distances on our earth. Although it is almost impossible for us to form any idea of these distances, they are all given in the table on page 170, as they may be convenient to refer to.

Besides these great planets, most of which are plainly visible to the unaided eye, there are many smaller ones, which can be seen only through a telescope. Of these, which are called asteroids, more than two hundred have been discovered, and there are probably many more. They all move round the sun in orbits between those of Mars and Jupiter.

We have already learned that our moon is a satellite or attendant of the earth, around which it is continually moving in an orbit while the earth is moving round the sun. But the earth is not the only planet which is thus attended, and some of the planets are even better off than we are. Thus, Mars has two moons or satellites, Jupiter four, Saturn eight, and Uranus four; but Neptune, the most distant of all the planets from the sun, has, like the earth, only one, and Mercury and Venus, the nearest ones to the sun, have none.

RECITATION FOR LESSON XX.

Is the earth the only body which revolves around the sun?

No; the earth is only one of several bodies called planets.

Why are they called planets?

The word planet means wanderer, and these bodies were so named by the ancients because in moving in their orbits around the sun they appear to wander among the stars, which move so slowly that they appear never to move at all.

Are the sun and the planets near the stars?

No; they occupy a place in the heavens alone by themselves, wholly separate from the places of the stars.

Why then do they appear to be near each other?

Because they are at such vast distances from us.

Do not the planets and the stars look much alike?

They do to the unaided eye; but when looked at through a telescope the planets are seen to be globes or spheres like the earth, while the stars still appear to be twinkling points of light, much as they do to the eye alone.

In what else do the planets differ from the stars?

The planets are cool bodies, like the moon, which have no light of their own, but only reflect the light of the sun; while the stars are hot bodies, like the sun, which shine by their own light.

What is the group of the sun and its planets called?

The Solar System—that is, the system or group of the sun.

How many principal planets are there in the Solar System?

Eight; namely, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

Are they all at the same distance from the sun?

No; the orbits in which they revolve are all at different distances from the sun, that of Mercury being nearest and that of Neptune farthest from the sun.

Are they all of the same size?

No; Mercury, Venus, and Mars are smaller than the earth, the others many times larger.

Which ones are called the interior planets?

Mercury and Venus, because their orbits are inside that of the earth.

Which are called the exterior planets?

Mars, Jupiter, Saturn, Uranus, and Neptune, because their orbits are outside that of the earth.

Are there not also many smaller planets?

Yes; the asteroids, whose orbits are between those of Mars and Jupiter.

How many moons have the principal planets?

Mars has two moons or satellites, Jupiter four, Saturn eight, Uranus four, and Neptune, like the earth, only one; Mercury and Venus have none.

LESSON XXI.

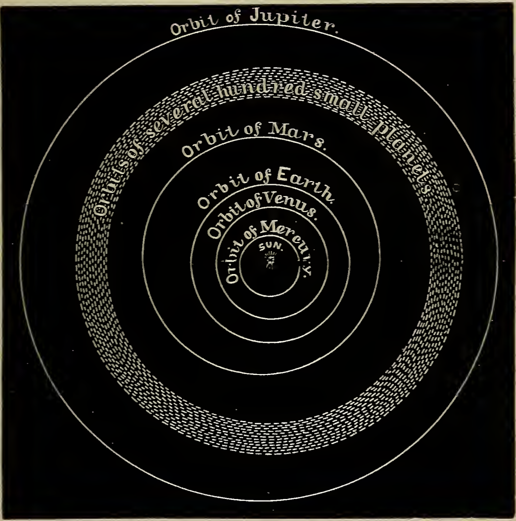
MOTION OF THE PLANETS IN THEIR ORBITS.

We have now learned that the sun and the planets (including the earth) which move around it form a family or group by themselves, called the Solar System, which occupies a separate place in the heavens, entirely apart from any of the bodies called stars. As it is almost impossible to form from figures alone any idea of the sizes of the planets compared with each other, it is best to have something on a smaller scale to compare them with. In the picture (46) in the last lesson their different sizes were shown as they would appear if they were all placed at the same distance from us; but we do not get any idea from this of their different distances from the sun. We must therefore try another plan.

Suppose then that we put in the middle of a large level field a ball about two feet wide and call it the sun. Now let us walk forty-one steps (82 feet: supposing that we go two feet at each step) from this ball and lay down a mustard seed, which will be the proper size for Mercury. Walk thirty steps farther (142 feet from the sun), and lay down a pea of average size for Venus; then thirty-six steps (215 feet from the sun) and lay down a little larger pea for the earth; and then fifty-six steps (327 feet from the sun) and lay down a very small pea for Mars. It will be easy enough to place these at the proper distances from the sun, but the others are so much farther away that we may have some difficulty in giving them their proper positions. Jupiter will be rightly represented by a common-sized orange placed nearly a quarter of a mile away from the sun; Saturn by a somewhat smaller orange about two fifths of a mile away; Uranus by a small plum more than three quarters of a mile away; and Neptune by a little larger plum about a mile and a quarter away from the sun. Imagine all these to be turning round the sun in great circles, and we may possibly get some idea of the different sizes of the sun and the planets and their distances from each other. The asteroids or minor planets, which move round the sun between Mars and Jupiter, cannot be shown, for they would be smaller than grains of sand.

In the picture (47) is shown the sun and the orbits of several of the planets. All cannot be shown, as it would take a very large sheet of paper to represent those farthest from the sun of the proper size. The moons or satellites of the planets are shown by dots near them. This picture shows the solar system not as we see it, but as it would appear to one looking at it from above. We on the earth see only a few of the planets at a time, and they appear as if they were moving along among thousands of stars; but we must bear in mind all the while that this is only an appearance, and that the stars, of which we shall learn more by and by, are much farther away from us than the planets.

We have learned heretofore (Lesson 6) that what we call the weight of anything means simply the force with which the earth attracts or draws that thing to itself; and that it is this force which keeps everything on the earth—the water, the air, even us ourselves—as it rolls round in the heavens. We have also learned that it is not only the earth which attracts, but that everything on the earth has an attraction for every other thing, and that the larger a thing is the greater is its power to draw other things to it; the earth, therefore, being so much larger than anything on it, attracts all other things with so much greater force that their attraction is not enough to be felt by us. We have now



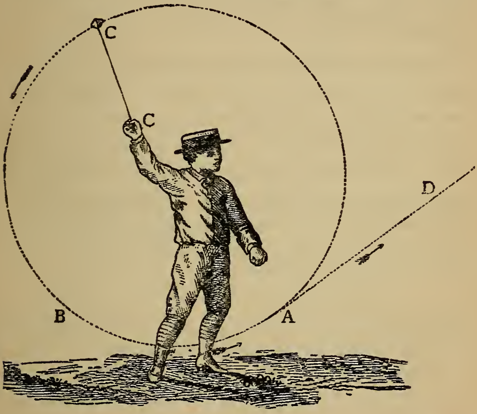
47. Plan of part of the Solar System. [Newcomb and Holden's Astronomy.]

to learn that this rule holds good not only for all things on the earth, but also for every thing in the heavens: every thing or body is attracting or drawing toward itself all other things or bodies, and the larger the thing is the greater is the strength of its attraction.

All the planets, then, attract each other; but the sun, which is about seven hundred times larger than all of them put together, attracts them much more strongly, so that everything in the Solar System is drawn with very great force toward the sun. But why, one may ask, if this is true, do not the earth and all the other planets get nearer and nearer to the sun all the time and at last fall upon it, just as a stone or other thing falls to the earth.

This would be so if they were not all kept in their places by another force, which we must now learn about. Almost every child has seen stones thrown with a sling. When we swing a sling with a stone in it about our head the stone goes round in a circle, of which the shoulder of the arm holding the string is the centre. The stone seems to pull on the string, and the harder we swing it the harder it pulls; and if we let go of the string it flies away quickly. The force with which the stone pulls and tries to get away when we swing it round our head is called centrifugal (centre-flying, from Latin *centrum*, centre, and *fugere*, to fly) force—that is, the force with which anything tries to fly off from the centre; and it is nothing but the string which keeps it from thus flying off.

The earth and the other planets turn round



48. Centrifugal Force. A B C, circle in which the stone moves when held by the string; A D, line in which it would move if the string be let go at A.

the sun just as the stone goes round our hand when we swing the sling, and like the stone they are all the time trying to get away; but they are all held in their orbits by the attraction of the sun, which keeps them from flying off just as the string of the sling keeps the stone from flying off. These two forces then, gravitation and centrifugal force, by acting together keep the planets in their orbits: if there were no gravitation they would fly away into space, and if there were no centrifugal force, they would fall into the sun.

By the action of the same two forces the moon is made to turn round the earth; the centrifugal force keeps it from falling to the earth, and the force of gravitation or attraction of the earth prevents it from flying away through the heavens. In the same way each satellite moves round its larger planet, kept in its path by these wonderful forces.

RECITATION FOR LESSON XXI.

If you should represent the sun by a ball two feet wide, what would be the proper sizes of the four smaller planets?

Mercury would be of the size of a mustard seed, Venus of an ordinary pea, the earth of a little larger pea, and Mars of a very small pea.

What would be the proper sizes of the four larger planets?

Jupiter would be of the size of a common orange, Saturn of a smaller orange, Uranus of a small plum, and Neptune of a larger plum.

Of what size would the asteroids be?

Smaller than grains of sand.

What have we learned to be the true meaning of weight?

Weight is the force with which the earth attracts or draws anything to itself.

Do the things on the earth have an attraction for each other?

Yes, everything on the earth has an attraction for every other thing, but the force of the attraction of the earth is so much greater that the attraction of the things on it is not felt by us.

What rule can you make from this?

That the larger the thing is the greater is the force of its attraction.

Is this true of things off of the earth as well as of things on it?

Yes; the planets all attract each other, but the sun, which is about five hundred times larger than all the planets put together, attracts them much more strongly.

Why then are not all the planets drawn to the sun, just as everything on the earth is drawn to the earth?

Because they are kept in their places by another force, called centrifugal force.

What do you mean by centrifugal force?

The force with which any thing tries to fly off from the centre around which it turns; for instance, when I whirl a stone round my hand in a sling, the force with which the stone pulls on the string in trying to get away from my hand is centrifugal force.

What keeps the stone from flying away?

The string which I hold in my hand.

How can you explain the motion of the planets from this?

The planets move round the sun just as the stone whirls in a circle round my hand; and like the stone they are all the time trying to fly away, but they are held in their orbits by the attraction of the sun, just as the stone is held by the string.

Are these two forces—the attraction of gravitation and centrifugal force—then equal to each other?

Yes; if there were no gravitation, the planets would fly away into space, and if there were no centrifugal force, they would all fall into the sun; but the action of the two forces together keep them forever revolving in their orbits.

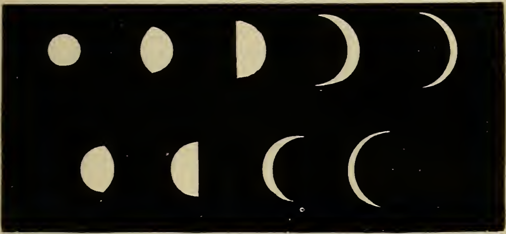
Do these forces also explain the movements of the moon and of the satellites of the other planets?

Yes; the attraction of the earth keeps its satellite from flying away, and centrifugal force keeps it from falling. It is the same with each of the other planets and its satellite or satellites.

LESSON XXII.

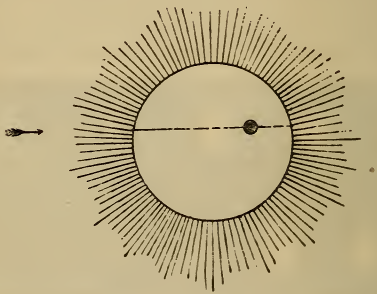
THE LESSER PLANETS.

When looked at with the eye alone all the planets appear much alike; but when viewed through a telescope the interior or inner planets, Mercury and Venus, show at different



49. Appearance of Mercury at different Points of its Orbit. [Newcomb and Holden's Astronomy.]

times phases like those of our moon—that is, they sometimes look like a crescent, sometimes like a half globe of light, and sometimes like a full globe of light. These phases are caused in the same way as those of the moon, which are explained in Lesson XV. The planets, all of which, like the moon, shine by reflecting the light of the sun, are light only on the side toward the sun. When either of them is between the earth and the sun, the dark side is toward us and we do not see it; but as it moves along we soon see a crescent, which grows larger and larger until, when it is on the opposite side of the sun from us, the



50. Transit of Mercury.

whole of its bright side is toward us. But it is then so far away from us, that it does not look so bright as when it shows less of its lighted side.

It has been said that Mercury and Venus are not seen when their dark sides are toward us; but there is one exception to this. Sometimes in moving round the sun one of them passes directly between us and the sun, and we can then see it moving across the sun's face like a little black spot. Such a passage across the sun's face is called a transit of Mercury or Venus, whichever it may be. Astronomers take great pains to watch these transits, and costly expeditions are often sent to different parts of the earth to observe them, because they give us the best means of calculating the distance of the sun from the earth.

MERCURY. This planet is the nearest of all the planets to the sun, and is so hidden by the sun's light that it can seldom be seen excepting just before sunrise and just after sunset. It shines with a bright white light, brighter than that of the stars. Its diameter or breadth is a little more than one third (about 3000 miles) that of the earth, so that it would take about eighteen globes of its size to make one like the earth. It goes round the sun in its orbit once in eighty-eight of our days, so that the year in Mercury is only about three of our months long. It is supposed by some astronomers that it turns round on its axis once every twenty-four hours and five minutes, which would make its day about as long as our day; but this is not certainly known. Nor do we know whether its surface is made up of land and water like that of the earth, or is waterless like that of the moon, nor whether it has an atmosphere or not; but, as it is so much nearer the sun than the earth is, it must get far more light and heat than we do.

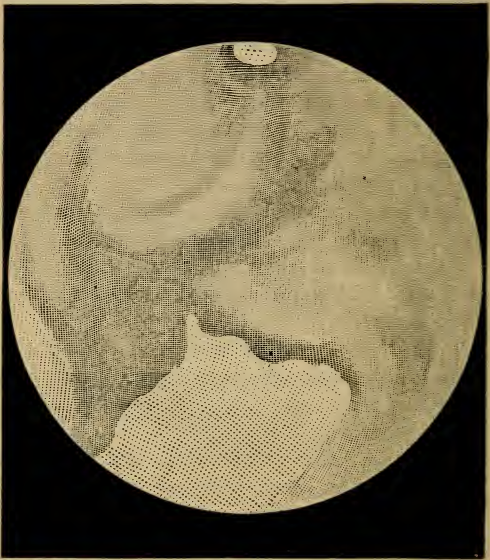
VENUS. This, the second planet in distance from the sun, is nearly the same size as the earth, its diameter being seven thousand seven hundred (7700) miles. It goes round the sun once every two hundred and twenty-five (225) of our days, so that its year is about seven and a half of our months long. Some have thought that it turns on its axis once in twenty-three and a half hours, which would make its day only a little shorter than ours, but this calculation is not trusted by the best modern astronomers. The axis of Venus is more slanted toward its orbit than that of the earth, and the changes of its seasons must therefore be greater than ours; it gets, too, about twice as much heat as the earth does. Very little is known of the surface of Venus. but some think that there is water upon it, because there are many things which seem to prove that it has an atmosphere even denser than that of the earth.

Venus is the brightest of the planets, and when most brilliant can be seen at midday by the unaided eye. It can generally be seen just before sunrise or just after sunset, according to its position in its orbit. When it rises before the sun it is called the morning star, and when it sets after the sun the evening star. These names are very old; the ancients believed that the morning and evening stars were two different stars, so they called the one Lucifer (light-bringer), and the other Vesper (evening star).

The last transit of Venus—that is, its passage across the sun's disk—took place in 1874; there will be another one in 1882, and after that none will take place for more than a hundred years.

MARS. The earth comes next among the planets in point of distance from the sun, but as it has been described before we will pass on to Mars, the first of the exterior planets. Mars is six times smaller than the earth, its diameter being four thousand two hundred (4200) miles, or a little less than half that of the earth. Its year is nearly twice as long as ours, for it is twenty-three months in going round its orbit, and it has a change of seasons much like ours. It turns on its axis once every twenty-four and a half hours, thus making its day about the same as ours.

As its orbit is outside that of the earth it can never pass between the earth and the sun, and



51. Mars seen through a Telescope. [Newcomb and Holden's Astronomy.]

it therefore does not pass through the different phases which Mercury and Venus do.

Mars has a reddish tint when looked at with the eye alone; but when examined through a telescope its surface around the equator is seen to be divided in color, some parts being reddish and some greenish; the former are supposed by some to be land and the latter water. Around the polar regions are also seen white spots, thought to be snow; but all these appearances are so doubtful that the best astronomers speak of them only as light and dark portions. It is believed, too, that it has an atmosphere; but as it is further from the sun than the earth, it does not get so much heat and light as we do. But Mars is better off than the earth in one respect: it has two moons, while the earth has but one. These were not known before 1877, when they were discovered by Professor Asaph Hall, of Washington.

ASTEROIDS. Next beyond Mars, between its orbit and that of Jupiter, are the orbits of the asteroids or minor planets, of which more than two hundred have been discovered, several being found almost every year. All of these are small, the largest being only from two hundred to four hundred miles in diameter, and the smallest from twenty to thirty miles. It would take several thousand of the size of the largest ones to make a planet as large as the earth. Among the principal ones are Ceres (discovered in 1801), Pallas (1802), Juno (1804), and Vesta (1807). Vesta is the only one ever seen with the unaided eye. Some astronomers have thought that the asteroids are the remains of a large planet broken into pieces by volcanic action or some other force, but this is not now believed to be probable.

RECITATION FOR LESSON XXII.

In what are Mercury and Venus like the moon?

They show phases like those of the moon.

What is the cause of this?

As they shine, like the moon, only by reflecting the light of the sun, they are bright only on the side toward the sun. When either of them is between the earth and the sun, its dark side is toward us and we do not see it; but as it moves along we see first a little of it, like a crescent, and finally, when it is the other side of the sun, the whole of it.

Do we never see Mercury and Venus when their dark side is toward us?

Yes; when either of them passes directly between us and the sun, we can see it moving across the sun's face like a black spot.

What is such a passage called?

A transit of Mercury or of Venus.

Why do astronomers take great pains to observe such transits?

Because they give the best means of calculating the distance of the sun from the earth.

Why do we seldom see Mercury?

Because it is so near the sun that it is commonly hidden by its light.

How large is it, compared with the earth?

It would take eighteen globes of the size of Mercury to make one as large as the earth.

How large is Venus?

Nearly the same size as the earth.

How bright is Venus, compared with other planets?

It is the brightest of the planets, and can sometimes be seen at midday with the unaided eye.

When is it called the morning star?

When it rises before the sun.

When is it called the evening star?

When it sets after the sun.

What is the size of Mars, compared with that of the earth?

It is six times smaller than the earth.

How does Mars look when seen through a telescope?

Its surface is covered with reddish and greenish spots, the former supposed to be land and the latter water; and something white like snow is seen at the two poles.

Does it get as much heat and light as the earth?

No; because it is farther from the sun.

How many asteroids have been discovered?

More than two hundred, and new ones are found almost every year.

Are they not all very small?

Yes; only one of them is large enough to be seen with the unaided eye.

LESSON XXIII.

THE GREATER PLANETS.

JUPITER. Next to the orbits of the asteroids is the orbit of Jupiter, the largest of all the planets—larger even than all the rest put together. It would take one thousand three hundred (1300) globes of the size of our earth to make one equal to that of Jupiter. Its diameter is about eighty-five thousand (85,000) miles. As it is about five times as far from the sun as the earth is, it has five times as far to travel in its orbit. It goes around this once every twelve of our years, and its year therefore is twelve times longer than ours. But it turns on its axis much faster than the earth, going round once every ten hours (9 h. 55 m.). Its days, then, are very short; and as its axis is only slanted a very little to the plane of its orbit, its days and nights are nearly equal in length, and there is therefore very little change in its seasons.

Next to Venus, Jupiter is the brightest of the planets. When looked at through a telescope, it has a light-yellowish color, with several grayish stripes or belts across it. These belts are all the time changing, from which it is supposed that we do not see the planet itself, but only a very cloudy atmos-

52. Jupiter, seen through a Telescope, with a Satellite and its Shadow on it.

phere around it; that the bright parts are clouds lighted up by the sun, and that the dark belts are openings through these clouds showing either parts of the planet beneath or lower masses of clouds.

Jupiter has four moons or satellites, which turn round it as our moon turns round the earth, but much more swiftly. The smallest one is about as large as our moon, and the largest one somewhat smaller than the planet Mars. These little moons cannot be seen with the unaided eye, but through a telescope they look like brilliant points of light. They were first seen by Galileo, the inventor of the telescope, in 1610. The astronomers of that time laughed at Galileo, and one of them said that to see moons around Jupiter one must have a telescope which would make them. Another one would not look through a telescope for fear that he should see them and have to change his mind. He died soon after without having seen them, which caused Galileo to remark: " I hope that he saw them while on his way to heaven."

The orbits of Jupiter's moons are at different distances from the planet, the nearest one going round in less than two days and the farthest one in about twenty days. They often pass through the shadow which the planet makes in the side farthest from the sun, and are then said to be eclipsed. Their passages across the face of the planet, when they look like black spots on its bright surface, are called transits.

SATURN. The most remarkable of all the planets is Saturn, whose orbit is next beyond that of Jupiter. It is the largest of all except Jupiter, its diameter being seventy thousand five hundred (70,500) miles, and its size about

53. Saturn and its Rings, seen through a Telescope. [Newcomb and Holden's Astronomy.]

seven hundred times that of the earth. The year in Saturn is very long, as the planet goes round the sun but once in twenty-nine and a half years. It turns on its axis once in ten and a quarter hours, so that its day is nearly the same as that of Jupiter; but as its axis is more slanting than that of Jupiter, its days and nights are unequal in length, and it therefore has a regular change of seasons, each lasting more than seven of our years.

Through a telescope Saturn looks much like Jupiter, having a cloudy atmosphere arranged in belts; but the most wonderful thing about it is its ring, which surrounds it opposite its equator. This ring is made up of two bright rings, one outside another, as shown in the picture (53), with a narrow dark line between them. Some think that there is a third darker ring inside, but this is not generally believed to be a separate ring, but only the shading of the inner one. Though many thousand miles broad, Saturn's ring is only about one hundred and thirty-eight (138) miles thick, so that when the edge is toward us, as it is when the planet is in some positions, it looks like a line of light. In the next picture (54) Saturn is shown moving in its orbit round the sun. It will be seen from this that its ring always slants the same way, which makes it easy to understand why it sometimes looks to us on the earth like a line of light, as it did in 1862 and in 1878. It is supposed that the ring is made up of a great number of little moons or satellites, all separate from each other, and all turning round in the same orbit.

Saturn has eight moons, of different sizes, which move round it in orbits outside of the

54. Different appearances of the Ring of Saturn, as seen from the Earth.

ring. The largest of these is about the size of the planet Mercury.

Of the planets known to the ancients, Saturn is the farthest from the sun; but they knew nothing of its ring nor its moons, for these cannot be seen without a telescope, and to the eye alone it looks only like a bright star of a yellowish color.

URANUS. The next planet to Saturn is Uranus, which was discovered to be a planet in 1781 by Sir William Herschel. It is such an immense distance away that we know very little about it; but it is about seventy-four times as large as the earth. It moves round the sun once in eighty-four (84) of our years, and it has four moons. It can be rarely seen with the eye alone; through a telescope it looks bright, with a sea-green tinge, and is without any spots or belts.

NEPTUNE. This planet, the most distant of the sun's family, was discovered in 1846 by Dr. Galle, of Berlin. It is eighty times larger than the earth, and moves round the sun once in a hundred and sixty-five (165) of our years. Through a large telescope, Neptune, which cannot be seen by the eye alone, shows a round pale-blue disk. It has but one moon known to us, which revolves around it once in a little less than six days.

The following table of the planets will be found useful to refer to:

TABLE OF THE PLANETS.

	Diameter in Miles.	Size compared with that of the Earth.	Distance from the Sun.	Time of Revolution around the Sun, or length of Year.	Time of Rotation on its Axis, or length of Day.	Number of Satellites.
Mercury..	3,000	18 times smaller.	40 million miles	88 days.	24 hours, 5 minutes?	
Venus....	7,700	About same size.	67 " "	225 days.	23 hours, 21 minutes?	
Earth	7,900	....	92 " "	365 days, 6 hours.	24 hours.	1
Mars.....	4,200	6 times smaller.	141 " "	1 year, 11 months	24 hours, 37 minutes.	2
Jupiter ..	85,000	1300 times larger.	480 " "	12 years.	9 hours, 55 minutes.	4
Saturn ...	70,500	700 times larger.	880 " "	29½ years.	10 hours, 14 minutes.	8 and a ring.
Uranus ..	32,000	74 times larger.	1,770 " "	84 years.	?	4
Neptune..	35,000	80 times larger.	2,775 " "	165 years.	?	1

RECITATION FOR LESSON XXIII.

Which is the largest of the planets?

Jupiter; it is larger than all the rest put together.

How large is it, compared with the earth?

It is thirteen hundred times larger than the earth.

How bright is it?

Next to Venus it is the brightest of all the planets.

How does Jupiter look through a telescope?

Of a light-yellowish color, with grayish belts across it.

What are these supposed to be?

It is thought that we do not see the planet at all, but only its cloudy atmosphere; that the bright parts are clouds lighted up by the sun, and the darker belts openings through the clouds.

How large are the moons of Jupiter?

The smallest one is about as large as our moon, and the largest one about the size of the planet Mars.

When are they said to be eclipsed?

When they pass through the shadow which

Jupiter makes on the side farthest from the sun.

What planet is next beyond Jupiter?

Saturn.

How large is it?

Next after Jupiter it is the largest of the planets. It is nearly seven hundred times larger than the earth.

How does Saturn look through a telescope?

Much like Jupiter, having also a cloudy atmosphere arranged in belts.

What makes it the most wonderful of all the planets?

Its ring, which surrounds it opposite its equator.

Of what is this ring made up?

Of two rings, one inside another, with spaces between them.

Can Saturn's ring be seen with the eye alone?

No, it can be seen only through a telescope; and the inner part, which is much darker than the two outer parts, can be seen only with a very large telescope.

How many moons has Saturn?

Eight, all of which revolve around it in orbits outside of its ring.

Are these moons very large?

The largest one is about the size of the planet Mercury.

Was Saturn known to the ancients?

Yes; but they knew nothing of its ring nor of its moons.

Did they not think it was the last of the planets?

Yes, for they did not know about Uranus and Neptune.

How large is Uranus, compared with the earth?

It is about seventy-four times larger than the earth.

Is much known about it?

No, it is too far away to be seen very well; but through a telescope it looks bright, without spots or belts.

How many moons has it?

Four.

What planet is farthest of all from the sun?

Neptune.

How large is it, compared with the earth?

It is one hundred and five times larger than the earth.

How many moons has it?

But one known to us.

LESSON XXIV.

COMETS AND SHOOTING STARS.

Besides the planets and their satellites, which we have called the members of the sun's family, there are other bodies in the Solar System some of which are rather visitors than regular members of it. Among these are comets, those singular bodies sometimes seen with long fiery tails, and meteors, which are commonly called falling or shooting stars.

Comets bright enough to be seen with the eye alone are generally made up of two parts —the head and the tail. The head consists of a bright centre, called the *nucleus* (Latin for a kernel), which looks much like a star, and which is surrounded by a fog or mist, bright near the nucleus, but shaded off at the edges. This foggy patch around the nucleus looks some like hair, and is therefore called the *coma* (Latin for hair), and from this comes our word comet. On the side farthest from the sun the coma extends in a long line of light, which usually grows wider and fainter as it gets farther from the nucleus, until it can no longer be seen. This, which is called the tail, is generally so thin that stars can be seen shining through it. In some comets the tail is very long and bright, in some it is short and dim, and in others it is split into two or more tails.

More than six hundred comets have been noted since the time of Christ, but there are

55. Telescopic Comet without a Nucleus.

56. Telescopic Comet with a Nucleus.

supposed to be many thousands of them, for several are seen with telescopes every year which are not bright enough to be seen with the unaided eye. Many of these telescopic comets are little more than patches of bright fog, having neither nucleus nor tail. The pictures show a telescopic comet without a nucleus (55), and one with a nucleus (56). Comets are not found in any particular part of the heavens, but are seen traveling everywhere. Some of them move always within the Solar System, and some appear to go far outside of it. They move round the sun in regular orbits—not circular, like those of the planets, but oval, so that they are sometimes very near the sun and sometimes at an immense distance from it. The picture shows the form of the orbit of a comet, S being the sun, and E the earth in its orbit.

57. Orbit of a Comet.

The orbits of some comets are so small that they go round the sun once every few years, while others are so large that they go round only once in several thousand years. Those whose orbits are so large must go far beyond the Solar System. Comets stay in sight sometimes for only a few days and sometimes for more than a year, but they are usually seen about two or three months. They are brightest when near the sun, and grow dimmer and dimmer as they move away from it until they go out of sight.

We do not know exactly of what comets are made. Some have thought that they are merely masses of glowing gas, but it is now generally believed that the nucleus of a comet is either a solid body or a dense mass of small particles of matter, and that the coma or fog around it is made by the heat of the sun, which is so strong as to turn parts of the nucleus into vapor. The tail is supposed to be a stream of this vapor, rising from it like the smoke from a chimney.

In ancient times, when men were more ignorant and superstitious than now, comets were objects of awe. They were believed to be the souls of great men, who, after living below a while after death, were at last carried to heaven in a kind of triumph. Thus the great comet which was seen at Rome a few years after the death of Julius Cæsar was believed to be the soul of that great man on its way to heaven. It was also thought that war, sickness, and famine were apt to follow the appearance of a comet, because it was a sign that the people were no longer to have the help of the soul thus carried away. Kings and princes looked upon comets as mes-

58. Donati's Comet of 1858. [Newcomb and Holden's Astronomy.] 178

sengers sent by the gods to warn them of trouble to come, or of some great event which was about to take place. When William Duke of Normandy was about to invade England (1066) a great comet shone in the sky, and this was taken as a good sign by him and his followers. In 1681 Halley, an English astronomer, showed that this comet was the same one seen in that year. He showed also that it went round the sun once every seventy-six years, and foretold that it would be seen again in 1759. It was seen in that year and again in 1835, and is now known as Halley's comet. It will be seen in the heavens again in 1911.

Though in these days people generally are too sensible to believe that comets have anything to do with the affairs of men, some have thought that one of these wanderers may some time strike the earth and destroy it. But little is to be feared on this account: in 1872 a comet came so near the earth as to touch its atmosphere with its tail, and all the harm it did was to give us a splendid shower of shooting tars.

Shooting Stars. On clear nights, bright bodies like stars are sometimes seen to move quickly across the heavens and disappear often leaving a streak of light for a few seconds behind them. These are commonly called shooting or falling stars, but they are not stars at all; they are more properly called meteors, and those which fall to the earth, as some of them do, meteorites or aërolites.

Meteors are now known to be small bodies moving through the heavens and around the sun in paths much like those of comets. Some are solid masses of stone or metal, some masses made up of small pieces, and others perhaps only bodies of gas. It is now believed by the best astronomers that the heavens within the Solar System are full of these little flying bodies, which are so small that they cannot be seen when they are out of the earth's atmosphere. Anything which will burn may be set on fire by only blowing air very swiftly against it; and a thing which will not burn may be thus made red-hot and perhaps melted. It is the same with things passing very swiftly through the air. So when the earth comes near enough to any of these little meteors to bring them within its atmosphere, they are made red-hot in passing through the air at great speed and burn, and thus make the lights which we call shooting stars. The small ones are entirely burned up, but sometimes one is large enough to pass through our atmosphere and fall on the earth. Some burst with a loud noise before reaching the earth, and fall in many small pieces; and men and cattle have been killed by them.

Shooting stars are usually seen in great numbers about the 10th of August and the 13th of November, at which times they sometimes fall in showers. It has been found that they always come from certain parts of the heavens, and astronomers generally look for them about those times. They differ much in size and brightness, but are generally small, though some have been seen almost as large and as bright as the moon.

It is believed by many that shooting stars or meteors differ from comets only in size; indeed, some think that comets are only flocks of meteors traveling along in an orbit together, and that shooting stars are some of the flock which are lost as the comet flies along.

RECITATIONS FOR LESSON XXIV.

What other members of the Solar System are there, besides the planets and their satellites?

Comets and shooting stars.

Of how many parts are comets which can be seen with the eye alone usually made up?

Of two parts—the head and the tail.

Of what is the head composed?

Of a bright part called the nucleus, and of a misty part around it called the coma.

From what is the word comet made?

From *coma*, which in Latin means hair, because this part in comets looks some like hair.

How is the tail formed?

By the coma stretching out, on the side farthest from the sun, in a long line of light.

Are the tails of all comets alike?

No; some are very long and bright, some short and dim, and others are split into two or more parts.

Can all comets be seen with the eye alone?

No; by the telescope several are seen every year, some of which are only patches of light, with neither nucleus nor tail.

Do comets move within the Solar System?

Some always do, but some appear to go far outside of it.

How do they move through the heavens?

Around the sun in regular orbits; not circular, like those of the planets, but oval, so that they are sometimes very near the sun, and sometimes very far from it.

Can we tell how long it takes a comet to go round in its orbit?

Yes; some go round once every few years, but the orbits of some are so large that they go round only once in several thousand years.

Do we know of what comets are made?

Not exactly; but it is now generally believed that the nucleus is either solid or a mass of small pieces, and that the coma is a part of the nucleus turned into vapor by the heat of the sun.

What is the tail supposed to be?

A stream of this vapor rising from the nucleus like smoke from a chimney.

What are shooting or falling stars?

They are not stars at all, but small bodies moving around the sun in paths much like the orbits of comets.

What are they properly called?

Meteors; and those which fall to the earth meteorites or aërolites.

Are not some of them solid?

Yes; some are solid masses of stone or metal, some masses made up of small pieces, and others perhaps only bodies of gas.

Are meteors very numerous?

Yes; the heavens within the Solar System are supposed to contain great numbers of them. They are generally so small that they cannot be seen, but when the earth comes near enough to any of them to bring them within its atmosphere, they become so heated that they burn and make shooting-stars.

Do they burn up entirely?

The small ones do, but sometimes a large one passes through our atmosphere and falls on the earth, or explodes and falls on it in pieces.

When do shooting stars often fall in showers?

About the 10th of August and the 13th of November, when the earth passes through their orbit.

Do not some think that meteors and comets differ only in size?

Yes; and it is believed by some that comets are only flocks of meteors traveling along in an orbit together.

LESSON XXV.

THE FIXED STARS.

Since the sun is the source of light and heat to the planets and the great centre around which they all revolve, it is the most important body in the Solar System; but we must not conclude from this that it is the most important body in the universe. We have learned (Lesson XIX.) that the Solar System, vast as it is, occupies only a small part of the heavens, entirely isolated from the other parts; and that the thousands of stars which bespangle the sky are beyond it, immeasurably outside of the orbit of the most distant planet. We have also learned that these stars appear through a telescope much as they do to the unaided eye, though brighter: they always look like twinkling points of light, and never show a disk—that is, look round—as the planets do through a telescope; indeed, none of them, even when viewed with the strongest telescopes, appear broad enough to be measured. Yet the light which they give is their own light, and not reflected light, like that of the planets and their moons; and since their light is very bright and strong, and much like the light of our sun, we are led to believe that they are bodies of very great size, and that they appear small to us because they are at such immense distances away.

There is good reason for believing that many of the stars are hundreds of times larger than our sun; indeed, astronomers believe that most of them are vast bodies giving out light and heat—that is, that they are suns like our sun—that nearly every one of them is the centre of a system like our Solar System, and is surrounded by a family of planets which revolve around it, as the earth and other planets revolve round our sun. The strongest telescopes do not show any such planets around the stars, but even if there were any they could not be seen, because planets' light being only reflected light, is not strong enough to reach us from so great a distance.

It may be thought that the stars are not far enough apart for each to be the centre of such a vast system as our Solar System, but they appear near together only because they are so far away. The distance of the nearest of them is more than five hundred thousand times the distance of our sun from the earth. Besides, it must be borne in mind that they are not all evenly placed over the surface of a great vault, as the ancients believed, but that some are behind others, so that, being in nearly the same line of sight, they appear to be near each other when they are really great distances apart. We may get some slight idea from this of the immensity of the universe; our earth, which seems so large to us, is little more than a grain of sand in the great Solar System, and the Solar System is not as much as a grain of sand in the vast universe, which is made up of countless numbers of such systems.

The stars are commonly called the fixed stars, a name given to them by the ancients because they believed them to be fixed in the heavens. The fixed stars shine with very different brightnesses; while some are brilliant, others are paler, and some are so very dim that they can scarcely be seen. This has enabled astronomers to divide them into classes called magnitudes, the word referring not at all to their size, but only to their brightness. Stars which shine the brightest are called stars of the first magnitude, the next brightest stars of the second magnitude, and so on. There are only twenty stars of the first magnitude, but they increase in number very fast as their brightness grows less, as will be seen by the following table, which shows the number of stars in the first nine magnitudes:

Mag.	*No. of Stars.*	*Mag.*	*No. of Stars.*
1st	20	6th	3,200
2d	65	7th	13,000
3d	190	8th	40,000
4th	425	9th	142,000
5th	1,100		

Of these, only the stars of the first six magnitudes can be seen with the unaided eye, and only the best eyes can see the smaller stars of the sixth magnitude. We can see, without a telescope, on the clearest nights, only about three thousand stars, for we do not see all the heavens at once; but when we look through a telescope, not only stars of the seventh, eighth, and ninth magnitudes are open to our view, but also millions of small stars of magnitudes below the ninth. The band of light stretching across the heavens, which is commonly called the Milky Way or Galaxy, is seen to be made up of an immense number of stars, apparently placed close together, but which are probably at great distances from each other.

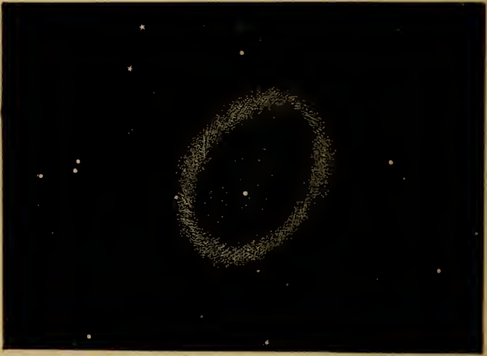
Besides the Milky Way, there are other

clusters of stars in different parts of the heavens, made up of stars crowded so closely together that they cannot be counted. Some of these clusters can be seen with the eye alone, and look much like pieces of the Milky Way; but through a telescope they appear

59. Star Cluster seen through a Telescope. [Newcomb and Holden's Astronomy.]

like a host of stars, shining with a blaze of light. By the aid of the telescope can also be seen here and there dim patches of light, which cannot be seen with the eye alone, and some of which even the strongest telescopes cannot separate into stars. These are called nebulæ, from the Latin word *nebula*, meaning a cloud. Most of the nebulæ are nearly round, but some are long, almost like a straight line, and others are like rings or spirals.

All the stars which can be seen with the unaided eye do not appear of exactly the



60. Ring Nebula. [Newcomb and Holden's Astronomy.]

same shade of color, some being ruddy, some yellowish, and some giving a white light; but when viewed through the telescope many are seen to be of bright colors, such as blood-red, orange-yellow, golden-yellow, and even blue, green, violet, lilac, gray, and olive. Sometimes, too, stars are grouped together in twos, threes, and fours, some of one color and some of another. By watching these double and triple stars for a long time, it has been found out that they turn round each other. If, then, these are the centres of systems like ours, and have planets revolving around them, the day-light on these planets, if seen with eyes like ours, is red, blue, and so on, according to the color of the sun which gives them light.

RECITATION FOR LESSON XXV.

Are any of the stars within the Solar System?

No; they are all far beyond the orbit of the most distant planet.

How do the stars look through a telescope?

Much as they do to the eye alone, but brighter; they never look round like the planets, but always like twinkling points of light.

Do they shine by reflected light, like the moon?

No; they shine by their own light, like the sun.

What do we conclude from this?

That they are bodies of very great size, which appear small because they are so far away.

Are not some of them thought to be larger than the sun?

Yes, many hundred times larger; and astronomers believe that they are suns like our sun, which give out light and heat.

Are they not also thought to have planets revolving round them?

Yes; and that each one of them is therefore the centre of a system like our Solar System.

If there are such planets, why can we not see them?

Because they are too far off, and shine only by reflected light, which is not strong enough to reach us.

What are the stars commonly called?

Fixed stars; a name given them by the ancients, because they believed they were fixed in the heavens.

How are the fixed stars divided by astronomers?

Into classes called magnitudes, according to their brightness.

How many of these magnitudes can be seen with the unaided eye?

Only six; and only the best eyes can see the smaller stars of the sixth magnitude.

About how many stars can be seen at once on a clear night?

Only about three thousand; for we do not see all the heavens at once.

But can we not see many more through a telescope?

Yes; through a telescope we can see millions which are not visible to the eye alone.

Of what is the Milky Way or Galaxy made up?

Of an immense number of stars, which look as if they were close together, but which are probably great distances apart.

Are there also separate clusters of stars in the heavens?

Yes; some, seen with the eye alone, look like pieces of the Milky Way, but through a telescope they appear like a host of stars shining with a blaze of light.

What are nebulæ?

Dim patches of light, which cannot be seen with the eye alone, and some of which even the strongest telescopes cannot separate into stars.

Are the nebulæ of different shapes?

Yes; some are round, some straight, and some like rings or spirals.

Are all stars of the same color?

No; many are of bright colors, such as red, yellow, blue, and green.

Are not different-colored stars sometimes grouped together?

Yes; sometimes in twos, threes, and fours, which revolve around each other.

If these are suns and have planets revolving around them, what kind of light must these planets have?

Their day-light, if seen with eyes like ours, must be of the color of the sun which shines on them.

LESSON XXVI.

THE APPEARANCE OF THE HEAVENS.

Though the fixed stars are at very different distances from us, let us imagine for the sake of convenience that they are fastened on the inside of a great globe, and all at the same distance from the earth, which is all the time turning round in the centre, this being the way in which they really appear to us. We on the earth can see of course only those stars which are opposite us, but as the earth turns round from west to east others are all the time coming into view in the east and appearing to move across the heavens toward the west, where they go down out of sight. Thus they appear to move from east to west because the earth moves the other way.

Now suppose that the axis of the earth be lengthened from each of the poles in a straight line until the two ends touch the heavens: this will be the axis of the heavens, around which they appear to turn, and the ends will be the poles of the heavens. If we could stand directly on the north pole of the earth we should see half of the heavens, but it would always be the same half; the same stars would appear to turn round and round the north pole of the heavens in circles, those near the pole moving in small circles and those nearer the horizon in larger ones, none ever going below the horizon. It would be the same at the south pole of the earth, only the other half of the heavens would be seen there; but if we stood at the equator, we would see at once the half of the heavens from one pole to the other, and during the twenty-four hours of the day all the stars would pass through the heavens, appearing to rise in the east and set in the west. We would see them, of course, only at night, for in the day-time they are hidden by the brighter light of the sun, but they are there both day and night.

To people living about the same distance from the north pole as New York, the heavens look a little different from their appearance at the poles or the equator. As we are nearly half-way between the north pole of the earth and the equator, the north pole of the heavens is about half-way between the horizon and the zenith, or point directly overhead. Therefore, while some of the stars appear to rise in the east and set in the west, those near the pole can be seen to move all the way round it in a circle, never going out of sight. This

61. Showing the Apparent Daily Motion of the Stars round the Pole Star. [Newcomb and Holden's Astronomy.]

can be better understood from the picture (61), which shows the north pole of the heavens and the stars around it. The star in the middle is the Pole Star, commonly called the North Star, because it is always in the north. All the stars within the circle move every day round the Pole Star and are always above our horizon; and all without the circle move round in the same way, but they are so far from the pole that a part of their circles are below our horizon, and they therefore appear to rise and set.

Thus different stars are seen by those on different parts of the earth; and while some stars around the north pole of the heavens are always in our view, there are many stars at the south pole of the heavens which are never seen by us. We must also bear in mind that the stars which rise and set on our horizon are not always the same at all seasons of the year, but are continually changing. This is caused by the earth's motion round the sun; as it is night only on the side of the earth which is furthest from the sun, and as the earth is sometimes on one side of the sun and sometimes on the other, it follows that one side of the heavens is opposite us in winter nights, and the other side in summer nights, and that the stars which we see in winter are different from those which we see in summer. It also follows that the stars around the pole which are always visible do not appear to us at the same time of night in the same positions, being sometimes on one side of the pole and sometimes on another.

There are maps of the heavens called celestial (Latin *cœlestis*, from *cœlum*, heaven) maps to distinguish them from terrestrial (Latin *terrestris*, from *terra*, the earth) maps, or maps of the earth, and also celestial globes on which all the principal stars are laid down, just as the principal places on the earth are marked on terrestrial maps and globes. As the stars all look much alike, differing chiefly in brightness alone, it has been found necessary to divide them into groups called constellations (Latin *constellatio*, a group of stars). This was first done by the ancients, who gave the names of animals, of men, and of other objects to the constellations because they thought that they saw in the stars of which they were formed some likeness to those things. These names are still kept by us, although in most cases the groups of stars do not look anything like the things from which they are named.

In beginning to learn astronomy one ought to learn the places in the heavens of the principal constellations so as to be able to know them at sight. It is best to have the use of a celestial globe or a set of celestial maps, but the beginner will be saved time and trouble if the teacher is able to point out the most important ones, and to show how they may be known. No telescope will be needed at first, as the principal constellations can easily be seen with the eye alone.

Among the most important of the stars is the Pole Star, because it is always in the north, and from it therefore we can get the points of the compass. When we face it, the east is on our right hand, the west on our left, and the south behind us. When the sailor can see the Pole Star he can steer his ship in the course he wishes to go, even if he has no compass. It is therefore important to know how to find it, and to know this we must first learn to find the constellation called the Great Bear.

RECITATION FOR LESSON XXVI.

How do the stars really appear to us?

As if they were all fastened on the inside of a great globe, at equal distances from the earth in the centre.

What makes them appear to be moving round the earth from east to west?

The turning of the earth from west to east.

What do you understand by the poles of the heavens?

If the axis of the earth were lengthened out at the poles until it touched the heavens at each end, the two ends where it touched would be the poles of the heavens, and the axis itself would be the line around which the heavens appear to turn.

If we could stand at the north pole of the earth, how would the heavens appear?

We could see only the northern half of the heavens, and the stars would appear to move round and round the pole of the heavens in circles, none going below the horizon.

Would it be the same if we stood at the south pole?

Yes, only we should see the southern instead of the northern half of the heavens.

How would the stars look if we stood on the equator?

Half of the heavens would be seen at once, stretching from pole to pole, and the stars would look as if they rose in the east and set in the west.

Would not all of the stars thus pass through the heavens?

Yes; but we should see only those opposite us at night, those passing in the day-time being hidden by the light of the sun.

How do the stars look to people living about as far from the north pole as New York?

As New York is nearly half-way between

the north pole and the equator, the north pole of the heavens is about half-way between the horizon and the zenith. Therefore some stars appear to move round the pole and others appear to rise and set.

What do you understand by the zenith?

The point in the heavens directly over our heads.

Do we see the same stars at all seasons of the year?

No; they are always changing a little on account of the earth's movement around the sun.

Are the stars seen in winter the same as those seen in summer?

No; they are entirely different: as it is night only on the side of the earth furthest from the sun, and as the earth in winter is on a different side of the sun from that on which it is in summer, it follows that different sides of the heavens are seen in winter and summer.

Are not the stars around the pole always visible to us?

Yes; but they do not always appear in the same positions, being sometimes on one side of the pole and sometimes on another.

How are the stars divided on maps of the heavens?

Into groups called constellations.

Why did the ancients give these the names of men, animals, etc.?

Because they thought they saw in the stars of which they are made up some likeness to those things.

Why is the Pole Star one of the most important ones to know?

Because it is always in the north, and from it we can get the points of the compass.

What constellation must we know to find the Pole Star?

The constellation of the Great Bear.

LESSON XXVII.

THE CONSTELLATIONS.

The constellation of the Great Bear (Latin *Ursa Major*) is sometimes called the Plow, but more commonly the Dipper; and though it does not look much like a bear or a plow, its stars may easily be imagined to form the

62. The Great Bear.

outline of a dipper with a bent handle, as will be seen in the picture. One who has once seen this will not be apt to forget it; it is made up of seven bright stars, four of which form the bowl and three the handle of the dipper. The two stars on the side of the bowl furthest from the handle are called the

Pointers, for they point very nearly to the Pole Star.

By looking at the picture on page 196 it will be seen that the constellation of the Great Bear or Ursa Major is within the circle enclosing the stars which are visible all the time at New York. It will also be seen by the dotted line how the Pointers point to the Pole Star. The Pole Star apparently never changes its place, because it is at the end of the axis around which the heavens appear to revolve, but the stars near it always appear to be turning round it. Therefore, if we look at the Great Bear early in the evening and again late at night we shall see that it has changed its position; if we see it again the next morning just before sunrise, we shall see that it has moved much farther; during the day it will be hidden from our view, but if we look for it at about the same hour of the next evening, it will be found in the same place it occupied the evening before, thus having gone entirely round the pole. But no matter on which side of the pole it may be, its stars never change their relative places —that is, the Dipper always keeps the same form, and the Pointers always point toward the Pole Star.

The Pole Star itself forms the end of the tail of the constellation called the Little Bear (Latin *Ursa Minor*), which is much like the Great Bear, but smaller. It is made up of seven small stars, which also are arranged

63. The Great Bear and the Pole Star.

something in the form of a dipper, but it is turned a different way from the Great Dipper.

On the opposite side of the Pole Star from the Great Bear is the constellation called Cassiopeia, formed of five stars of the third magnitude and some smaller ones, making a figure a little like the outline of a chair. These constellations, the Great Bear or Great Dipper, the Little Bear or Little Dipper, and Cassiopeia, are the three nearest ones to the pole; and when we have learned how to find them it will be easy to trace out the others on a celestial globe or map, and then to find them in the heavens.

64. The Great Bear, the Little Bear, and Cassiopeia.

The brightest and most beautiful of the constellations is Orion, named after a mighty giant and hunter of Greek fable. It is easily found by the picture (65) given of it. The three bright stars in a line about the middle are called Orion's belt. Below it is another row of three smaller ones. The two brightest stars in Orion are Betelguese (the higher one), which looks reddish, and Rigel, a beautiful white star. Near Orion is Canis Major (Latin for Great Dog), one of the stars of

65. Orion.

which, Sirius, is the brightest fixed star in the heavens. The ancient Egyptians used to believe that when this beautiful star rose in the morning the waters of the Nile began to rise also, and so they named it the Nile Star, and called the constellation in which it was the Dog, because it acted the part of a faithful dog in giving them warning of the coming of the flood, and gave them time to move to safer spots. We still call Sirius

66. The Pleiades.

the Dog Star, because it was at one time believed that it caused very hot weather during certain days in summer, which, on that account, were called Dog-days. We still speak of the Dog-days, but we now know that they are not caused by this star.

The constellations called Gemini (The

Twins), Taurus (The Bull), and Eridanus (The River Eridanus, or Po) are near Orion as shown in the picture. Aldebaran, a bright red star, is in Taurus. Taurus may easily be known by the Pleiades, a beautiful group of stars better shown in the picture (66). They are sometimes called the Seven Stars, and are said to have been named after the seven daughters of Atlas and Pleione, who, according to Greek fable, were placed by Jupiter in the heavens; but there are really only six stars in the group which can be seen by common eyes, and any eye strong enough to see seven would probably see four more, or eleven stars in all. But when looked at through a telescope seventy or eighty other little stars can easily be seen. In the picture the six brightest stars are those commonly seen by the eye alone; nearly all the others need a telescope. The Pleiades, though only a part of a constellation (Taurus) and not a constellation by themselves, have been more important in the past than any other heavenly object, except the sun and moon. In ancient times many nations made their years, seasons, and festivals by their movements, and their risings and their settings were watched all over the world.

The stars of which the different constellations are made up are not all of the same brightness, some being of the first and some of the second, third, fourth, and other magnitudes. To distinguish them from each other they are marked by the letters of the Greek alphabet, the brightest by Alpha (α), the next brightest by Beta (β), and so on. Thus the brightest star in the constellation of the Great Bear (Ursa Major) is called α Ursæ Majoris, or in English, α of the Great Bear; the second brightest, β Ursæ Majoris, and so on. When there are more stars in a constellation than there are letters in the alphabet, they are numbered 1, 2, 3, and so on. Some of the principal stars also have other names, given them in early times. For instance, α Canis Majoris, or α of the Great Dog, is the same as Sirius; α Tauri, or α of the Bull, the same as Aldebaran, and so on. Thus all the stars we have been able to see in the heavens are named, lettered, or numbered, so that they may easily be found by the aid of a celestial globe or map.

RECITATION FOR LESSON XXVII.

What is the constellation of the Great Bear more commonly called?

The Dipper.

Of how many stars is the Dipper made up?

Seven, four of which form the bowl and three the handle.

Which of these are called the Pointers, and why are they so called?

The two stars of the bowl furthest from the handle; they are so called because they point nearly to the Pole Star.

Does the Pole Star ever change its place?

No; it is always in the north, at the end of the axis around which the heavens appear to turn.

Does the Great Bear or Dipper ever change its place?

It appears to be always turning round the Pole Star, but its stars always keep the same form, and the Pointers always point toward the Pole Star.

To what constellation does the Pole Star itself belong?

The constellation of the Little Bear.

Is not the Little Bear somewhat like the Great Bear?

Yes; its stars are arranged also like a dipper, but it is turned a different way from the Great Dipper.

Where is the constellation called Cassiopeia?

On the opposite side of the Pole Star from the Great Bear, and at about the same distance from it.

What is the brightest and most beautiful of the constellations?

Orion, named after a mighty giant of Greek fable.

What is the brightest fixed star in the heavens?

Sirius.

What did the Egyptians call this star?

The Nile Star, because they thought that when it rose the waters of the Nile rose also.

What name did they give to the constellation in which Sirius is?

The Dog, because it gave warning of the coming of the flood.

What do we sometimes call Sirius?

The Dog Star, because it was at one time believed that it caused the hot weather commonly called Dog-days.

What remarkable group of stars is in the constellation Taurus?

The Pleiades.

What other name has it?

It is sometimes called the Seven Stars, though only six can be seen by common eyes.

Can more be seen through a telescope?

Yes, seventy or eighty more.

How are the stars of the different constellations told from each other?

They are marked by the letters of the Greek alphabet, the brightest being called Alpha, the next brightest Beta, and so on.

When there are more stars than there are letters in the alphabet, how are they marked?

They are numbered.

Have not some of the principal stars names given to them?

Yes; names which were given them in very early times, and are still kept.

LESSON XXVIII.

THE JULIAN CALENDAR.

In the first lesson it is said that astronomy enables us to measure time correctly. By this is meant that by our knowledge of the movements of the heavenly bodies we are enabled to divide time accurately into years, months, and days, and thus to make almanacs. This division of time is called the calendar (Latin *calendarium*, from *calendæ*, the first day of the Roman month, from *calare*, to call, because the Roman priests used to call the people together on that day to tell them of the days to be kept sacred during the month).

We have already learned that the earth rolls around the sun once a year, that the moon rolls around the earth once a month, and that the earth turns on its axis once a day. We thus get time divided into years, months, and days. By dividing the day into twenty-four equal parts we get our hours, which we again divide into minutes and seconds; so that all our divisions of time depend on the movements of the heavenly bodies. From this it will be seen how very necessary it is that our knowledge of astronomy should be accurate.

In dividing time the most important thing to know first is the exact length of the year—that is, the exact time of each revolution of the earth around the sun; for if we should get this wrong the seasons would come wrong, and we might in time have winter in the summer months. This really happened in old times. The ancient Egyptians gave the year three hundred and sixty-five (365) days, when it is really about three hundred and sixty-five days and a quarter long. This quarter of a day made such a difference in the length of the year that in the time of Julius Cæsar spring came in the time of summer. To remedy this Cæsar got an astronomer named Sosigines to make a change in the calendar (46 B.C.). Sosigenes saw that the loss of a quarter of a day each year would amount in four years to a whole day. So to make the year come right he proposed to add a day to every fourth year, thus making in every period of four years three years of 365 days each and one of 366 days. We call this fourth year leap year, but the Romans named it bissextile year, and it is generally so called in the almanacs.

To understand why this was called bissextile, we must first learn something about the months. The Romans began their year on the first of March. December was therefore their tenth, January their eleventh, and February their twelfth month, or the last month in their year. At that time every February had twenty-eight days, but when Cæsar added the extra day to every fourth year he put it at the end of the year, thus making February twenty-nine days long every fourth year. If we should add a day to a month, we would put it at the end of the month, but the Romans counted differently from us. They looked upon February 23 as the real end of the year, and celebrated it with a feast called Terminalia, named after Terminus, their god of bounds or limits; and the five remaining days in February were considered a kind of interval or space between the end of one year and the beginning of the next one. They did not number the days of the month as we do, but reckoned them backward, counting so many days before each feast day, much as children count the days before Christmas. For instance, instead of saying February 28, they said "the second day of the calends (first) of March;" instead of February 27, the third day of the calends of March, and so on, always counting the feast day itself as the first day. When Julius Cæsar added the extra day to February, he put it after the feast of Terminalia (Feb. 23), that is, between the 23d and 24th of February, or, as the Romans called it, between the seventh and the sixth days of the calends of March. As this would change the count he ordered that the new day should be called a second sixth (Latin *bis*, twice, and *sextilis*, sixth); and from this the year which had this odd day in it was called a bissextile (Latin *bissextilis*) year, and we have ever since kept the name. The calendar thus changed by Julius Cæsar is commonly called, in honor of him, the Julian calendar.

We also get our names of the months from the Romans. January was called by them Januarius, from the god Janus; February, Februarius, from Februus, the god of the dead, because this month was the end of the year; March, Martius, from Mars, the god of war; April, Aprilis, from the Latin word *aperire*, to open, because the buds open in this month; May, Maius, from Maia, the mother of Mercury; June, Junius, from the goddess Juno. The other six months were at first named according to their number in the year, counting March as the first month. Thus, the fifth month (now July) was named Quintilis (Latin *quinque*, five), the sixth (now August), Sextilis (Latin *sex*, six), the seventh, September (Latin *septem*, seven), the eighth, October (Latin *octo*, eight), the ninth, November (Latin *novem*, nine), and the tenth, December (Latin *decem*, ten). After the death of Julius Cæsar the name of Quintilis was changed to Julius (July), in honor of him, and Sextilis was made into Augustus (August) in honor of the Emperor Augustus. The others still bear the names the Romans gave them when the year began on the first of March, and we still say September, which means the seventh month, though it is really the ninth month of the year.

RECITATION FOR LESSON XXVIII.

How do we divide time correctly into years, months, and days?

By means of our knowledge of astronomy.

What is this division of time called?

The calendar.

Why is it so called?

It is named from *calendæ*, the first day of each Roman month.

In dividing time, what is the most important thing to know first?

The exact length of the year, or of the revolution of the earth around the sun.

What would happen if we should get this wrong?

The seasons would come wrong, and we might have winter in the summer months.

Did this ever happen?

Yes; in the time of Julius Cæsar, spring came in summer.

What was the cause of this?

It was caused by making the year only 365 days long, when it is really about 365¼ days.

How did Cæsar change this?

He added a day to every fourth year, thus making in every period of four years three common years of 365 days each, and one year of 366 days.

What is such a fourth year called?

We commonly call it leap year, but the Romans called it bissextile year, and this is the name given it in the almanacs.

What is the calendar thus changed by Julius Cæsar called?

The Julian calendar.

With what months did the Romans begin and end their year?

They began it with March and ended it with February.

To what month did Cæsar add the odd day?

To February, so that February has twenty-nine days in leap years.

From what were the months named?

January, February, March, May, and June were named after Roman gods and goddesses; April was named from a Latin word meaning to open, because the buds open in that month; and the other six were at first named according to their number in the year, counting March as the first month.

Were any changes made in these numbered months?

The name of the fifth month of the Roman year, at first called Quintilis, was changed to Julius (July) in honor of Julius Cæsar, and that of the sixth month, Sextilis, to Augustus (August) in honor of the Emperor Augustus.

LESSON XXIX.

THE GREGORIAN CALENDAR.

The Julian Calendar was used everywhere until about three hundred years ago. It was then seen that the adding of a day every fourth year was too much, for the earth really goes round the sun in a little less than three hundred and sixty-five and a quarter days, the time being very nearly 365 days, 5 hours, 48 minutes, and 49 seconds. To add one day to every fourth year is about eleven and a quarter minutes too much, and it was found out in time that the seasons had got ahead of the true year about ten days. So Pope Gregory XIII. ordered in 1582 that ten days should be dropped out of the calendar, and October 5 of that year was called October 15 in all countries which were then Roman Catholic. Protestant countries were a long time in making the change, and in Great Britain it was not done until 1752, when Parliament ordered that September 3d should be called September 14th, thus dropping eleven days, because the calendar was then eleven days behind instead of ten. In old records, and in many books, dates are often seen with the letters O. S. or N. S. after them; these mean Old Style and New Style, the first being according to the Julian Calendar, and the second according to the Gregorian Calendar, as the new one was named after Pope Gregory. The Russians still keep the old style, and in their books it is customary to see double dates given—that is, the date according to both calendars. For instance, the difference now being twelve days, the date July 4, 1881, would be written in Russia $\frac{\text{June 22,}}{\text{July 4,}}$ 1881.

In order to keep the year right in the future, Pope Gregory made a new rule for telling which years were leap years. In the Julian Calendar every year whose number could be divided evenly by four was a leap year; but as this was too many, Gregory ordered that each centesimal or hundredth year should be a leap year only when it could be divided by four after the two ciphers were cut off. For instance, 1600 was a leap year, because, after cutting off the two ciphers, 16 can be evenly divided by 4. In the same way, 1700 was not a leap year, for with the ciphers cut off, 17 cannot be divided by 4 without leaving a remainder. So the year

1800 was not a leap year, and 1900 will not be one; but 2000 will be one, for 20 is divisible by 4 without a remainder. This drops three days from the calendar every four hundred (400) years, and keeps the calendar year very nearly the same as the solar year—that is, the time of the earth's movement around the sun. The calendar thus changed is called the Gregorian Calendar.

In very early times the year was divided into parts according to the revolution of the moon around the earth, the time between one new moon and the next one being called a month. Our word month comes from the Anglo-Saxon word *monath*, month, which is made from another Anglo-Saxon word *mona*, meaning the moon. As there are about twenty-nine and a half (29½) days between every two new moons, it was found that twelve months of this length would make only 354 days, or not enough to fill up the year; so the odd days were finally added to the months, and now some of them have 31 days, and the others 30 days each, excepting February, which has commonly 28, and in leap years 29 days. The number of days in each month may be easily remembered by learning the following verse:

"Thirty days hath September,
April, June, and November;
February hath twenty-eight alone,
All the rest have thirty-one."

The division of the days of the month into periods of seven days called weeks is also very ancient. When men thought that the earth was the centre of the universe, they also thought that the sun, the moon, and the planets moved around it. Indeed, they reckoned the sun and the moon among the planets, so that, with the five real planets which they knew (Mars, Mercury, Jupiter, Venus, and Saturn), they counted seven planets in all. From these seven planets the Romæns named the days of the week, as is shown in the following table, where the names of the Roman days are given in Latin, with the translations of the names into English, and our names of the days:

Solis Dies	Day of the Sun	Sunday.
Lunæ Dies	Day of the Moon	Monday.
Martis Dies	Day of Mars	Tuesday.
Mercurii Dies	Day of Mercury	Wednesday.
Jovis Dies	Day of Jupiter	Thursday.
Veneris Dies	Day of Venus	Friday.
Saturni Dies	Day of Saturn	Saturday.

Thus the Romans gave the names of their gods to the planets, and made the days of the week sacred to them. We have kept these old Roman names for three of the days of the week, Sunday, Monday and Saturday, but we have changed the names of the other four. This was done by our Saxon forefathers in honor of their gods Tuesco or Tuisco, Wodin or Odin, Thor, and their goddess Friga. So Tuesday is the day of Tuesco, Wednesday the day of Wodin, Thursday the day of Thor, and Friday the day of Friga.

In every common year (365 days) there are just fifty-two (52) weeks and one day ($52 \times 7 = 364$), so that every common year ends on the same day on which it began. For instance, 1881 began on Saturday and will end on Saturday; 1882 will begin on Sunday and end on Sunday; and 1883 will begin on Monday and end on Monday. Thus, in most common years every date in the year is put one day beyond the same date of the year before. But when a leap year comes this order is changed, because the addition of a day to February makes one more day in that year, so that in the following year all dates will move forward two days instead of one day. For instance, 1884 will be a leap year, because it can be divided by four without a remainder, and will therefore have 366 days. As it will begin on Tuesday, it will therefore end on Wednesday instead of Tuesday, and January 1, 1885, will fall on Thursday, instead of Wednesday as it would if 1884 were not a leap year.

RECITATION FOR LESSON XXIX.

Until when was the Julian Calendar used?

Until about three hundred years ago.

What was then found out?

It was found out that the adding of a day every fourth year was too much.

Why was it too much?

Because it takes the earth a little less than 365¼ days to go round the sun.

What had happened from adding a day every fourth year?

The seasons had got ten days ahead of the true year.

Who made a new change in the calendar?

Pope Gregory XIII.

What did he order?

He ordered that ten days should be dropped out of the calendar.

Was this change made everywhere?

It was made in Roman Catholic countries; but Protestant countries were a long time in doing it.

When was the change made in Great Britain?

About a hundred and thirty years ago.

How many days was it then necessary to drop from the calendar?

Eleven days, because the calendar was then one day more behind than in the time of Pope Gregory.

What is the calendar as changed by Pope Gregory called?

The Gregorian Calendar.

What do you understand by Old Style and New Style?

Old Style is the date according to the Julian Calendar, and New Style according to the Gregorian Calendar.

Does any nation still keep the Old Style in its calendar?

The Russians still keep the Old Style, and in writing dates commonly give both styles.

What is the difference now between Old Style and New Style?

Twelve days.

What new rule did Pope Gregory make for counting leap years?

He ordered that three leap years in every four hundred years should be counted as common years, and have only 365 days each.

How do we now tell which of the years are leap years?

All years which can be divided by four without a remainder are leap years, excepting the hundredth years; only those are leap years which can be thus divided after the two ciphers have been cut off.

What is the word month made from?

From the Anglo-Saxon word *mona*, meaning the moon.

Why was the month named after the moon?

Because in early times the year was divided into parts of even length, according to the revolution of the moon around the earth.

Do we still follow this plan?

Not exactly; we divide the year into twelve parts or months, but not of even length.

Why are the months made of uneven length?

Because we cannot divide the year of 365¼ days into twelve months of the same number of days each.

From what were the seven days of the week named?

From the seven planets known to the ancients.

What heavenly bodies did the ancients call the seven planets?

The sun, the moon, Mars, Mercury, Jupiter, Venus, and Saturn.

Have we kept the same names for the days of the week?

We have kept only three: Sunday, or the day of the sun; Monday, or the day of the moon; and Saturday, or the day of Saturn.

From what do the names of the other four days of the week come?

From the names of the heathen gods of our Saxon forefathers.

On what day of the week do common years end?

On the same day on which they began.

What happens from this?

That every date in the year is put one day beyond the same date of the year before.

What change does a leap year make in this order?

The adding of a day to February makes all dates in the following year move forward two days instead of one.

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