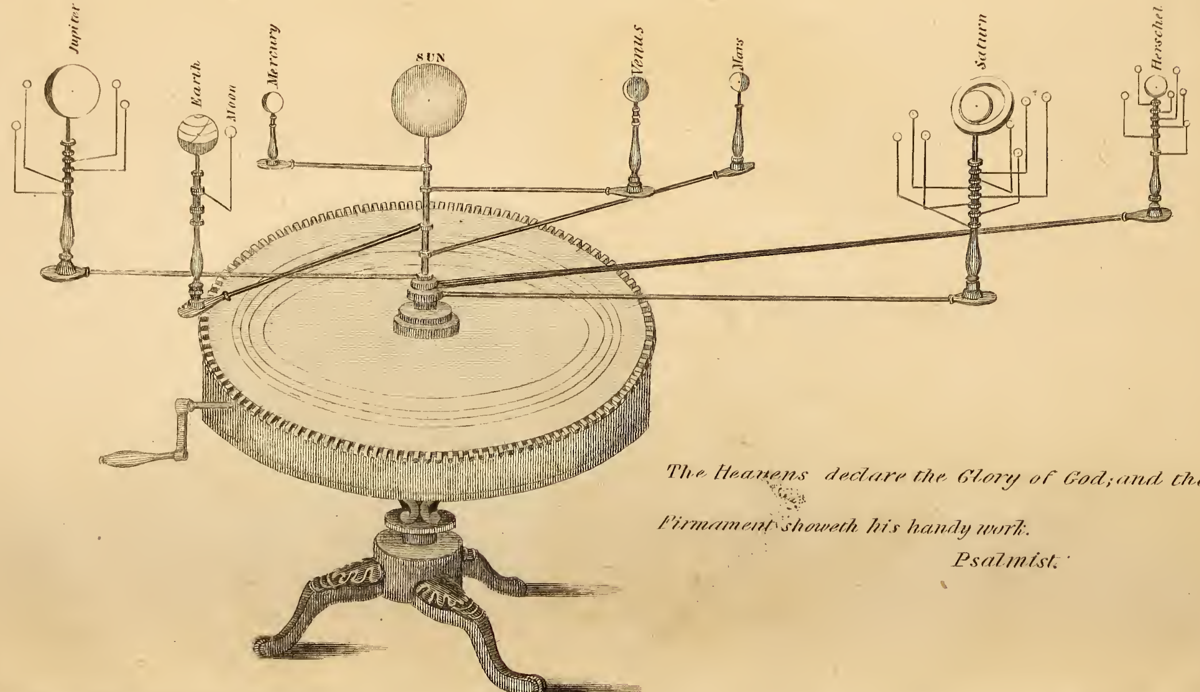
PLATE I.



The Heavens declare the Glory of God; and the Firmament showeth his handy work.

Psalmist.

O Pelton sc

FIRST BOOK IN ASTRONOMY,

ADAPTED TO THE

USE OF COMMON SCHOOLS.

ILLUSTRATED WITH STEEL PLATE ENGRAVINGS.

BY REV. J. L. BLAKE, A. M.

AUTHOR OF THE HISTORICAL READER, IMPROVEMENTS IN BLAKE'S NATURAL PHILOSOPHY, BIBLICAL READER, GEOGRAPHY FOR CHILDREN, AND OTHER WORKS ON EDUCATION.

"All Nature is a glass reflecting God,
As by the sea reflected is the sun,
Too glorious to be gaz'd on in his sphere."

BOSTON:

LINCOLN AND EDMANDS.

Portland, S. Colman: Hartford, Packard & Butler: New-York, Roe Lockwood: Philadelphia, L. A. Key: Baltimore, Joseph Jewett: Charleston, J. J. M'Carter: Cincinnati, N. & G. Guilford.

1831.

PREFACE.

Two objects are to be continually kept in view by every person engaged in communicating literary and scientific knowledge. One of these objects is, to make a judicious selection of topics; and the other is, to present them in a form most likely to interest the attention, and thereby produce distinct and deep impressions on the understanding and the memory. These objects are too much neglected both by teachers and the authors of elementary works on education. A teacher may possess an abundance of erudition in the branches to be taught; but completely fail in rendering his instructions of much value to his pupils by an inattention to the particulars named. And a book, on elementary education, may excel in the accuracy of its details, as well as in relation to the ability with which the general plan is executed; but still be most defective in answering the purpose for which it was designed. To answer the purpose contemplated in such a work, it must be suited to the taste and the mental capacity of the persons to be benefitted by it.

It sometimes happens, and not very unfrequently, that an author will crowd into a book, whether needed or not, everything he knows on the subject of which it treats. Hence, we see in school books for the use of quite young scholars, matters altogether above their comprehension. The evil arising from such instances of ostentation is far more extensive than at first imagined. It is not simply a waste of space occupied by the irrelevant matters alluded to; but, if scholars find one half of a book above their comprehension, they will be likely to throw aside the whole of it in disgust. A teacher also may be influenced by a similar desire to excite admiration, and adopt similar means for securing it. Accordingly, he will bring into school, for the use of mere boys and girls, books which are suited to the highest grade of students in college; but which his own scholars will understand about as well as they would the entire system of Egyptian hieroglyphics. Place before young scholars one book, and another, and another, which they cannot understand, and they will be likely to have an aversion to everything in the form of books.

To produce the best possible effects from the use of books, they should contain nothing that children of ordinary capacity, with proper instruction, are unable to comprehend. They should also be filled with what is enticing in its appearance. The very form in which things suitable for young persons are presented, should be pleasing to the eye. Hence, long paragraphs, long articles on the same subject, a long succession of pages filled precisely in the manner, presenting an aspect as dull and monotonous, as a sand desert without variation or limits, are alike unfavorable in their effects on the interests of education.

It is proper to remark, that the author has attempted to prepare the following little work in accordance with the foregoing suggestions. How far he has been successful in making this attempt teachers and the public generally will determine. Whatever is abstruse, and difficult, and suited only for the highest class of learners, has been carefully excluded. To supply the place of what is thus excluded, there is introduced a mass of miscellaneous matter, on a level with the mental perceptions of those for whose improvement and gratification the volume is prepared. Meteorology is nearly allied to Astronomy, and is in a high degree interesting. A small volume on this subject might be furnished, in every respect calculated to excite a taste in young persons for literary pursuits.

No subject is more imposing and sublime than Astronomy. No one is better calculated to gain the attention of children; and to raise in the mind a highly improved state of moral sentiment, and moral feeling. The poet truly said, "an undevout astronomer is mad." Intellectual and moral discipline should always be united, in pursuing a course of education. For such an union of beneficial results, we may rationally look in presenting to the youth of our country, the present brief compend. And the more effectually to aid in the accomplishment of a purpose so desirable, may teachers and pupils ever be enabled piously to unite in the following aspiration:

> "Astronomy! Parent of Devotion, engage my midnight vigils;
> Elevate my thought to contemplate thy vast realities;
> Warm my soul with adoration pure, and fervent praise
> To HIM, whose finger fashioned yon revolving worlds."

FIRST BOOK IN ASTRONOMY.

ASTRONOMICAL AND GEOMETRICAL DEFINITIONS.

LESSON I.

The Definitions here given are in as few words as possible, with a view to their being committed to memory. Each one may be considered an answer to a distinct question, which the teacher should propose at the time of reciting. For instance, What is astronomy? What is a circle? What is a planet? &c. If this lesson is too long to be recited at one time, it can easily be divided into two or more lessons.

Astronomy is the science which describes the heavenly bodies; the Sun, Planets, Fixed Stars, and Comets.

A *planet* is an opaque, or dark body, deriving its light from another body, around which it revolves.

A *comet* is a body which moves round the sun in a very eccentric orbit or tract, and is usually accompanied with a long train of light.

The *orbit* of any celestial body is the curve or path it describes in revolving round another body.

Two celestial bodies are said to be in *opposition*, when they are in opposite points of the heavens.

Two celestial bodies are said to be in *conjunction*, when they are in the same point of the heavens.

A planet is said to move *direct*, when it appears to move according to the signs of the ecliptic.

A planet is said to move *retrograde*, when it appears to move contrary to the signs of the ecliptic.

A planet is said to be *stationary*, when it appears to remain any particular time in a certain point of the heavens.

A *circle* is a plane figure bounded by a curved line, called the circumference, every part of which is equally distant from the centre.

The *diameter* of a circle is a line drawn through the centre, terminated both ways by the circumference.

The *radius* of a circle is a straight line drawn, in either direction, from the centre to the circumference.

A *semicircle* is any half of a circle, or circumference, cut off from the other half by the diameter.

A *quadrant* is half a semicircle, or circumference; or it is one fourth part of a whole circle.

All *circles*, whether great or small, are supposed to be divided into 360 equal parts, called degrees, and are marked °.

Each *degree* is divided into sixty minutes, marked ′; and each minute is divided into sixty seconds, marked ″.

An *arc* of a circle is any portion of the circumference, less than one half, or less than a semicircle.

The *chord* of a circle is a straight line joining together the extremities of an arc.

An *angle* is the space contained between two lines meeting in a point.

A *right* angle is an angle formed by one line falling perpendicular upon another line, containing ninety degrees, or the quadrant of a circle.

An *obtuse* angle is greater than a right angle; containing more than the quadrant of a circle, or ninety degrees.

An *acute* angle is less than a right angle; containing less than ninety degrees, or the quadrant of a circle.

Parallel lines, whether straight or circular, are everywhere at the same distance from each other; and, if drawn ever so far either way, will never meet.

A *sphere* is properly a globe; but, in astronomy, the celestial sphere means the apparently concave orb of the heavens, in which all the heavenly bodies appear to be placed.

Concentric circles are circles drawn round the same centre, at different distances from it.

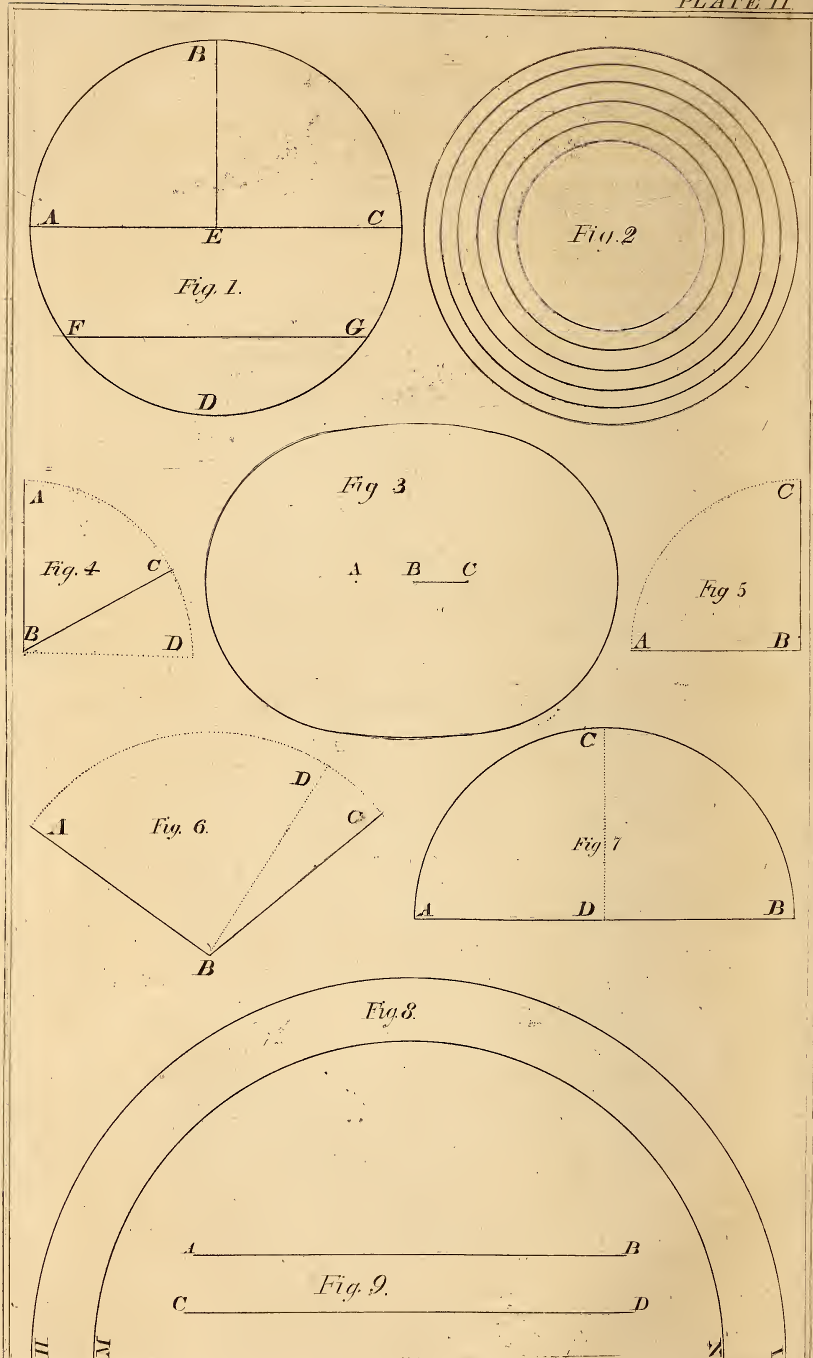
Cardinal points are certain fixed points that never change, and to which all calculations are referred.

An *ellipsis* is an oval. This figure differs from a circle, in being unequal in its diameters, and in having two points called its *foci*.

The *foci* are the two points in the longest axis of an ellipsis, on which as centres the figure is described.

The *eccentricity* of an ellipsis is the distance between the centre and either foci.

PLATE II.



O. Pelton Sc.

ILLUSTRATION OF GEOMETRICAL DEFINITIONS.

LESSON II.

The following Questions are to be answered from the figures in Plate II, being an illustration of the Geometrical Definitions. It will be well for the Instructer to add other similar questions, till the pupil becomes perfectly familiar with the matters they are intended to explain.

1. Which figure represents a circle?
2. By what is the centre of it represented?
3. By what is the diameter represented?
4. What part of that circle makes an arc?
5. By what is the chord of that arc represented?
6. By what line is the circle divided into semicircles?
7. Which figure exhibits a right angle?
8. Why is that figure a right angle?
9. Which figure exhibits an obtuse angle?
10. Why is that an obtuse angle?
11. Which figure represents an acute angle?
12. Why is that figure an acute angle?
13. By which figure are concentric circles represented?
14. Which two figures represent parallel lines?
15. Which figure contains six parallel lines?
16. What two lines in fig. 1, are parallel?
17. By which figure is an ellipsis represented?
18. By what are the foci of it represented?
19. What is the eccentricity of this ellipsis?
20. Which figure represents a semicircle?
21. How many right angles does it contain?
22. What lines are the radii of the circle in the first figure?
23. How might fig. 4, be made into a right angle?
24. How can a right angle be made of figure 6?
25. How can an acute angle be made in it?
26. In fig. 7, which line is the chord of the arc?
27. Which dotted lines in Plate II, are arcs of circles?
28. Which dotted lines are radii of circles?

GENERAL VIEW OF THE CELESTIAL BODIES.

LESSON III.

When we direct our eyes towards the heavens, we perceive an apparent hollow hemisphere, at an infinite distance, of which each spectator seems to constitute the centre. The earth stretches like an immense plane, and at a certain distance appears to meet and to bound the celestial concavity.

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1. What do we observe on directing our eyes towards the heavens?——
2. What makes the centre?

The most obvious celestial phenomena are the daily rising of the *sun* in the *east*, and its setting in the *west*; next to which we also see the *moon* and *stars* rise and set in like manner, keeping the same westerly course.

These cannot be long observed, before we perceive that neither the sun nor the moon always rise exactly in the same point of the horizon, nor ascend to the same height.

If, in these northern parts of the world, we observe the sun from the beginning of the year, it will be found to rise daily more northward, to continue longer above the horizon, and to be more elevated at mid-day, till near the end of June, when it will be observed to move backwards in like manner, till near the end of the year.

When the *new moon* first becomes visible, it appears in the western part of the heavens, not far from the setting sun. Every night it increases in size, and removes to a greater distance from the setting sun; till at last it appears in the east part of the horizon, just at the time the sun disappears in the west.

In an unclouded evening the hemisphere is seen studded with stars, and its appearance is changing every instant. New stars are continually ascending in the east, while others are descending in the west.

Those stars, that towards the beginning of the evening were just visible in the east, are seen late at night over our heads, and may be traced moving gradually westward, till at last they disappear altogether.

If we look to the north, we may perceive that many stars in that quarter never set at all, but move round, describing a complete circle in every twenty-four hours.

These stars will be found to describe their circles round a fixed point of the heavens, near which is a star of the second magnitude, called the *north* or *pole star*.

Thus the heavenly sphere appears to turn round two fixed points, called the poles, once every twenty-four hours. The imaginary line which joins these points is called the *axis* of the world.

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3. What are the most obvious celestial phenomena?——4. And of the moon and stars?——5. Do the sun and moon always rise in the same point of the horizon?——6. How do they vary?——7. Where does the new moon first become visible?——8. What change in its place and size takes place every night?——9. What is said of the stars in an unclouded evening?——10. Where will those be seen late at night, which at the beginning of the evening, were seen just above the horizon?——11. Afterwards what is observed of them?——12. If we look to the north, what may be observed of the movement of the stars?——13. Round what do they describe their circle?——14. Around what does the heavenly sphere appear to revolve?——15. How often does it thus appear to revolve?——16. By what are these two points connected?

The chief part of the stars keep their places with respect to each other. Thus, if two stars have a certain apparent distance from each other on one night, they keep the same distance every night, and are called *fixed stars.*

But some of the stars are not of this fixed kind. They change their places, as well with regard to the fixed stars, as to one another. These are called *planets.*

DIFFERENT SYSTEMS OF ASTRONOMY.

LESSON IV.

It is natural to conclude, that the beauty and the continually varying appearance of the heavenly bodies, at an early period of the world, became objects of scientific inquiry and of religious contemplation. To this the pastoral life, when persons were employed by night in watching their flocks, was particularly favorable.

Accordingly it is found, that within a few centuries of the deluge, Astronomy was cultivated in China, in Hindostan, at Nineveh, at Babylon, and in Egypt. The Phœnicians are said to have applied it to the purposes of navigation, but we have no reason to believe it was reduced to a regular science till the time of Pythagoras.

The present system of astronomy was first taught by Pythagoras, 590 years before the Christian era ; but it was afterwards rejected, until the sixteenth century, when it was revived by Copernicus, a native of Poland, from whom it is called, the Copernican system.

Thales, a celebrated philosopher of Miletus, was the first person who advanced the opinion that the earth is round, and that the moon is the attendant of the earth, both deriving their light and heat from the sun. He also supposed that the eclipses of the moon are occasioned by an immersion in the earth's shadow,

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16. What are called fixed stars ?——17. Are all the stars in the heavens fixed stars ?——18. What ones are called planets ?

1. What situations in the early ages of the world were favorable to the study of Astronomy ?——2. At what places, was it at first cultivated ?——3. How soon was it there cultivated ?——4. At what time, and by whom, was the science of astronomy first reduced to a regular system ?——5. By whom was first taught the present system of Astronomy ?——6. Who was Copernicus ?——7. Who was Thales ?——8. What did he teach ?——9. What did he suppose respecting eclipses ?

Such was the ignorance and superstition of the age in which Pythagoras lived, that he was obliged to give his instructions in private; and his disciples became the victims of religious and political persecution. Many of them were imprisoned and compelled to recant their faith; others were banished from their country, and some even suffered death.

The pagan priests were the chief instruments in causing his opinions to be thus rejected. They taught the people to believe that the earth was a level plane of great extent; that heaven was another of like dimensions, stretched out a little beyond the sun; and that hell consisted of a third plane of similar extent, situated at some distance below the earth. These and other notions which they held, had been artfully interwoven into their religion, and into all their political institutions, so that any innovation was not only treason against the state, but a species of profanity, which incurred the indignation of the multitude.

Ptolemy, the Egyptian astronomer, lived one hundred and thirty years before Christ. He supposed the earth to be at rest in the centre, around which moved the sun and the planets, once a day in the following order; the Moon, Mercury, Venus, the Sun, Jupiter and Saturn. Beyond these were placed the fixed stars. His system is called the Ptolemaic system. See Plate VI. Fig. 6.

From the time of Ptolemy, astronomy was much neglected, until near the close of the thirteenth century, when Alphonso, King of Castile, revived the subject. Still no essential change in the science was effected, until Copernicus, in the sixteenth century, embraced and published to the world the system of Pythagoras.

Nicolas Copernicus was a native of Poland. A printed copy of his work was handed him but a few hours before his death. As he was considered the inventor, the system has been called after his name—the Copernican system.

Europe, however, was still immersed in ignorance, and the general ideas of the world were not able to keep pace with those of a

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10. What is said of the age in which Pythagoras lived?——11. What is said of his disciples?——12. Who were the chief instruments in causing his opinions to be rejected?——13. What was the system of astronomy taught by the pagan priests?——14. How was innovation upon their system considered?——15. When did Ptolemy, the Egyptian astronomer live?——16. What was his system?——17. What figure illustrates his system?——18. What was the state of astronomical science, subsequent to the time of Ptolemy?——19. Who next to him revived the study?——20. When?——21. Who was Nicolas Copernicus?——22. At what time did he flourish?——23. What did he do for the science of astronomy?——24. Why is the present system of astronomy called the Copernican system?——25. What was the intellectual condition of Europe at the time of Copernicus?

refined philosopher. This caused Copernicus to have few abettors and many opponents.

About the same time, Tycho Brahe, a Danish nobleman, anxious to reconcile the appearances of nature with the literal sense of some passages of Scripture, adopted portions of the Ptolemaic system, while in other respects, he made his views conformable to the principles of modern astronomy.

The projected system of Tycho was this; in the centre of it he placed the earth, with the sun and moon moving round it as their centre; while Mercury, Venus, Mars, Jupiter, and Saturn revolve round the sun, and are carried with it about the earth.

In the sixteenth century lived the celebrated astronomer Galileo, an Italian. He was the first who applied the telescope to the examination of the heavens. This enabled him to make discoveries in the science, of which all his predecessors were utterly ignorant.

Galileo was the victim of the persecuting spirit, which prevailed at that age of ignorance and superstition. When passed the age of three score and ten years, he was obliged by the priests, standing upon his knees, over the Bible, to disclaim belief in a system to which he had devoted his days, and which had filled his soul with the most elevated conceptions of nature and its divine Author. Subsequently to this, merely because he had the honesty to maintain that the earth turned on its axis, he was condemned by a board of Cardinals to perpetual imprisonment. He did not long survive the loss of his liberty. He died at the age of eighty-four years.

SCIENTIFIC VIEW OF THE SOLAR SYSTEM.

LESSON V.

The Solar System consists of the Sun, the Planets, and the Comets. The term solar is derived from the Latin word *Sol*, which signifies Sun. Around the sun, the planets and the comets, in their respective orbits, constantly revolve.

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26. What fact is stated in proof of this?——27. Who was Tycho Brahe? ——28. When did he live?——29. What was his system?——30. Why did he form it?——31. Who was Galileo?——32. When did he live?—— 33. What enabled him to make more discoveries in the science than his predecessors?——34. What was he compelled to do, when passed the age of seventy years?——35. By whom?

1. Of what does the solar system consist?——2. From what is the term solar derived?

The sun is the centre of the solar system, and is the source of light and heat. Its form is nearly that of a sphere or globe.

Planets are dense, dark bodies, resembling the globe, which we inhabit. Of course, they are not seen by their own light, but by the reflected light of the sun, which shines upon them.

Planets are of two kinds, Primary and Secondary. The primary planets are those which revolve immediately about the sun. The secondary are those which revolve about some of the primaries. Secondary planets are sometimes called moons or satellites.

There are eleven primary planets; namely, Mercury, ☿; Venus, ♀; Earth, ⊕; Mars, ♂; Saturn, ♄; Vesta, ⚶; Juno, ⚵; Ceres, ⚳; Pallas, ⚴; Jupiter, ♃; and Herschel, ♅. Vesta, Juno, Ceres, and Pallas, are frequently called Minor Planets, and also Asteroids.

Mercury and Venus are denominated Interior planets, because they are nearer the sun than the earth. All the others are called Exterior planets, because they are more distant from the sun than the earth; or because their orbits are without the orbit of the earth.

Five of the primary planets, at certain times are visible to the naked eye. They are Mercury, Venus, Mars, Jupiter, and Saturn. Herschel is too distant to be seen without the aid of a telescope, except rarely to a very good eye, in a clear night when the moon is absent.

All the satellites of Jupiter, Saturn, and Herschel; and also the planets Ceres, Pallas, Juno, and Vesta, are invisible to the naked eye.

The secondary planets are distributed among the primary planets in the following manner. Our earth has one, commonly called the the moon; Jupiter has four; Saturn has seven; and Herschel has six.

All the planets, in their revolutions, move from west to east; unless there be an exception for the satellites of Herschel, which have been thought, by some astronomers, to revolve in a contrary direction.

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3. What is the centre of this system?——4. What is the form of the sun?——5. What are planets?——6. How are they seen?——7. How many kinds of planets are there?——8. What are primary planets?——9. What are secondary planets?——10. By what other name are secondary planets called?——11. How many primary planets are there?——12. What are their names?——13. Which ones are called asteroids?——14. Which two are called interior planets?——15. Why?——16. Which ones are called exterior planets?——17. Why are they so called?——18. Which planets are seen by the naked eye?——19. Is Herschel ever seen by the naked eye?——20. When?——21. What ones are not seen by it?——22. How are the secondary planets distributed among the primaries?——23. In what direction do the planets move?——24. Is there any exception?

Mercury, Venus, Earth, Mars, and Saturn, are known to revolve round an imaginary line, passing through their centre, which is called their axis. The period of this revolution is called their day. The time, which a planet takes to revolve round the sun is called its year.

The comets are wandering bodies, which revolve round the sun, in very eccentric orbits; and are only seen when in that part of their orbit nearest the sun.

DESCRIPTION OF AN ORRERY, OR PLANETARIUM.

LESSON VI.

An orrery, or planetarium, as it is sometimes called, is a machine so constructed, as to represent, by the movement of its several parts, the motions and phases of the planets in their orbits.

This machine was invented, in the seventeeth century, by George Graham, an eminent clock and watchmaker of London. Rowley, a workman, borrowed it of him, and made a copy for the Earl of Orrery, after whom it was named.

An orrery may be considered as a diametrical section of the universe, the upper and lower hemispheres being suppressed.

On the upper plate, which answers to the ecliptic, are placed in two opposite but corresponding circles, the days of the month, and the signs of the ecliptic, with their respective characters.

Through the centre of this plate is a stem, on which is a brass ball to represent the sun. Round this stem are different sockets to carry the arms by which the several planets are supported.

The planets are represented by ivory balls, having the hemisphere which is next the sun white, and the other black, to exhibit their respective phases. And these balls may be taken off, or put on, with ease, as occasion may require.

About the primary planets are placed the secondary planets or moons; and by turning the handle, which communicates with a

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25. What planets are known to revolve on their axis?——26. What period is a planet's day?——27. What is its year?——28. What are comets?

1. What is an orrery?——2. By what other name is it called?——3. By whom and when was it invented?——4. Why was it called an orrery?——5. What part of the universe does it represent?——6. What is on the upper plate?——7. By what is the sun represented?——8. By what are the planets represented?——9. How are their hemispheres exhibited?——10. What are placed about the primary planets?

train of wheel work concealed in a circular box, the planets are put in motion, moving round the ball that represents the sun.

If the ivory ball representing the earth, in an orrery, be taken as the standard, the other ivory balls will move with the same relative velocities, and in the same periodical times, with which the planets traverse the regions of space.

By placing a small lamp on the end of the central stem, instead of the brass ball representing the sun, and the most pleasing effects will be produced especially if the orrery be in a darkened room. The side of each ivory ball next to the lamp will be enlightened, while its opposite side will be shaded ; the same as the side of each planet next the sun is illuminated, while its opposite side is in darkness.

If an orrery were put in motion by machinery, resembling an eight day clock, the revolutions of the planets would be represented according to their exact times, as in nature. This is sometimes done in a large and expensive orrery.

PERIODICAL REVOLUTION OF THE PLANETS.

LESSON VII.

There is nothing in nature more wonderful, or that more clearly shows the power and wisdom of God, than the revolution of the planets. They move in their orbits with so much precision and regularity, that no material variation takes place for ages, and even for thousands of years

If a body be put in motion, by the application of a single force, it will move forward in a straight line. If several powers be differently applied to it, at the same time, as it cannot obey them all, it will obey no one of them, but will move in a direction between them.

It is through the agency of this mechanical principle, that the heavenly bodies are enabled to perform their periodical revolutions.

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11. By what means are the planets put in motion ?——12. What will be the consequence if the ivory ball, in the orrery, representing the earth, be taken as the standard ?——13. If a small lamp be put in the place of the brass ball representing the sun, what will be exhibited ?——14. How may an orrery be so constructed as to represent the exact times of the revolutions of the planets ?——15. Is this ever done ?

1. What does the revolution of the planets show ?——2. How will a body move, if acted on by a single force ?——3. How will it move if acted on by several different forces at the same time ?

The application of two distinct forces, upon the planets in the solar system, acting in right angular direction, causes them to move in their orbits. One of these forces is called centrifugal, and the other centripetal.

The centrifugal force, which is also called the projectile power, impels the planet forward in a straight line. The centripetal force, which is the same thing as gravitation, draws the planet to a fixed point. These two forces act upon each so equally, as to cause the planet to move round a given point called the centre of gravity.

In Plate IV, Fig. 3, let S represent the sun, A the earth, and A D G I the earth's orbit. If the earth A were operated on by the centrifugal force only, it would be carried forward to the letter B. If it were operated on by the centripetal force only, it would be drawn directly to the sun S. But the earth A being acted on by these two forces united, it is carried to the letter D; and, then in like manner to the letter G, and finally again to the letter A where it originally started.

A simple illustration of circular motion, can easily be made, by a stone fastened to the end of a string. Let the other end of the string be held in the hand, and the stone, whirled round. The stone being confined to the hand, by the string, will move round it, in a circular form, as the earth or any other planet moves round the sun. In this experiment the string represents gravitation, or the centripetal force; and the power which puts the stone in motion represents the centrifugal force.

Mercury performs its revolution about the sun in 88 days; Venus, in 244, 2–3; the Earth, in 366 1–4; Mars, in 687; Vesta, in 1335, 1–4; Juno, in 1591; Ceres, in 1681, 1–2; Pallas, in 1681, 2–3; Jupiter, in 4332, 3–5; Saturn, in 10759; and Herschel, in 30682, 2–3 days.

It will be seen from the above table, that the length of the years, in the different planets, is regularly in proportion to the distance

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4. What are the two forces called in the production of circular motion? ——5. By what other name is centrifugal force called?——6. What power is the same as the centripetal force ——7. How is circular motion illustrated by Fig. 3, of Plate IV?——8. How may circular motion be represented by the whirling of a stone?——9. In this experiment what represents the centrifugal force?——10. What the centripetal?——11. How many of our years are equal to one year of Herschel?——12. To one year of Saturn?——13. To one year of Jupiter?——14. To one year of Mars?——15. How many years of Mercury are equal to one of Herschel?——16. How many years of Mars are equal to one of Saturn?——17. How many of Venus to one of Jupiter? ——18. In what proportion do the years of the different planets vary in length?

they are from the sun. The four minor planets, or asteroids, which are about equally distant from the sun, perform their revolutions in nearly the same period.

Motion, in astronomy, may be divided into real and apparent. Real motion is the actual movement of any body; as the revolution of the earth. Apparent motion is when a body appears to move, but is actually at rest; as the apparent motion of the sun and stars, produced by the real motion of the earth.

DIFFERENT THEORIES OF THE SUN.

LESSON VIII.

THE sun has ever been esteemed an object of the first importance in the solar system. Being the great source of light and heat, it diffuses its rays to every part of an immense sphere, giving life and motion to innumerable objects. Like its divine Author, while it controls the greatest, it does not overlook the most minute portions of the creation.

According to the Copernican system, now universally received, the sun is the centre of all the planetary and cometary motions, all the planets and comets revolving round it in different periods, and at different distances. The sun, although stationary in respect to surrounding objects, is not destitute of motion. It turns on its own axis, from west to east, in about twenty-five days.

There has been much speculation concerning the physical organization of the sun. It was formerly supposed to consist of liquid fire, exhaustless in its nature; which, by constantly emitting rays in every direction, imparted a cheering influence to every part of the system. By modern astronomers this theory has been found untrue. They have supposed, with more plausibility, that it is a solid body, surrounded by a luminous atmosphere.

It is estimated that the atmosphere with which the sun is surrounded, extends to the distance of two thousand miles from its surface; and, that its density is at least eighty times greater than that which environs the earth. Herschel supposes that the density

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19. Which four planets have years about of the same length?——20. What is the difference between real and apparent motion in astronomy?

1. Why has the sun always been an interesting object?——2. What motion has it?——3. Of what was it formerly supposed to consist?——4. How do modern astronomers view the sun, as to its physical organization?——5. What is said of the density of the sun's atmosphere?——6. And of its height?

of the luminous solar clouds need not be greater than that of our Aurora Borealis, to produce the effects with which we are acquainted. Euler makes the light of the sun equal to 6500 candles at a foot distance.

A knowledge of chemical agencies, as made known in modern scientific discoveries, makes it highly probable that the heat and light of the sun are occasioned by some invisible action between the atmosphere of the sun and the atmosphere of other bodies. The collision of a flint against steel, not only causes heat, but produces fire; and the action of water upon lime, not only causes heat, but forces the water to fly off in steam.

The sun is a spherical body, and has a diameter of about 880,000 miles; being more than equal to 100 diameters of the earth. So great is the power of gravitation upon its surface, that a body weighing one pound at the surface of the earth, will there weigh about thirty pounds. Thus a common sized man removed to the surface of the sun would weigh between two and three tons.

On different parts of the sun's disc may be seen dark spots, called *maculæ*. These consist of a *nucleus*, which is much darker than the rest, surrounded by a mist or smoke; and they are so changeable as frequently to vary during the time of observation. Some of the largest of them seem to exceed the bulk of the whole earth, and are often seen for three months together. They were first observed by the celebrated Galileo.

Some have supposed these spots to be deep cavities in the body of the sun; some have supposed them to be the smoke of volcanoes, or the scum floating upon a huge ocean of fluid matter; and others, among whom was Dr. Herschel, supposed that the spots are nothing else than portions of the opaque body of the sun, perhaps high mountains, seen in consequence of the accidental opening of the luminous atmosphere with which the sun is overshadowed.

The similarity of the sun to the other globes of the system, in solidity, atmosphere, surface diversified with mountains and vallies,

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7. What comparison does Herschel make between its atmosphere, and the Aurora Borealis?——8. How did Euler estimate its light?——9. How is it supposed that the light and heat of the sun may be produced?——10. In support of this supposition what two illustrations are given?——11. What is the form of the sun?——12. What is its diameter?——13. How does it compare with the diameter of the earth?——14. What comparison is made between the gravitation of the sun and of the earth?——15. How much would a common sized man weigh removed to the surface of the sun?——16. How large are some of the spots on the sun's disc?——17. By whom were they first observed?——18. What have these spots been supposed to be?

and rotation on its axis, lead us to conjecture that it is inhabited, like the rest of the planets, by beings whose organs are adapted to their peculiar circumstances.

Dr. Elliot, an English astronomer, allows his imagination, in speaking of it, to depict the most delightful rural scenery, with purling brooks, meandering streams, and rolling oceans, and with all the vicissitudes of foul and fair weather. And as the light of the sun is eternal, so he imagined, were its seasons. Hence, the Doctor infers, that this luminary offers one of the most blissful habitations which the mind of man is capable of conceiving.

MAGNITUDES AND PLACES OF THE PLANETS.

LESSON IX.

A person unacquainted with the effect produced on the apparent magnitude of a body, by change of distance, would be likely to conclude that the moon is larger than either of the other planets in the system. But this is found to be an optical illusion. The diameter of the moon is only about half equal to the diameter of Mercury, the smallest of the seven principal primary planets.

Although the planets, viewed by the naked eye, seem to occupy but a mere point of space, yet this is owing to the great distance at which they are placed from us. The earth viewed from one of the remote planets would appear as they now appear to us; and our sun, seen from a still further distant part of the heavens, would appear like one of the fixed stars.

A child can easily make observations in illustration of such effects. A man, at the distance of half a mile from us, will appear in size like a boy of fifteen years; and other objects, by being removed from us, will lose a corresponding portion of their apparent

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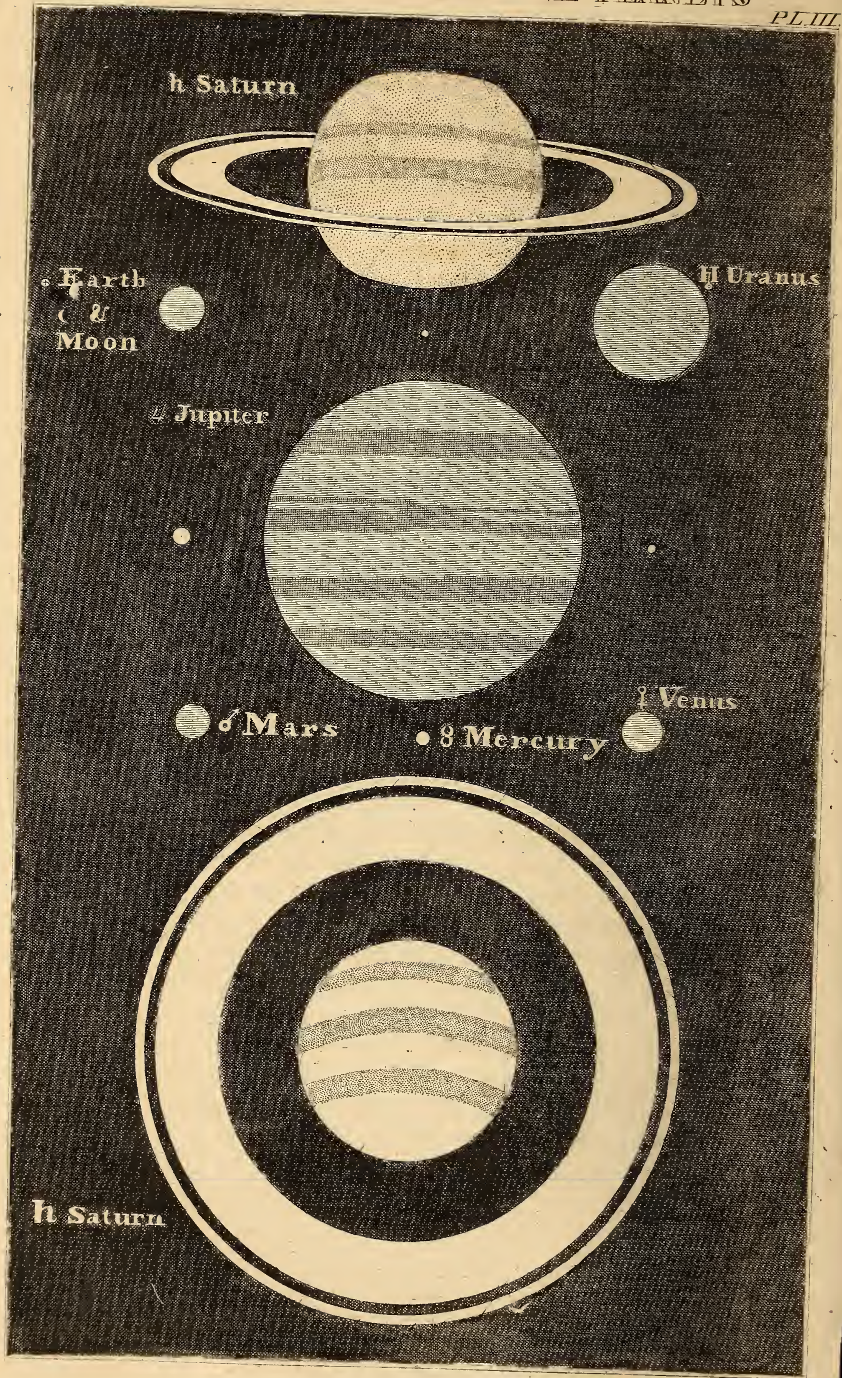
19. What inference may we draw from the analogy between the form and organization of the sun and of the planets?——20. What was Dr. Elliot's opinion on the subject?

1. Who would be likely to consider the moon the largest planet in the system?——2. How does the diameter of the moon compare with that of Mercury?——3. Why do the planets appear so small?——4. How would the earth appear viewed at one of the distant planets?——5. How would the sun appear viewed at a more distant part of the universe?——6. What is said of the apparent size of a man, seen at a distance?

RELATIVE SIZES OF THE PLANETS

PL. III.



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magnitude. A large kite, as it rises in the air, is gradually diminishing in apparent size till it dwindles into a mere black speck, and at last is entirely lost to the sight. So also it is with birds as they soar in the regions above us.

To avoid the labor of committing to memory in miles, the several distances, at which the planets are situated from the sun, astronomers have adopted a more simple method. The distance between Herschel and the sun is supposed to be divided into one hundred and ninety-five parts. Mercury is estimated at *four* of these parts from the sun; Venus, at *seven;* the Earth, at *ten;* Mars, at *fifteen;* Jupiter, at *fifty-two;* Saturn, at *ninety-five;* and Herschel, as already given, at *one hundred and ninety-five.*

These proportionate distances may not be perfectly accurate; but they are sufficiently so to answer all needed purposes in a work like the present. They are obtained by multiplying the respective distances of the planets by *ten,* and dividing the product by *ninety-five,* the mean distance of the earth from the sun.

A similar plan has been proposed for fixing with facility in the mind the comparative magnitudes of the planets. Thus the Earth is computed to be *fourteen* times as large as Mercury; a very little larger than Venus; *three* times as large as Mars; and more than a *million* times as large as Pallas. But Jupiter is more than *fourteen hundred* times as large as the earth; Saturn, exclusive of his ring, above a *thousand* times as large; and Herschel *eighty* times as large.

The bulk of the sun is one million and four hundred thousand times the bulk of the earth; but as its density is less than one fourth of that of the earth, it has only about 333 thousand times as much matter. It may, therefore, be concluded that the sun contains, at least, three hundred thousand times as much matter as all the planets in the solar system.

The following is another method of fixing on the mind an idea of the relative size of the sun and planets. Supposing a globe of 24 inches diameter to be the size of the sun, the proportionate diameter of Mercury would be about one eighth of an inch—of Venus,

7. What is said of a kite as it rises in the air?——8. Has any more simple method of remembering the relative distances of the planets been adopted than committing to memory their real distance?——9. If the distance of Herschel from the sun be divided into 195 parts, how many of these parts will Mercury be?——10. How many Venus?——11. How many the Earth?——12. How many Mars?——13. How many Jupiter?——14. How many Saturn?——15. How are the proportionate distances found?——16. How does the Earth compare with Mercury in size?——17. With Venus?——18. With Mars?——19. With Pallas?——20. With Jupiter?——21. With Saturn?——22. With Herschel?——23. With the Sun?——24. If a 24 inch globe represent the size of the Sun, what would be the proportionate diameter of Mercury?

one fifth of an inch—of the Earth, one fourth of an inch—of Mars, one sixth of an inch—of Jupiter, two inches and one half—of Saturn, one inch and nine tenths—and of Herschel, one inch and one tenth.

According to these proportions of their bulk, Mercury would be about 32 yards from the centre of the sun; Venus, 60 yards; the Earth, 82 yards; Mars, 126 yards; Jupiter, 340 yards; Saturn, 788 yards; and Herschel, 1570 yards. In this proportion, the moon's distance from the centre of the earth, would be only seven inches and a half.

Again; suppose, that a body projected from the sun should continue to fly with the swiftness of a cannon ball, which is at the rate of 480 miles an hour; this body would reach the orbit of Mercury in 8 years 290 days; of Venus, in 16 years 59 days; of the Earth, in 22 years 211 days; of Mars, in 34 years 82 days; of Jupiter, in 116 years and 116 days; of Saturn, 213 years 229 days; and of Herschel, in 427 years 290 days.

AN ACCOUNT OF MERCURY AND VENUS

LESSON X.

Mercury is the planet nearest the sun, and its orbit is consequently contained within the orbit of the earth. It is also the most dense of all the planets belonging to the solar system; and as its situation is next to the sun, so the portion of solar light and heat imparted to it, is much greater than that received by any of the other planets.

Mercury may be seen when crossing the sun's disc, which sometimes happens; and also when west of the sun, just before sunrise, and when east of the sun, a little after sunset. The light of this planet is very white and dazzling, and appears to twinkle like the light of a fixed star.

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25. Of the Earth?——26. Of Jupiter?——27. Of Saturn?——28. Of Herschel?——29. And with these proportions of their bulk, what would be the distance of the earth from the centre of the sun?——30. And of the moon from the centre of the earth?——31. At what rate does a cannon ball move?——32. At this rate, how long would it take a body to come from the sun to the orbit of the earth?——33. And to the orbit of Herschel?

1. Which planet is nearest the sun?——2. What is said of the density of Mercury?——3. When may it be seen?——4. What is said of its light?

When viewed with a telescope of high magnifying power, Mercury exhibits nearly the same phases as the moon, and they are to be accounted for in the same manner. But, owing to the splendor of its light, and the intense brightness of the sun, astronomers have been unable to make any very extensive or accurate discoveries in this planet.

Mr. Shroeter imagined that he discovered not only spots on the disc of Mercury, but even high mountains. He affirmed that one was more than ten miles in height; nearly three times as high as Chimborazo in South America. Dr. Herschel was unable to discover any thing of the kind.

The intensity of the sun's light and heat at Mercury is about seven times greater than at the earth, in the middle of our summer; which, as Sir Isaac Newton found by experiments made for that purpose, with a thermometer, is sufficient to make water fly off in steam. Such a degree of heat must render this planet uninhabitable to creatures of our constitution; but we may presume that the inhabitants of this planet are formed with natures suited to their situation; so that they may have as many comforts and enjoyments in point of residence as we have.

Mercury revolves round the sun, at nearly the distance of thirty millions of miles, and completes its revolution in about three months. The velocity of Mercury in revolving about its axis is about twenty-eight miles an hour; and in its orbit about the sun, more than 100,000 miles an hour. So great is the rapidity with which it moves, that the Grecian astronomers considered it the messenger of the gods; and hence they represented it with wings at its head and feet, from which is derived (☿) the character used to represent it.

It would require 20,000,000 bodies of the magnitude of this planet to make one of equal size to the sun.

Venus revolves in an orbit between the orbit of the earth, and that of Mercury, being a distance of sixty-eight millions of miles from

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5. Of its phases?——6. Why have not more astronomical discoveries been made respecting it?——7. What discovery did Mr. Shroeter affirm he had made?——8. How do the light and heat of this planet, compare with what is experienced at the earth?——9. What experiment did Sir Isaac Newton make on the heat of Mercury?——10. What is said of its being inhabited?——11. How far distant from the sun is Mercury?——12. In what time does it revolve about it?——13. What is the velocity of Mercury in its orbit?——14. And on its axis?——15. How did the Grecian astronomers view this planet?——16. How does it compare in magnitude with the sun?——17. Where is Venus situated?

the sun. This revolution is completed in about seven an a half of our months, turning on its axis in a little less than twenty-four hours. Venus moves in its orbit, at the rate of 75,000 miles an hour.

Venus is the most beautiful, and, as presented to the naked eye, the largest of the primary planets. Its light is white and very brilliant. Once in about eight years, when brightest, it is calculated that Venus may be seen at noonday. When at the west of the sun, it rises before the sun, and is called the morning star; when, appearing at the east of the sun, it shines in the evening, and is called the evening star. It is in each situation alternately for about two hundred and ninety days.

Although the moon reflects more light than Venus does, yet this light is dull, and has none of the briskness which attends the beams of Venus. This difference is supposed to arise from the circumstance of Venus having an atmosphere far more dense than that of the moon. This atmosphere has been estimated to be fifty miles in height. The solar light and heat at the surface of Venus are about double of what is experienced at the earth.

Venus exhibits all the moon-like phases which Mercury does; and, like Mercury, is sometimes seen passing over the sun's disc, in the form of a dark round spot. This is called the *transit* of Venus, and is a rare occurrence, and one which has very much excited the attention of astronomers. During the last century there were two transits; one in June, 1761, and the other in 1769. No other one will occur till the year 1874.

There have been discovered on this planet dark spots; and, on its borders, irregular, but brilliant shades. These telescopic appearances may be examined in figures 1, 2, 3, 4, 5, and 6, of Plate IV. High mountains have also been discovered in Venus, particularly one in the southern hemisphere, which is estimated to be twenty-two miles high; about four times the height of the most elevated mountains on our globe.

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18. In what time does it perform a revolution in its orbit?——19. And on its axis?——20. What is the velocity of Venus in its orbit?——21. What is said of the appearance of Venus?——22. What takes place with it once in eight years?——23. When is Venus the evening star?——24. When the morning star?——25. How long time does it continue in each situation?——26. How does the light of Venus compare with that of the moon?——27. Why is it more beautiful?——28. How high is the atmosphere of Venus?——29. How do the solar light and heat at Venus compare with what is experienced at the earth?——30. What is said of the phases of Venus?——31. What is meant by the transit of Venus?——32. When has this taken place?——33. When will it again?——34. What telescopic discoveries have been made on Venus?——35. By which figures are these appearances exhibited?——36. What is said of a mountain discovered there?

ASTRONOMICAL VIEW OF THE EARTH.

LESSON XI.

The earth is round or spherical, like all the other planets. This is proved, by its shadow on the moon, in lunar eclipses; by its own convexity, as exhibited in the appearance of a vessel at sea; and by the fact, that it has frequently been sailed round or circumnavigated. The hills and valleys, on its surface, detracting no more from its rotundity, than the proturberances in the rind of an orange prevent that fruit from being circular.

The earth is situated next to Venus, in distance from the sun. Its mean distance from that luminary is about 95 millions of miles. The revolution of the earth about the sun is performed in a little more than 365 days.* This period is called a year. It moves in its orbit, at the rate of 68,000 miles an hour, which is about 1100 miles a minute.

That such a velocity should be imperceptible, may shock the credulity of those who are unaccustomed to the contemplation of such objects. But we are to consider, that every object around, even the atmosphere, is carried with us; so that there is nothing by which we can compare our motion, except the heavenly bodies. By observations on these, such motion is now rendered past doubt.

The velocity of the earth's motion being imperceptible, is not wonderful to those who have sailed in a ship or boat on still water. There, a person, having obtained the motion of the vessel, feels no inconvenience from its swiftness, and is nearly insensible of movement, except from surrounding objects, till he strikes a shore or other obstruction. The motion of the earth is far more uniform and even, than any movement on the stillest water.

Besides the motion of the earth round the sun, it revolves on its own axis, once in twenty-four hours. The regular succession of day and night is occasioned by this revolution on its axis; the sun and all the heavenly bodies appearing to rise in the east, above the

* 365 days, 5 hours, 48 minutes, and 51.6 seconds.

1. How is it shown that the earth is globular?——2. What is said of its hills and valleys?——3. What is the distance of the earth from the sun?——4. What is the time of its revolution?——5. What is its velocity in its orbit?——6. What objection might be made to the idea of so much velocity in the earth's motion?——7. How is this reconciled to our experience?——8. What comparison is made between the motion of the earth, and of a vessel on the water?——9. How often does the earth revolve on its axis?——10. What sensible effects result from the motion of the earth on its axis?

horizon; to ascend to their meridian height; and, then, in the west, to sink below the horizon.

The path or tract in which the sun appears to move round the earth is called the ecliptic. It is called by this name, because all the eclipses of the sun and moon happen when the moon croses this path, or is nearly in one of those parts of her orbit where it crosses this path. The points in which the moon's orbit crosses the ecliptic are called the moon's nodes.

The earth viewed, at the moon, will exhibit much the same changes, as seen by us, in that body. But the earth appears more than thirteen times larger when viewed from the moon, than the moon appears to us; and hence, far more luminous. When the moon is new to us, the earth will appear full to that satellite, and the contrary.

DESCRIPTION OF ARTIFICIAL GLOBES.

LESSON XII.

There are two kinds of artificial globes, *terrestrial* and *celestial.* On the terrestrial is represented the surface of the earth, diversified with land, water, and the principal divisions of each, forming a spherical map of the whole. On the celestial is represented the visible heavens, as distinguished into constellations, by the picture of the animal or other object of the constellation, and the principal stars by which it is formed.

The globes commonly used are composed of plaster on which the maps, or descriptions, are pasted. When finished, they are hung in a brass meridian, with an hour circle, and a quadrant, and fitted into a wooden horizon. There are two kinds of circles drawn on artificial globes; the greater and the lesser. The *greater circles* divide the globe into equal parts; these are the equator, the ecliptic, the meridian, and the horizon. The *lesser circles* divide it into unequal parts; these are tropics, the polar circles, and the parallels of latitude.

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11. What is the ecliptic?——12. Why is it so called?——13. What are the moon's nodes?——14. How would the earth appear viewed at the moon?——15. With what difference in apparent size?——16. With what variation as to time?

1. How many kinds of artificial globes are there?——2. What is represented on the terrestrial?——3. What on the celestial?——4. How are globes made?——5. What are greater circles?——6. What are lesser circles?

The *axis* of the earth is an imaginary line passing through the centre of it, from north to south; upon which is produced its diurnal motion, causing its regular succession of day and night. The axis is represented by the wire on which the globe turns. The poles of the earth are the extremities of its axis. One is called the north, and the other the south pole.

The *equator* is an imaginary line extending around the centre of the globe, from east to west, equally distant from the poles, and dividing it into northern and southern hemispheres. The equator on the celestial globe is called the equinoctial. The ecliptic is represented on the globe by a circle cutting the equator with an angle of 23½ degrees.

Latitude, on the terrestrial globe, is the distance of any place from the equator, either north or south. It is reckoned in degrees and minutes, or in geographical miles, on the brass meridian, from the equator to the poles. The highest latitude of any place cannot exceed 90 degrees.

The *tropic of Cancer* is a circle 23½ degrees north of the equator and parallel to it. The *tropic of Capricorn* is a circle 23½ degrees south of the equator and parallel to it. The *arctic circle* is a line 66½ degrees north of the equator and parallel to it; being also 23½ degrees from the north pole. The *antarctic circle* is a line 66½ degrees, south of the equator and parallel to it; being also 23½ degrees from the south pole.

The brass ring, in which an artificial globe is suspended, is called the *brass meridian*. It is divided into 360 degrees, each quadrant or quarter containing 90 degrees. This circle divides the globe into two equal parts called eastern and western hemispheres.

Meridian lines are those circles drawn on a globe through the poles, and cutting the equator at right angles. There are usually 24, and consequently 15 degrees distant from each other. They denote the longitude of the places over which they pass. The de-

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7. What is the axis of the earth?——8. How is it represented on the globe? ——9. What are the poles?——10. How are they distinguished from each other?——11. What is the equator?——12. What is it called on the celestial globe?——13. How is the ecliptic drawn?——14. What is latitude?——15. How is it reckoned?——16. What is the highest latitude?——17. What is the tropic of Cancer?——18. What is the tropic of Capricorn?——19. What is the arctic circle?——20. What is the antarctic circle?——21. What is said of the brass meridian?——22. What are meridian lines?——23. How many are there?——24. How far distant are they from each other?——25. What do they denote?

grees of longitude eastward and westward are marked on the equator. Longitude is usually reckoned from Greenwich near London.

Latitude on the *celestial globe,* is the distance of any star or planet, from the ecliptic, either north or south of that circle. Longitude, on this globe, means the distance of any planet or star from the first degree of Aries.

The *quadrant of altitude* is a thin slip of brass, divided into degrees. It is so contrived as to be capable of being fixed to any part of the brazen meridian.

The *zenith* is a point in the heavens directly over head. On the artificial globes, it is the elevated pole of the horizon, and ninety degrees above it. The *nadir* is a point directly under foot, and is the depressed pole of the horizon.

The *horizon* is an imaginary great circle in the heavens, which divides the celestial sphere into two equal parts, called upper and lower hemispheres. We usually call the circle which bounds our prospect, or where the sky and the earth appear to meet, the horizon. But this, by way of distinction, is denominated the *sensible horizon.* The *rational horizon* is the great circle, which divides the earth into two equal parts, being parallel to the plain of the sensible horizon. The rational horizon is represented by the broad thin wood circle in which the globe is suspended.

The *colures* are two great circles, supposed to intersect each other at right angles in the poles of the earth, and to pass through what are called the solstitial and equinoctial points of the ecliptic. The equinoctial points are Aries and Libra: the solstitial points are Cancer and Capricorn. These divisions of the ecliptic mark the seasons of the year.

The *zodiac,* on the celestial globe, extends eight degrees each side of the ecliptic; making a girdle or belt in the heavens, sixteen degrees in width. Within this space revolve all the planets, with the exception of Ceres, Pallas, and Juno. A more particular account will be given of the zodiac in the lesson on the constellations.

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26. From what place is longitude usually reckoned?——27. What is latitude on the celestial globe?——28. What is longitude on the celestial globe?——29. What is the quadrant of altitude?——30. What is the zenith?——31. What is the nadir?——32. What is the horizon?——33. What is the sensible horizon?——34. What is the rational horizon?——35. By what is it represented?——36. What are the colures?——37. What are the equinoctial points?——38. What are the solstitial points?——39. What is the use of these points?——40. What is the zodiac?

PLATE IV.

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The *hour circles* of an artificial globe are drawn around the poles in the form of a clock dial. They are divided into 24 equal parts, corresponding to the hours of the day. To these circles, an index or pointer is fixed, for the purpose of pointing out the hour.

ELEMENTARY ACCOUNT OF MARS.

LESSON XIII.

Mars, the planet next to the earth, in distance from the sun, is distinguished by the remarkable dusky red color of its light; by the great number and the diversified appearance of spots seen upon its surface; and by the brightness of its polar regions.

The dusky red appearance of Mars is thought to be owing to a thick atmosphere with which it is surrounded; and the brightness about the poles is supposed to be occasioned by large quantities of snow and ice which there exist.

From the red appearance of this planet, it was by the ancients called Mars, which is the same as God of War; and it is represented by a character (♂) denoting a man with a spear in his hand. The same character is also used to represent iron among metals.

The whole disc of Mars generally appears illuminated; though at times, permanent dark spots have eclipsed its brilliancy; and sometimes it has a gibbous appearance, that is, its disc is more than half, but not wholly illuminated.

Dr. Herschel noticed occasional changes of partial bright belts near the equatorial regions of this planet; and on one occasion, he noticed a darkish one in a high latitude. These he ascribes to the clouds and vapors, which float in the atmosphere of Mars. Some of the most remarkable telescopic appearances of this planet may be seen in figures 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18, of Plate IV.

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41. What are the hour circles?

1. By what is Mars distinguished?——2. To what is its red dusky appearance owing?——3. To what is the brightness about the poles owing?——4. From what did this planet derive its name?——5. What character represents it?——6. What else does this character denote?——7. How does the disc of Mars appear?——8. What did Herschel observe on it?——9. To what did he ascribe them?——10. Which figures represent them?

Mars revolves round the sun in the period of 687 days, or a little less than two of our years. Its mean distance from the sun is 144,000,000 of miles; moving in its orbit at the rate of 55,000 miles an hour.

This planet sometimes rises before the sun, and becomes a morning star. Sometimes it sets after the sun, and then becomes an evening star. It is also seen, at other times, in the same part of the heavens with the sun, and beyond that luminary, being in conjunction.

The inhabitants of Mars have three interior planets, Mercury, Venus, and the Earth. Each of these will sometimes be a morning star, and sometimes an evening star; although the earth will be the brightest and most luminous.

Summer and winter at Mars, are each about twice as long as they are on the earth; and the proportion of light and heat received from the sun is less than one half of what is enjoyed at the earth.

VESTA, JUNO, PALLAS, AND CERES.

LESSON XIV.

These four planets revolve in orbits between those of Mars and Jupiter. They have been recently discovered, and are so very small compared with the other primary planets, that they are frequently called asteroids; or bodies having the appearance of stars.

Ceres was discovered in the year 1801; Pallas, in 1802; Juno, in 1804; and Vesta, in 1807. Ceres was discovered by Piazzi, an Italian; Juno, by Mr. Harding, a German; and Pallas and Vesta, by Dr. Olbers, of Bremen.

It has been supposed that these bodies are the largest fragments of a great planet, which once revolved in an orbit about midway between Mars and Jupiter; and which, either by some internal convulsion, or external violence, has been separated into these, and probably many other smaller parts.

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11. In what time does Mars revolve in its orbit?——12. What is its velocity?——13. How far is it from the sun?——14. When is Mars a morning star?——15. When an evening star?——16. When else is it seen?——17. How many interior planets has it?——18. What are they?——19. Which is the brightest?——20. What is said of the seasons of Mars?——21. And of its light and heat?

1. By what name are Vesta, Juno, Pallas, and Ceres called?——2. Why are they called asteroids?——3. When and by whom was each of them discovered?——4. What has been supposed as to the origin of these planets?

Against the above supposition, it is urged, that if the asteroids formerly constituted one large planet, it would have been seen by ancient astronomers, and enumerated among the planets. It is also supposed that the idea of an explosive force, that would overcome the mutual attraction of the parts separated, and cause them to fly forty millions of miles asunder, is most extravagant.

The mean distances of these planets from the sun has been calculated as follows: Vesta, 225,000,000 of miles; Juno, 252,000,000 of miles; Ceres, 263,000,000 of miles; and Pallas, 265,000,000 of miles. The light and heat received by them from the sun, is about one ninth as great as at the earth.

Vesta performs its revolution about the sun, in three years and two months; Juno, in four years, four months, and eight days; Ceres, in four years, seven months, and ten days; and Pallas, in four years, seven months, and eleven days. By this it will be seen that Ceres and Pallas differ but one day in the time of their revolution.

These newly discovered planets exhibit various changes in appearance and size; so that their real magnitude has not been ascertained with certainty. The diameter of the largest has been computed at 2000 miles, and the smallest at 80 miles. Their density is somewhat more than twice the density of water.

Ceres is surrounded with a dense atmosphere, which is estimated, by Shroeter, the German astronomer, to extend to the height of 676 miles. The atmosphere of Pallas is 468 miles in height.

ELEMENTARY ACCOUNT OF JUPITER.

LESSON XV.

Jupiter is much the largest planet in the solar system. The diameter of it is eighty-nine thousand miles. It is distant from the sun 490 millions of miles, revolving round it in a little less than

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5. What two objections are made to the idea that these planets are fragments of one large planet?——6. What is the mean distance of Vesta from the sun?——7. Of Juno?——8. Of Ceres?——9. Of Pallas?——10. What degree of light and heat do they enjoy?——11. In what time does Vesta perform its revolution?——12. In what time does Juno?——13. In what time does Ceres?——14. In what time does Pallas?——15. How much do Ceres and Pallas differ in the time of their revolution?——16. What is said of the changes of these planets?——17. Of their size?——18. Of the atmosphere of Ceres?——19. Of the atmosphere of Pallas?

1. What is the relative size of Jupiter?——2. What is its diameter?

twelve of our years. It turns on its axis in less than ten hours.

Jupiter has nearly fourteen hundred times the bulk of the earth; but its density being only $1\frac{1}{4}$ to water, it contains about 300 as much matter as the earth. The amount of light enjoyed at Jupiter, is about one twenty-fifth part of what is enjoyed at the earth.

The great bulk of this planet, and the short space of time in which it revolves on its axis, cause the velocity of its equatorial parts to be prodigiously great; being not less than 26,000 miles per hour.

Although Jupiter is about sixteen times farther from us than we are from Venus; and although the solar light on this planet is only about one fiftieth part of what is had at Venus; yet to the naked eye, Jupiter frequently appears as large as Venus.

On account of its superiority in size among the planets, this one is called Jupiter; that being the name of the most distinguished of the heathen deities. It is represented by this character, (♃) to denote its whiteness, the same being used to denote tin among other metals.

As the axis of this planet has no inclination, there is no change of seasons: in the polar regions there being perpetual winter, and about the equator perpetual summer. Were the axis inclined like that of the earth, one portion of its surface would alternately be deprived of the sun's light, and have constant day for nearly the space of six of our years.

Jupiter appears to be surrounded with belts, which are supposed to be clouds floating in the atmosphere. These belts are always parallel to his equator, and are interspersed with dark spots, which are supposed to be clouds more dense than the others. By observing these spots through a telescope, the time of Jupiter's rotation on its axis has been ascertained. These belts and spots are represented in figures 19, 20, and 21, of Plate IV.

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3. How far from the sun is it?——4. In what time does it revolve round the sun?——5. In what time does it turn on its axis?——6. How does Jupiter compare with the earth in bulk and quantity of matter?——7. What is its density?——8. What is the velocity of its diurnal motion?——9. How much farther from us is Jupiter than Venus?——10. What is the proportionate degree with which Jupiter and Venus are seen by us?——11. What is their comparative appearance, seen by the naked eye?——12. Why is this planet called Jupiter?——13. By what character is it represented?——14. What is said of its summer and winter?——15. Why is this?——16. What would be the consequence if the axis of Jupiter were inclined like that of the earth?——17. With what is Jupiter surrounded?——18. In what direction do these belts extend?——19. What are they supposed to be?——20. Which figures represent them?

As if to compensate, in part, for the want of light occasioned by ts remoteness from the sun, Jupiter is constantly attended by four moons or satellites, which revolve round it. These moons are too distant from us to be seen by the naked eye; but with a telescope they present a very majestic appearance. They were discovered in the year 1609.

ELEMENTARY ACCOUNT OF SATURN.

LESSON XVI.

Saturn is situated between the orbits of Jupiter and Herschel, at a mean distance of 900,000,000 of miles from the sun, around which it revolves in about thirty of our years, its velocity being 22,000 miles an hour. It turns on its axis in a little more than ten hours.

Half a century ago, Saturn was the remotest planet from the sun which had been discovered; and from its splendid appendages, it is still an object of intense interest to the scientific observer. It is represented by this character, (♄) denoting an old man supporting himself upon a staff. The same character is also used to denote lead among metals.

Saturn receives about one ninetieth part of the light enjoyed at the earth. Its density is about one half the density of water, making about one hundred times as much matter, and more than one thousand times as much bulk in Saturn, as in the earth. At the equator of this planet, there are in one of its years not less than 25,000 days.

When viewed through a good telescope, Saturn exhibits a beautiful appearance, being decorated with various belts, interspersed with spots, and encompassed by a bright luminous double ring, which very much resembles the wooden horizon of an artificial globe. This ring was discovered by Galileo, in 1609.

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21. How many moons has Jupiter?——22. When were they discovered?

1. How far from the sun is Saturn?——2. In what time does it revolve?——3. What is its velocity?——4. In what time does it turn on its axis?——5. What does the character representing this planet denote?——6. How does the solar light at Saturn compare with what is experienced at the earth?——7. What is the density of Saturn?——8. How does it compare with the earth in quantity of matter and bulk?——9. How many days are in one of its years?——10. How does Saturn appear viewed through a good telescope?——11. When and by whom was the ring of Saturn discovered?

The ring casts a deep shadow on that part of the body of Saturn, which is opposite the sun. Each half of the planet in succession must be involved in this dark shadow, during one half of the planet's annual revolution, almost fifteen of our years. For the same term, each, in succession, must enjoy the light of the double ring, a light more brilliant than that of the planet itself.

The distance between Saturn and his inner ring, is more than 20,000 miles; and between the inner and the outer ring, nearly 3000 miles. The inner ring has a breadth of 20,000 miles, and the outer one, of more than 7000 miles. Thus the whole distance from the surface of Saturn to the most distant part of the outer ring, is about 50,000 miles.

There have been various conjectures concerning the substance of Saturn's ring. Some have supposed it to be composed of a vast assemblage of planets; others have supposed it to be a permanent bright cloud; and Dr. Herschel considers it a solid body, of equal density with the planet. He is also of the opinion, that the edge of the ring is not flat, but spheroidical in its form.

Beyond the rings of Saturn are situated seven satellites or moons which constantly attend the planet in its revolution about the sun. These satellites are unequal in size, the largest being nearly of the magnitude of the earth.

The rings and moons of Saturn serve to reflect the solar light upon the planet, especially that part which is turned away from the sun.

There is not, perhaps, says Dr. Herschel, another object in the heavens, that presents us with such a variety of extraordinary phenomena, as the planet Saturn; a magnificent globe, encompassed by a stupendous double ring; attended by seven satellites; ornamented with equatorial belts; turning upon its axis; mutually eclipsing its ring and satellites, and eclipsed by them; and all the parts of this superb apparatus occasionally reflecting light to each other.

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12. On what part of the body of Saturn does the ring cast a shadow?—— 13. For what length of time is each half the planet successively involved in dark shadow?——14. What is said of the light of the ring?——15. What is the distance between Saturn and the inner ring?——16. And between the inner and the outer ring?——17. What is the breadth of the inner ring?—— 18. What is the breadth of the outer one?——19. What is the distance from the surface of Saturn to the most distant part of the outer ring?——20. What conjectures have been made concerning the nature of Saturn's ring?—— 21. How many satellites has Saturn?——22. What is said of their size?—— 23. What do the rings and moons of Saturn serve to do?——24. What does Dr. Herschel say of the general appearance of this planet?

At the top of Plate III. is a representation of Saturn, when the ring is very oblique to the observer. At the bottom of the same plate, is a representation of it as it would appear to the spectator, placed in a line at right angles to the plane of the ring.

ELEMENTARY ACCOUNT OF HERSCHEL, OR URANUS.

LESSON XVII.

The inequalities observed in the motions of Jupiter and Saturn, which could not be accounted for from the mutual actions of these planets, led some astronomers to suppose that there existed another planet, beyond the orbit of Saturn, by whose action these irregularities were produced. This conjecture was confirmed in the year 1781, when Dr. Herschel discovered the planet called after his own name.

This planet is also called the Georgium Sidus, in honor of George III. the king of Great Britain, at the time of its discovery. It is also called Uranus, in allusion to the heathen deities, by which the other planets are distinguished. Thus in heathen mythology, Uranus was the father of Saturn; Saturn the father of Jupiter; and Jupiter the great progenitor of Mars, Venus, and Mercury.

Herschel revolves in an orbit at the chilling distance of eighteen hundred millions of miles from the sun; being about double the distance of Saturn. Heat and light are about three hundred and sixty times less than at the earth. It shines with a bluish light, and is seldom seen without the aid of a telescope of great magnifying power.

The density of Herschel is equal to water. Its revolution about the sun is performed in about eighty-four of our years, moving at the rate of 15,000 miles an hour. It has not, for a certainty, been

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25. What does the figure at the top of Plate III. represent?——26. What does that at the bottom of the same plate represent?

1. What led astronomers to suspect the existence of a planet beyond Saturn?——2. When was the planet Herschel discovered?——3. By whom?——4. Why is this planet called Georgium Sidus?——5. Why is it called Uranus?——6. What account is given of the origin of the names of the different planets?——7. How far distant from the sun is Herschel?——8. How does this distance compare with that of Saturn?——9. How does the degree of solar light and heat at Herschel compare with what is enjoyed at the earth?——10. What is the color of its light?——11. Can it be seen without a telescope?——12. What is the density of Herschel?——13. In what time is its revolution round the sun performed?——14. What the velocity of motion?

ascertained to have a rotation on its axis; but it is supposed to have one, which is completed in ten or eleven hours.

Judging from the little we know of this planet, and from our notions of heat and cold, it seems rational to suppose that it is altogether uninhabitable. But if the planets are really phosphorescent, as is conjectured; and, if they are all furnished with internal native heat, which seems highly probable, by these means any deficiency of the sun's light and heat can be easily supplied, even at Herschel. The wisdom and goodness of the Almighty are infinite; and it is presumption in man to set bounds to them. It requires no exertion of credulity to suppose that this planet may be rendered as suitable to intelligent creatures for a residence as the earth.

Herschel has six satellites; but they are so distant from us, and have been so recently discovered, that we know but little of the physical laws which govern them. Dr. Herschel, who discovered them, observes that they revolve round their primary at different distances, in different periods, with different velocities, and in orbits which are nearly at right angles with the ecliptic.

DESCRIPTION OF THE MOON.

LESSON XVIII.

The Moon is a satellite to the earth, and partially supplies it with light, in the absence of the sun. It is an opaque body, in shape nearly globular, and in size about one fifth part of the earth. Its diameter is 2,180 miles; and its circumference about 6,851 miles. The mean distance of the Moon from the earth, is 240,000 miles; and from the sun, 95,000,000 miles.

The Moon is about twenty-nine days and a half in revolving round the earth, and is carried with the earth round the sun once a year. It turns on its axis in the same time that it performs its revolution round the earth. The light of the sun illuminates one half of its surface, and leaves the other half in darkness.

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15. In what time is it supposed to turn on its axis?——16. What inference might be drawn from the small amount of light and heat at Herschel?——17. On what ground might it be supposed that it is inhabited?——18. How many satellites has this planet?——19. Who discovered them?——20. What does he say of them?

1. How does the moon compare with the earth in size?——2. What is its diameter?——3. Its circumference?——4. How far is it from the earth?——5. In what time does it revolve round the earth?——6. In what time does it turn on its axis?

Of the illumination of the Moon we perceive different degrees, according to its various positions with respect to the sun and the earth. We see one half of its body enlightened, or a full moon, when it is placed in opposition to the sun, or when the sun is in one part of the heavens, as west, and the Moon in the opposite part, as east.

When the Moon is in conjunction with the sun, or in that part of its orbit which is between the earth and the sun, its enlightened surface is turned from us, which renders it invisible; this is the time of the new moon. When the Moon appears in the intermediate parts of its orbit, between the conjunction and opposition, and about half its illuminated surface is turned towards us, it is in its quadratures.

When more than half of its illuminated surface is turned towards us, it is called gibbous; when less than half, it is called horned. The conjunction and opposition of the Moon are frequently called syzygies. Its phases are its various appearances from the new to the full moon.

As the Moon illuminates the earth by light reflected from the sun, so it is reciprocally illuminated by the earth, which reflects the sun's rays to the surface of the Moon. And, as the surface of the earth is more than thirteen times greater than that of the Moon, the earth must appear, to the inhabitants of the Moon, thirteen times larger than the Moon does to us.

The rotation of the Moon on its axis being performed in the same time that it goes round the earth, it is plain that the inhabitants of one half of the lunar world are totally deprived of the sight of the earth, unless they travel to the opposite hemisphere. If the Moon did not complete a rotation on its axis in the same time of performing a revolution about the earth, it would not always in this monthly revolution present to us the same face.

The dark parts of the Moon, formerly thought to be seas, are found to be only vast deep cavities, and places not reflecting the

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7. In what position with respect to the sun and earth do we see the moon when it is full?——8. What do we mean when we say the moon is in opposition to the sun?——9. And when do we say it is in conjunction with the sun?——10. When is the moon *new*?——11. When is it in its quadratures?——12. When is it called gibbous?——13. When is it horned?——14. What are its syzygies?——15. What are its phases?——16. By what figure are the phases of the moon represented?——17. How does the earth appear at the moon?——18. Is the earth seen upon every part of the moon?——19. How do we know that the moon turns on its axis in the same time that it revolves round the earth?——20. What were the dark parts of the moon formerly supposed to be?——21. What are they?

sun's light. Some of these excavations are thought to be four miles in depth, and forty in width. A high ridge generally surrounds them, and often a mountain is seen, by the aid of a telescope, to rise in the centre. These immense depressions probably very much resemble what would be the appearance of the earth at the Moon, were all the seas and lakes dried up.

Several of the lunar mountains have been estimated to be four or five miles in height. It is also conjectured that the Moon has extensive volcanoes. One of them was particularly described by Dr. Herschel. He says it exactly resembled a small piece of burning charcoal, when it is covered with a thin coat of white ashes; and that its brightness was equal to that with which such a coal would be seen to glow by faint day light.

That the spots in the Moon, which are taken for mountains and valleys, are in reality such, is evident from their shadows; for in all situations of this luminary, the mountains or elevated parts cast a triangular shadow in a direction opposite to that of the sun. The cavities or hollows, on the contrary, are always dark on the side next the sun, and are illuminated on the opposite side.

If the surface of the Moon were smooth and polished like a mirror, or covered with water, it would never reflect the rays of the sun in the copious manner they are now diffused; but in some positions would show us the image of that luminary not larger than a point, with such a lustre as to be hurtful to the organs of vision.

The difference between the rising of the Moon on one day and the preceding is generally about fifty minutes. But in places of considerable latitude, there is a remarkable difference about the time of harvest, when at the season of full moon it rises several nights together only about twenty minutes later on the one day than on that immediately preceding.

By thus succeeding the sun before the twilight is ended, the Moon prolongs the light, to the great benefit of those who are engaged in gathering in the fruits of the earth; and hence the full moon at this season of the year is called the Harvest Moon. It is

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22. Of what depth and extent are some of these cavities?——23. By what are they surrounded?——24. What do they resemble?——25. Of what height are some of the lunar mountains?——26. What is conjectured of the lunar mountains?——27. How did Dr. Herschel describe one of them?——28. How is it evident that there are mountains and valleys in the moon?——29. How would the rays of the sun be reflected by the moon, if the surface of it were smooth and polished like a mirror?——30. What is the difference between the rising of the moon from one day to another?——31. With what exception is this?——32. What advantage results from this?——33. What is the full moon at this season of the year called?

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believed that this was observed by persons engaged in agriculture, at a much earlier period than it was noticed by astronomers. This phenomenon is occasioned by the Moon's orbit lying sometimes more oblique than at others.

The light of the Moon, condensed by the best mirror, produces no sensible heat upon the thermometer. The quantity of light which falls on the hemisphere of a full moon is so rarefied before it reaches us, that it would require, according to the calculation of Dr. Hooke, more than 100,000 full moons to give a light and heat equal to that of the sun at noon.

The seasons of the Moon are subject to about one fourth part of the variety which ours experience; from this it might be inferred, that they are mild and considerably uniform. But the day and night being each equal to about fifteen of our days, together with the conclusion that there is no water on its surface, seem to be strong arguments against the Moon's being a habitable globe. However, if the Moon be inhabited, the Creator has undoubtedly fitted the inhabitants to the situation which they occupy.

Among many of the heathens of antiquity, the Moon was an object of stated worship. The new moons were particularly observed by the Israelites as the times of their festivals. The feast of the new moon was held on the first, or the first and second days of their month. The period of time between one new moon and another, was called a moon. They reckoned their time by moons, and it is probable that this was the first division of time. The term month, is evidently derived from the word moon. Twelve moons are very nearly equal to one revolution of the earth round the sun.

Telescopic views of the new and full moons, may be examined in figures 1 and 2, of Plate V. In figure 3, of Plate VII. may be examined the several phases of the Moon, as presented to the earth in its revolution about that planet.

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34. By whom was this phenomenon first discovered?——35. By what is it occasioned?——36. Can heat be produced by the condensed light of the moon?——37. What comparison is made between the light of the sun and moon?——38. What is said of the seasons of the moon?——39. What circumstances are against the idea that the moon is inhabited?——40. How did the heathens of antiquity view the moon?——41. What regard had the Israelites to the moon, connected with their religious rites?——42. How did they reckon their time?——43. From what is the term probably derived?——44. What is represented by figures 1 and 2, of Plate V.?——45. What is represented by figure 3, of Plate VII.?——46. How is the moon represented at A, in that figure?——47. How is it represented at E?——48. How is it represented at C?——49. How is it represented at B and F?——50. How is it represented at D and I?

AN ACCOUNT OF COMETS.

LESSON XIX.

Comets are planetary bodies moving in very elliptical orbits, sometimes approaching so near the sun as to be within the orbit of Mercury, and, at other times, receding so far from it, as to be greatly beyond the known boundary of the solar system. They appear in every region of the heavens, and move in every possible direction.

Comets are distinguished by a lucid train or tail, issuing from that side which is turned away from the sun. The train is so transparent that the fixed stars may be seen through it; and sometimes it extends to an immense distance in the heavens. The farther it reaches, the broader it seems to become, and at times it is divided into rays.

In a clear sky, the solid body of a comet often reflects a splendid light. If viewed through a telescope it appears full of spots and inequalities. Sir Isaac Newton supposed that the tail of a comet was caused by a thin vapor, which was raised in consequence of the intense heat it received from the sun.

Comets were formerly considered as supernatural agents, sent by the Almighty, as omens of plagues, famines, pestilences, and other scourges of mankind, for their sins. The comet of 1456 was viewed with feelings of horror. Its long train spread consternation over all Europe, already terrified at the success of the Turkish arms, which had just destroyed the great empire. Pope Callixtus, on this occasion, ordered a prayer, in which the comet and the Turks were included in the same anathema.

Modern discoveries in astronomy have proved that all such fears were groundless; that comets are governed by laws similar to those which govern the planets. No doubt the all-wise Creator of the universe formed these bodies for benevolent purposes, although most of these purposes must be unknown to us, or deduced only by reasoning from analogy.

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1. What are comets?——2. What is said of their orbits?——3. By what are comets distinguished?——4. What is said of the transparency of this train?——5. How does it appear when viewed by a telescope?——6. By what did Sir Isaac Newton suppose the train was caused?——7. How were comets formerly considered?——8. What is said of the one in 1456?——9. And of Pope Callixtus in relation to it?——10. What do modern discoveries prove in relation to comets?——11. What is said of the purposes of the Deity in relation to their formation?

It is not to be presumed that he would hurl worlds at random through the immensity of space, or permit any portion of his works to be affected injuriously by fortuitous circumstances. Religion glories in the test of reason, of knowledge, and of true wisdom; it is everywhere connected with, and elucidated by them. From philosophy we may learn that the more his works are contemplated, the more he must be adored; and the more evinced his government and superintendance over every portion of his works.

Tycho Brahe, a Danish astronomer, was the first who restored comets to their true rank in the creation, by assigning them their situation in the solar system.

The number of comets belonging to the solar system is unknown. More than five hundred since the Christian era have been observed. The orbits of ninety-six comets, up to the year 1808, have been calculated; but of all these, the periodical returns of three only are known, with any degree of certainty. One of these returns at intervals of seventy-five years; one, at intervals of one hundred and twenty-nine years; and the other, at intervals of five hundred and seventy-five years. Of these, that which appeared in 1680 is the most remarkable.

Sir Isaac Newton calculated the heat of this comet, when nearest the sun, to be 2000 times greater than that of red hot iron. He also calculated that its heat must be retained a very long time. Supposing it to have been as large as our earth, and that it had the property of cooling 100 times faster than red hot iron, he states that it would take the comet 500 years to lose the heat it had acquired from the sun.

As comets have but a feeble action on other bodies, it is concluded that they contain but a small quantity of matter. This may be illustrated by the comet of 1454, which is said to have eclipsed the moon, so that it must have been very near the earth. Yet it pro-

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12. What are we not to presume in relation to them?——13. In what does religion glory?——14. From philosophy what may we learn?——15. Who first assigned to comets their proper place in the solar system?——16. How many comets have been observed since the Christian era?——17. To the orbits of how many have calculations been applied?——18. What are the periodical returns of the three which have been determined?——19. Which one is the most remarkable?——20. What was the heat of that comet?——21. How long time did Sir Isaac Newton suppose it would retain its heat?——22. What is said of the quantity of matter which comets contain?——23. What is said of the comet of 1454, in illustration of this?

duced no sensible effect on the earth's motions. The comets of 1472 and 1760, also came very near the earth; yet their attractions produced no sensible effect on the earth's motions. Also the comet of 1770, came very near the satellites of Jupiter, but produced no derangement in the system.

THEORY OF FIXED STARS.

LESSON XX.

The universe, so far as human observation has extended, consists of infinite or boundless space, in which are numberless fixed stars, of the nature, bulk, and properties of the sun; but because they are at such immense distances from the earth, they appear to our eyes only as so many beautiful shining points. They are called fixed stars, because they do not change, like the planets, their relative position; and they are distinguished from the planets by their twinkling light.

It is supposed that the fixed stars have primary and secondary planets revolving round them, as the planets of our system revolve round the sun. Were the sun as far from us as these stars are, it would doubtless appear as they now do. It is certain that they do not reflect the sun's light as do the planets; for their distance is so great, that they would not, in that case, be visible.

All the fixed stars, with the exception of the polar or north star, notwithstanding they do not change their relative position, appear to have a motion like the sun and moon, rising in the east, increasing in altitude until they approach the meridian, and declining to the western horizon, where they disappear. This apparent motion is caused by the revolution of the earth on its axis from west to east.

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24. What is said of those comets which appeared in 1472, 1760, and 1770?

1. Of what does the universe consist?——2. Why do they appear so small?——3. Why are they called fixed stars?——4. How are they distinguished from the planets?——5. What is supposed of them?——6. Under what circumstances would our sun appear like one of them?——7. How is it known that the fixed stars do not reflect the sun's light?——8. What motion do the fixed stars appear to have?——9. By what is this apparent motion caused?

The immoveable appearance of the polar star is occasioned by the axis of the earth pointing directly to it. Its elevation above the horizon of any place is always equal to the latitude of that place, or its nearest distance to the equator.

The number of fixed stars visible to the naked eye, in either hemisphere, is not more than a thousand. They seem indeed to be innumerable, when, in a clear winter's evening, we turn our eyes towards the heavens. But by looking attentively, we shall find that most of those bright spots, which appeared to be stars, vanish from our view. This illusion is owing to the twinkling light with which the fixed stars are seen; and, to our viewing them confusedly, and not reducing them to any order.

By the aid of a telescope we are enabled to discover myriads of stars, which were before invisible to the unassisted eye; and, as we increase the power of the instrument, more and more stars are brought into view, so that the number may be considered infinite. Dr. Herschel was enabled, in one quarter of an hour, to count one hundred and sixteen thousand, which passed through the space embraced by his powerful glass.

Many stars, which to an observer unaided by instruments appear single, are found, on being examined by a telescope, to consist of two, and sometimes of three or more stars. Dr. Herschel discovered four hundred of this description. Other astronomers have discovered a much greater number.

Upon viewing the heavens during a clear night, we discover a pale irregular light, and a number of stars whose mingled rays form the luminous tract called the *milky way*. The stars themselves are at too great a distance to be perceived by the naked eye; and among those which are visible with a good telescope there are spaces apparently filled with others in immense numbers Many whitish spots or tracts, called *nebulæ*, are visible in different parts of the heavens, which are supposed to be milky ways at an inconceivable distance.

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10. Why does not the pole star have this apparent motion?——11. What elevation above the horizon has this star?——12. How many fixed stars can be seen by the naked eye?——13. How do they appear as to number?——14. Why do they appear more numerous than they are?——15. What is said of the number seen by a telescope?——16. How many did Dr. Herschel count, in a given time and place?——17. How do some stars, appearing to the naked eye single, appear when viewed through a telescope?——18. How many of these have been discovered?——19. What forms the milky way?——20. How does the milky way appear viewed through a telescope?——21. What are nebulæ?

The magnitudes of the fixed stars appear to be different from one another, which difference may arise either from a diversity in their real magnitudes, or distances; or from both these causes acting together. The difference in the apparent magnitude of the stars is such as to admit of their being divided into six classes. The largest are called stars of the first magnitude, and the least which are visible to the naked eye, stars of the sixth magnitude. Stars that cannot be seen without the help of glasses are called telescopic stars.

Some stars are subject to periodical variations in apparent magnitude; at one time being of the second, or third, and at another, of the fifth or sixth. Some have alternately been noticed to appear and disappear; being visible for several months, and again invisible. Several stars mentioned by ancient astronomers are not now to be found; and some are now observed, which are not mentioned in the ancient catalogues.

It is conjectured that the fixed stars are at such an immense distance, that light, which moves at the rate of 100,000 miles per second, would be nearly one year and a quarter in passing from the nearest fixed star to the earth; and a cannon ball discharged from a twenty-four pounder with a velocity of nineteen miles a minute, would be seven hundred and sixty thousand years passing from the nearest star. Sound, which moves at the rate of thirteen miles a minute, would be about one million, one hundred and twenty eight thousand years in passing through the same space.

Dr. Herschel has calculated that the distance of the remotest nebulæ, exceeds that of the nearest fixed star at least three hundred thousand times. Upon this fact, he thus remarks; that from facts well known, it might be proved, the rays of light, which enter the eye from the star Sirius, cannot have been less than six years and four months and a half in their passage to the observer. Hence, he says, it follows that when we see an object at a calculated distance, at which one of these very remote nebulæ may still

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22. Why do the fixed stars appear to be of different magnitudes?——23. Into how many classes are they divided?——24. What ones are called telescopic stars?——25. To what periodical variations are some of the fixed stars subject?——26. What difference is there between the ancient and modern catalogues of stars?——27. What calculation has been made, as to the distance of the nearest fixed star, by the circulation of light?——28. How is this distance illustrated by a cannon ball?——29. And by sound?——30. What calculation has Dr. Herschel made of the distance of the most remote nebulæ?——31. What does he say of the time which light occupies in coming from the star Sirius to the earth?

be perceived, the rays of light which convey its image to the eye, must have been almost two millions of years on their way; and that consequently so many years ago, this object must already have had an existence in the sidereal heavens, in order to send out those rays by which we now perceive it.

But when we have reached the utmost distance to which the power of our instruments can penetrate, who will say, that we are approaching any limits of the creation? Who will say that if the disembodied spirit should travel forward through eternity, numberless systems would not be continually spreading before it?

We cannot contemplate the fixed stars without exclaiming, How inconceivably great and wise and good is the Being who made, governs, and sustains them! We behold not one world only, but a system of worlds, regulated and kept in motion by the sun; not one sun and one system only, but millions of suns and systems, multiplied without end, perpetually submissive to the laws which govern them. Such a view of the material creation may well induce us to adopt, as our own, the language of the royal Psalmist of Israel, and say—"When I consider thy heavens, the work of thy fingers, the moon and the stars which thou hast ordained; what is man, that thou art mindful of him? or the son of man, that thou visitest him?"

THE ZODIAC AND THE TWELVE SIGNS.

LESSON XXI.

The Zodiac is an imaginary belt round the heavens, among the fixed stars, sixteen degrees wide, the centre of which is the plane of the ecliptic. In this space or belt all the primary planets revolve round the sun, with the exception of Juno, Pallas, and Ceres, three of the asteroids.

The ecliptic, and consequently the Zodiac, has been divided into twelve equal parts, consisting of thirty degrees each, called signs. As one half of the ecliptic is situated north of the equator, and

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32. What inference does he hence draw of the distance of the nebulæ from us?——33. Is it to be supposed that the most distant nebulæ are the boundaries of the material universe?——34. How does a contemplation of the fixed stars impress us with regard to the Supreme Being?——35. With what quotation from Scripture is the lesson concluded?

1. What is the zodiac?——2. Within this space which of the planets revolve?——3. Which ones do not revolve in it?——4. How has the ecliptic been divided?

the other half south of it, so six of these signs are in the north equatorial hemisphere, and the other six in the southern hemisphere.

These signs are fanciful, but refer to the business of the season which they represent. Their names are, Aries ♈, the Ram; Taurus ♉, the Bull; Gemini ♊, the Twins; Cancer ♋, the Crab; Leo ♌, the Lion; Virgo ♍, the Virgin; Libra ♎, the Balance; Scorpio ♏, the Scorpion; Sagittarius ♐, the Archer; Capricornus ♑, the Goat; Aquarius ♒, the Water Bearer; and Pisces ♓, the Fishes. The first six are northern signs, and the latter six are southern signs.

The sun enters the sign, Aries, on the 21st of March; Taurus, the 19th of April; Gemini, the 20th of May; Cancer, the 21st of June; Leo, the 22d of July; Virgo, the 22d of August; Libra, the 23d of September; Scorpio, the 23d of October; Sagittarius, the 22d of November; Capricornus, the 21st of December; Aquirius, the 20th of January; and Pisces, the 19th of February.

The names of the twelve signs are the same as of the twelve constellations situated within the zodiac. The constellations formerly were in the same places of the signs, to which they respectively gave names; but the zodiac being immoveable, and the stars having a motion from west to east, the constellations do not now correspond to their proper signs. Hence arises what is called the precession of the equinoxes. This change amounts to a sign in 2150 years; and in 25,791 years the whole circle will be completed, producing a perfect correspondence between the signs and constellations.

There is sometimes observed in the zodiac, a brightness resembling that of the galaxy or milky way. It appears at certain seasons of the year, in the morning before sunrise, and at evening after the setting of that luminary. About the first of March, at 7 o'clock in the evening is the best time for observing it. According to Foulqueir, it is to be seen at all seasons of the year, at Gaudaloupe,

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5. How many of these signs are north, and how many south of the equator?——6. What are their names?——7. Which ones are the northern signs?——8. Which ones are the southern signs?——9. At what times in the year does the sun enter these signs respectively?——10. From what do these signs derive their names?——11. Do the constellations correspond with the signs as to situation?——12. Why do they not correspond?——13. How many years does it require to produce a variation of one sign?——14. And how many years to produce an entire circle of change?——15. When this circle is completed, how will the signs and constellations be in relation to each other?——16. What is sometimes observed in the zodiac?——17. What is it called?——18. At what hours may it be seen?——19. When is the best time for observing it?——20. What does Foulquier say of it?

when the weather admits. Since the time of Cassini, in the year 1693, by whom it was particularly observed, it has been called *Zodiacal Light.* Previous to that period, it did not attract much notice.

HISTORY OF THE CONSTELLATIONS.

LESSON XXII.

As soon as astronomy begun to be studied, it must have been found necessary to divide the heavens into separate portions, and to give each some name and representation, in order that astronomers, in speaking of the stars, might be understood. Accordingly we find that at a very early period of the world, the visible heavens were separated into constellations or collections of stars. Those called Orion, Arcturus, and the Pleiades, are mentioned in the book of Job; and, in other ancient books, there are references to the same subject.

The sections of the sky or clusters of stars, when first made, were represented by the ancients under the outlines of natural objects, or of certain imaginary figures suggested to them by their own fancy, or else by the actual disposition of the stars themselves, which in some instances is very striking. Thus we have obvious representations of crosses and triangles; the Northern Crown, or Corona Borealis bears a strong resemblance to a wreath or garland; and the head of the Bull, or Taurus, is known under the same name by different nations, who probably never had, at the time of its invention, any intercourse with each other. Even our Indians who wander near the banks of the Missouri call it the Deer's Head. This analogy, however, in most cases is exceedingly faint and imperfect.

As a specimen of what ingenuity can accomplish, when aided by an active imagination, an account will here be given of the characters which denote the signs or constellations in the zodiac. These are thought to be less arbitrary than those in the other parts

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21. By whom and when was it first particularly observed?

1. Whence was the necessity for dividing the heavens into constellations? ——2. What are constellations?——3. What ones are named in the book of Job?——4. How were the constellations at first represented?——5. What is said of the Northern Crown?——6. And of the constellation Taurus?——7. Which constellations are to be particularly described?

of the heavens. The animals by which they are denoted are Chaldean or Egyptian hieroglyphics; and were perhaps designed as emblems of the different productions of nature, in those seasons over which they preside, or else represented some remarkable occurrence in each month.

Thus, the spring signs, Aries, Taurus, and Gemini, were distinguished for the production of such animals as were held in the highest esteem; the third month, being the most abundant, was represented by Gemini. When the sun enters the fourth sign, it retrogrades, or begins to return towards the south pole, which motion is represented by Cancer, or the Crab, which often runs backwards. The heat which usually follows in the next month is denoted by the Lion, an animal remarkable for its fierceness, and which at this season, impelled by thirst, leaves the desert, and visits the banks of the Nile.

About the time of harvest the sun enters the sixth sign, and this season was characterized by a Virgin, or female reaper, bearing an ear of corn. When the sun enters Libra, the days and nights are equal all over the world, and seem to observe an equilibrium, like a balance. Autumn, which produces fruit, brings with it a variety of diseases, and this season is denoted by the venomous Scorpion, which is thought to wound with its sting as it receded. The fall of the leaf was the season for hunting, and the stars, which marked the sun's path at this time, were aptly represented by a huntsman or archer.

The Goat, which delights in clambering, is the emblem of the winter solstice, when the sun begins to ascend from the southern tropic, and gradually to increase in height for the ensuing half year. Aquarius is represented by the figure of a man pouring out water from an urn, an emblem of the rainy and uncomfortable season of winter. The Fish, or twelfth and last old zodiacal sign, denoted the fishing season. The severity of winter being over, and the flocks not affording sustenance, the seas and rivers were then open and abounded with fish.

The number of constellations is now ninety-two; of which twelve are in the zodiac; thirty-five are in the northern hemisphere; and

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8. By what are these denoted?——9. And for what might they have been designed?——10. Which are the spring signs?——11. How are they explained?——12. How is Cancer explained?——13. How is the Lion?——14. How is Virgo?——15. How is Libra?——16. How is the Scorpion?——17. How is the Archer?——18. How is the Goat?——19. How is Aquarius?——20. How are the Fishes?——21. What is the present number of constellations?——22. How are they distributed in the heavens?

forty-five in the southern hemisphere. The ancient constellations, including those in the zodiac, were only forty-eight in number. As it is not very probable that the ancients crossed the equator, they never could have seen the stars in the south polar circle ; and it therefore remained for modern astronomers to group the stars in that portion of the heavens. The ancients likewise often left spaces in the sky, between their groups, filled with what they call unformed stars, some of which have since been arranged into constellations; so that at present we have represented on our celestial charts the number above given.

The heavens being thus divided, it is comparatively an easy task to number and name the stars which compose each group. By this means the astronomer becomes as familiar with the heavens, as the geographer is with the earth. The former can as readily refer to the place of any particular constellations or to the several stars which compose them, as the latter can, on a map of the world, to any particular country, or to the cities which are found in it.

SHOOTING STARS, OR METEORS.

LESSON XXIII.

The luminous appearances, known by the name of shooting stars, are too common not to have been seen by most of the persons for whom this book is designed. But as frequent as they are, the phenomenon is not well understood. Some imagine that they are occasioned by electricity, and others that they are nothing but luminous gas, perhaps phosphuretted hydrogen. Others have again supposed, that some of them are luminous bodies which accompany our planet in its revolution about the sun, and that their return to certain places might be calculated with as much certainty and exactness as that of any of the comets.

Signior Baccaria supposed they are occasioned by electricity. His opinion is confirmed by the following observations. About an hour after sunset, he and some friends that were with him observed

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23. How many constellations did the ancients count?——24. Why did they not form them in the south polar circle?——25. What did they call unformed stars?——26. Is it an easy or a difficult task to become acquainted with the stars?——27. What comparison is made to illustrate the ease with which it may be done?

1. Is the phenomena of shooting stars well understood?——2. To what have they by different persons been ascribed?——3. How did Baccaria suppose they were occasioned?——4. What account is given of one which he observed?

a falling star, directing its course directly towards them, and apparently growing larger and larger, but just before it reached them it disappeared. On vanishing, their faces, hands, and clothes, with the earth and all the neighboring objects, became suddenly illuminated with a diffused and lambent light. It was attended with no noise. During their surprise at this appearance, a servant informed them, that he had seen a light shine suddenly in the garden, and especially upon the streams which he was throwing to water it.

Baccaria also observed a quantity of electric matter collect around his kite, which had very much the appearance of a falling star. Sometimes he saw a kind of halo accompanying the kite, as it changed its place, leaving some glimmering of light in the place it had quitted.

Shooting stars have been supposed by those meterologists who refer them to electricity or luminous gas, to prognosticate alterations in the weather, such as rain, wind, &c. The duration of the brilliant track which they leave behind them, in their motion through the air, will be found to be longer or shorter, according as watery vapor abounds in the atmosphere.

On the 12th of November, 1799, there was seen a very remarkable exhibition of shooting stars, at Cumana, in South America, and over most of the West India Islands. The following account of it is from the pen of a gentleman who witnessed it. He says, "I was called up about three o'clock in the morning, to see the shooting of stars, as it is called. The phenomenon was grand and awful. The whole heavens appeared as if illuminated with sky rockets, which disappeared only by the light of the sun after daybreak. These meteors appeared as numerous as the stars, flying in all possible directions except from the earth, towards which they all inclined more or less, and some of them descended perpendicularly over the vessel we were in, so that I was in constant expectation of their falling on us."

About thirty years previous to this time, a similar phenomenon was observed on the table land of the Andes. At Quito, there was seen in one part of the sky, above the volcano of Gayamba, so great a number of falling stars, that the mountain was thought to be in flames. This extraordinary light lasted more than an hour.

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5. What else did he observe, which confirmed him in the opinion that they are occasioned by electricity ?——6. What is it supposed that they prognosticate ?——7. Who suppose this ?——8. When and where was there a very remarkable scene of shooting stars observed ?——9. How is it described ?——10. When and where had there been witnessed a similar phenomenon ?——11. What is said of this one ?

Those meteors which are heard to burst, the explosion being followed, as is sometimes the case, by the fall of stones, are called *Aerolites*. These stones often descend with such force as to bury themselves several feet in the earth. Many attempts have been made to account for the formation and ignition of these grand objects; but the subject still remains enveloped in mystery.

It has been said that the stones, thus incontestibly proved by different authorities, and from various places, to have fallen after the explosion of meteors, are heated and luminous when they reach the earth, and they have been seen in Europe, Asia, and America. The stones are of different sizes, and from a few ounces in weight to several tons. They are generally of a circular form, and covered with a rough black crust. Meteoric stones have been subjected to chemical analysis, and are found to be entirely different from all known stones belonging to the earth.

The most remarkable of these meteors, so recently seen, were those of 1783, and 1805. The former was very luminous, and its diameter was estimated to be a thousand yards. The latter passed with such astonishing rapidity, that amazement had not subsided ere it vanished ; consequently, but very little dependance can be placed on what has been said concerning its bulk and shape. The light which it emitted was a pale blue, and almost as instantaneous as a flash of lightning, and the rushing of the enormous body produced a sound like very distant thunder.

AURORA BOREALIS AND HALOS.

LESSON XXIV.

We often see in the north, near the horizon, usually a short time after sunset, a dark segment of a circle, surrounded by a brilliant arch of white or fiery light; and this arch is often separated into several concentric arches, leaving the dark segment visible between

12. What are Aerolites ?——13. What is said of the force with which meteoric stones descend to the earth ?——14. Is the theory of them understood ?——15. In what parts of the world have they fallen ?——16. What is said of their sizes ?——17. Do they resemble the stones of our globe ?——18. What are the most remarkable meteors named ?——19. How is the first described ?——20. How is that of 1805 described ?

them. From these arches, and from the dark segment itself, in high latitudes, columns of light, of the most variegated and beautiful colors, shoot up towards the zenith; and sometimes masses, like sheaves of light.

This phenomenon is called the Aurora Borealis, or northern light. It is supposed by some to be occasioned by the combustion of inflammable air, ignited by electricity. This kind of air is very light, and floats in the extreme regions of the atmosphere. By others, it is supposed that the Aurora Borealis is caused by the circulation of the electric fluid, from the poles of the earth to the equator.

The Aurora Borealis is chiefly visible in the winter season, and in cold weather. It never appears near the equator, but of late years has frequently been seen towards the south pole. In the arctic regions these lights afford important relief to the gloom of the long winter nights. A very brilliant one is mentioned to have been visible in November, 1554, from the west of Ireland to the confines of Russia, extending over at least thirty degrees of longitude, and from about the fiftieth degree of north latitude, over almost all the northern part of Europe. In every place, it exhibited, at the same time, the same wonderful features.

In serene weather, we often observe a circular light, or luminous ring surrounding the moon, which is called a *Halo*, or crown. Its outline sometimes faintly shows the colors of the rainbow. The moon is in the middle of this ring, and the intermediate space is generally darker than the rest of the sky. When the moon is at full, and considerably elevated above the horizon, the ring appears most luminous. It is often very large.

We are not right in supposing that this ring really surrounds the moon: the true cause for such an appearance must be looked for in the atmosphere, the vapors of which make a refraction of the rays of light. False moons are sometimes seen near the real moon, and appear as large, but their light is paler. They are generally ac-

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1. How is the Aurora Borealis described?——2. What is the first supposition here named, as to the occasion of it?——3. What is the second one?——4. At what times is it mostly visible?——5. Does the Aurora Borealis ever appear near the equator?——6. Has any thing like it been seen near the south pole?——7. Of what use are these lights in arctic regions?——8. What is said of the very brilliant one in November, 1554?——9. What is a halo?——10. When do we see it?——11. What colors does it exhibit?——12. When does it appear most luminous?——13. Does this ring really surround the moon?——14. What then is the cause of such an appearance?——15. How are false moons, as they are called, described?

companied by circles, some of which have the same colors as the rainbow, whilst others are white, and others have luminous tails. All these appearances are produced by refraction. The rays of light falling from the moon upon aqueous, and sometimes frozen vapors, are refracted in various ways; the colored rays are separated, and reaching the eye, present a new image of the moon.

Halos, or luminous circles, also appear round the sun, and even round the stars, as well as round the moon. Those round the sun are sometimes accompanied by *parhelia*, or Mock Suns, as they are termed.

THE ATTRACTION OF GRAVITATION.

LESSON XXV.

By attraction is meant that property in bodies which gives them a tendency to approach each other. There are several kinds of attraction. Thus, the magnet attracts the needle; this is called the attraction of magnetism. Thus, a feather, suspended near the electric conducter, is attracted by it; this is called the attraction of electricity. And that property which connects or firmly unites the different particles of matter of which a body is composed, is denominated the attraction of cohesion.

The attraction of gravitation is the power by which different bodies tend towards each other; and this attraction or tendency towards each other, is in proportion to the quantity of matter they contain. The tendency which bodies have to fall, is produced entirely by the attraction of the earth; for the earth is so much larger than any body on its surface, that it forces every body, which is not supported, to fall upon it. If a brick fall from the top or a house, or a stone from the height in the air to which it is thrown, it is by the attraction of gravitation; or the tendency which they possess to gravitate towards the centre of the

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16. By what are they generally accompanied?——17. How are all these appearances produced?——18. Are halos ever seen except round the sun?——19. What sometimes accompany those round the sun?

1. What is meant by attraction?——2. What is an instance of the attraction of magnetism?——3. Of the attraction of electricity?——4. What is cohesive attraction?——5. What is the attraction of gravitation?——6. In what proportion does it operate?——7. Why do bodies tend to fall to the earth?——8. What instances in illustration of this are named?

earth. It is by the same tendency that the water of the ocean is kept in its place; and that we are enabled, on all parts of the earth, to stand with our feet pointing to the centre.

The power of gravitation is greatest at the earth's surface, from whence it decreases both upwards and downwards; but not both ways in the same proportion. It decreases upwards as the square of the distance from the centre of the earth increases; so that at a double distance from the centre, above the surface, the force would be only one fourth of what it is at the surface. But below the surface, it decreases in the direct ratio of the distance from the centre; so that at the distance of half a semi-diameter from the centre, the force would be but half what it is at the surface.

The attraction of gravitation and weight may be taken, in particular cases, as synonymous terms. We say a piece of lead weighs a pound, or sixteen ounces; but if by any means it could be carried 4000 miles above the surface of the earth, which is about the distance from the surface to the centre of the earth, it would weigh only one fourth of a pound, or four ounces; and if it could be transported to 8000 miles above the earth, which is three times the distance between the centre and the surface, it would weigh only one ninth of a pound, or something less than two ounces. The same body at the centre of the earth would be without weight; at 1000 miles from the centre, would weigh one fourth of a pound; at 2000 miles from the centre, one half of a pound; at 3000 miles, three fourths of a pound; and at 4000 miles, or at the surface, one pound.

The complicated effects resulting from the existence of this principle in nature, were first reduced to a system by the celebrated Newton. One day happening to be sitting under an apple-tree, and an apple falling on his head, it suggested to him a variety of the most important reflections. Because there was motion, he reasoned there must be force to produce it. He was accordingly induced, in the first place, to investigate the phenomena of falling

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9. What is said of the ocean, and of our standing on the surface of the earth in illustration?——10. Where is the power of gravitation the greatest?——11. In what proportion does it decrease upwards?——12. And in what proportion downwards?——13. What is a synonymous term with weight?——14. What would be the weight of a pound of lead raised 4000 miles above the surface of the earth?——15. At 8000 miles above it?——16. At 1000 miles below the surface?——17. At 2000 miles below it?——18. At 3000 miles below it?——19. At the centre?——20. Who first reduced the principles of gravitation to system?——21. What led him to reflect on the subject?——22. How did he reason upon the falling of the apple?

bodies; but afterwards extended his researches to the heavens, and was enabled to comprehend the various motions in the solar system, which had hitherto been veiled in deep mystery.

By the attraction of gravitation, the sun, the largest body in our system, attracts the earth, and all the other planets; and they, in turn, have a corresponding tendency to approach or gravitate towards the sun. And thus the moon, being smaller than the earth, gravitates towards the earth, and is attracted by it, in the same manner that all bodies in the vicinity of the earth are attracted by it. The moon would be completely drawn to the earth, and the earth and the other planets would be completely drawn to the sun, were it not that their tendency thus to gravitate, is counteracted by the centrifugal or projectile force, which propels them forward in their orbits. It is a law of attraction, that in circular motion, the attraction decreases as the squares of the distances from the centre increase. Any number multiplied into itself is the square of that number; four being the square of two, nine the square of three, and sixteen the square of four.

It is also proper to state, that bodies attract one another with force proportional to the quantities of matter they contain, and not with one proportional to their magnitudes. All bodies of equal magnitude contain not equal quantities of matter. For instance, a ball of cork, equal in bulk to one of lead, being more porous, will not contain so much matter. So the sun, though more than a million of times as large as the earth, not being so dense and compact a body, contains, according to estimation, a quantity of matter only 330,000 times as great, and hence attracts the earth with a force only 330,000 times more than the earth attracts that luminary.

Hence suppose there are in a river two boats of equal bulk, at any distance, suppose twenty yards from each other, and that a man in one boat pulls a rope which is fastened to the other, the boats will meet in a point which is half way between them. But if one boat were three times the bulk of the other, then the lighter would be moved three times as far as the heavier one, or fifteen yards, while the heavier moved only five.

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23. What is said of the sun and planets in illustration of the subject?——24. And of the earth and moon?——25. What counteracts the tendency of gravitation in the planetary system?——26. In what proportion do bodies gravitate towards each other?——27. Do all bodies of equal magnitudes contain the same quantity of matter?——28. What illustrations are named?——29. Why does lead contain more matter than cork of the same bulk?——30. What comparison is made between the sun and the earth in illustration?——31. What is the first illustration of the two boats?——32. What is the second supposition?

ATTRACTIVE AND PROJECTILE FORCES.

LESSON XXVI.

As mentioned in the preceding lesson, the sun, being so immense a body, would, by the power of attraction, draw all the planets to it, unless counteracted by another force. The manner in which this is done is explained in Lesson VII, and by reference to figure 3, in Plate VI. The force of gravitation in the sun is counteracted or balanced by the force of projection, or the power which impels or revolves bodies forward in their orbits. The joint action of these two forces retains the planets in their orbits; the primaries around the sun, and the secondaries around their primaries.

If the attractive power of the sun were uniformly the same in every part of their orbits, they would be true circles, as seen in that figure, and the planets would pass over equal portions in equal times; but the attractive power of the sun is not uniformly the same, hence the orbits of the planets are not true circles, but a little elliptical, and they must pass over unequal parts of their orbits, in equal portions of time. The cause of this inequality, in the sun's attractive influence, is owing to its being exerted on a planet when at different distances from that luminary, and to its acting in different angular directions.

It has been clearly demonstrated by Kepler and others, that, in passing round a point towards which it is attracted, a body passes over equal areas, in equal times. The whole of the space supposed to be contained within the earth's orbit, as represented in figure 1, of Plate VI. is divided into twelve areas or spaces, all of which, though of very different forms, some long and narrow, others broad and short, but they severally contain an equal quantity of space. An imaginary line drawn from the centre of the earth to that of the sun, and keeping pace with the earth in its revolution, passes over equal areas in equal times; and consequently, as will be seen from the figure, will pass through unequal portions of its orbit in equal

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1. How is the force of gravitation in the sun counteracted?——2. By what are the planets kept in their places?——3. Do the planets pass through equal portions of their orbits in equal times?——4. Why do they not?——5. Are the orbits of the planets true circles?——6. Why are they not?——7. To what is owing the inequality of the sun's attractive force on the planets?——8. What has been demonstrated by Kepler?——9. By which figure is this illustrated?——10. How is that figure described?——11. How is it seen by the figure that a planet passes through unequal portions of its orbit in equal times?

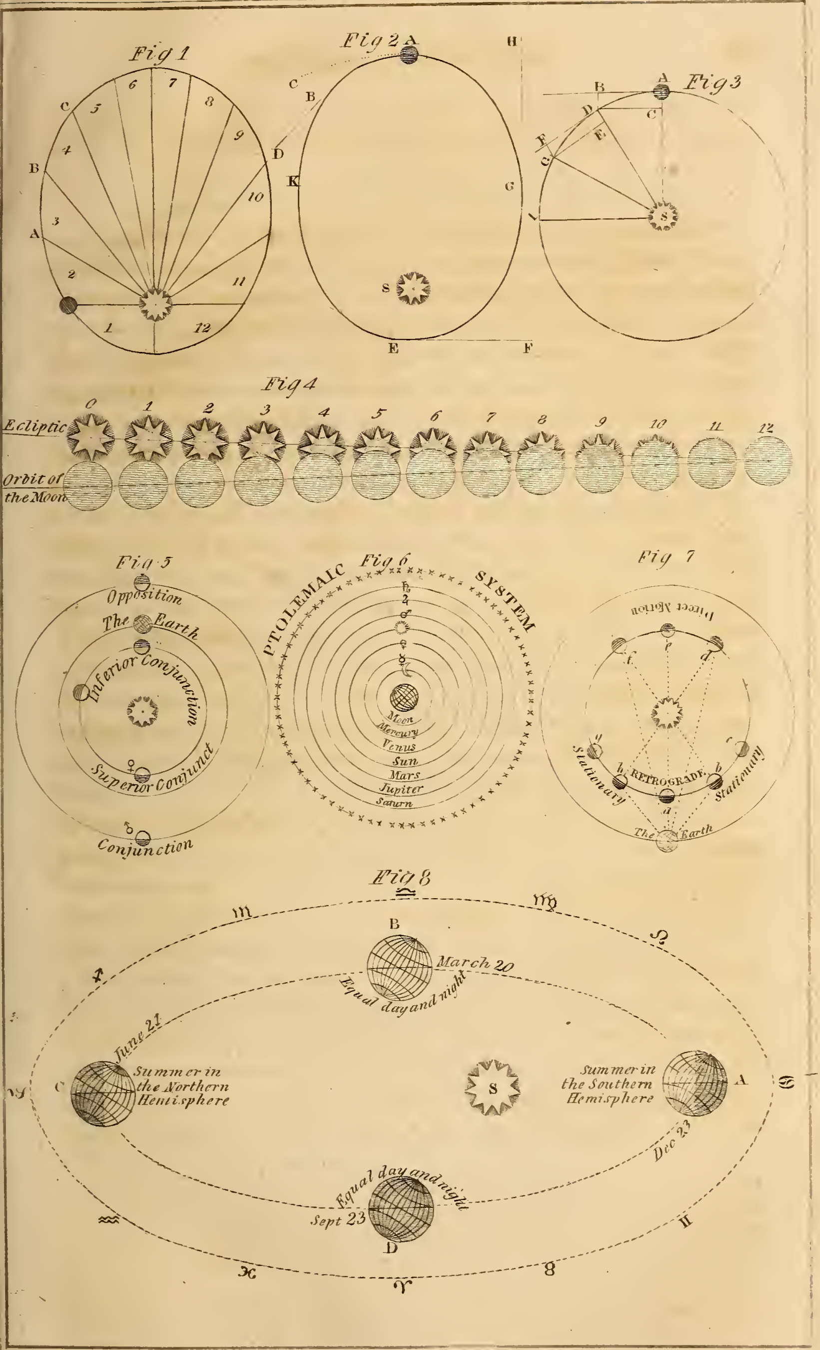
Fig 1
Fig 2
Fig 3
Fig 4
Ecliptic
Orbit of the Moon
Fig 5
Opposition
The Earth
Inferior Conjunction
Superior Conjunct
Conjunction
Fig 6
PTOLEMAIC SYSTEM
Moon
Mercury
Venus
Sun
Mars
Jupiter
Saturn
Fig 7
Direct Motion
Stationary
RETROGRADE
Stationary
The Earth
Fig 8
March 20
Equal day and night
June 21
Summer in the Northern Hemisphere
Summer in the Southern Hemisphere
Dec 23
Equal day and night
Sept 23

times. Thus, while the space numbered 6, contains the same area as that numbered 12, the former contains only about one half as much extent of orbit as the latter.

The reason for this inequality in the earth's velocity, as it moves in its orbit, may be explained in the following manner. In figure 2, of Plate VI. let S represent the sun, A, the earth, and A E, the orbit of the earth. It will be seen that the sun is not in the centre of the orbit, but in one of the foci. Supposing the earth, when put in motion at A, had not sufficient projectile force to carry it round the sun in a circle, according to the direction C, it would, by the force of the sun's attraction, be drawn in an elliptical form, as denoted by the letters B, K, and E. By this means, the attractive and projectile forces cease to operate in a right angular direction; the former acting much in the direction of the latter, till the earth, by the time of reaching its perihelion, has acquired about double the velocity it had in its aphelion. Likewise, in continuing its course from E, the velocity has become so great as to prevent it from revolving round the sun, in a small circle of the distance of E from S, that it recedes off in the direction G; at which time its projectile force is so far abated as to be carried by the force of gravity from G to A, instead of being carried to H. As the earth's velocity was continually increasing in passing from A to E, in consequence of the two forces acting upon each other in an angular direction of less than ninety degrees, so in passing from A to E, the velocity was continually decreasing, in consequence of their acting upon each other in an angular direction of more than ninety degrees.

The eccentricity of the earth's orbit is one million and a half miles; making its perihelion distance about three millions of miles less than its aphelion distance from its centre of motion. Mercury's orbit, having an eccentricity of 7,500,000 of miles, will have its perihelion 15,000,000 of miles nearer to the sun than its aphelion.

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12. By which figure is the inequality of the earth's velocity in its orbit explained?——13. In that figure, why is not the earth carried to the letter C, instead of being brought to B?——14. Why in reaching its perihelion at E, does the earth acquire an increased velocity?——15. When at E, why does it not revolve in a small circle, instead of receding off to G?——16. When it reaches G, why does it not proceed on in the direction H, instead of being turned to A?——17. What is the angular direction of the earth in passing from A to E?——18. What is it in passing from E to A?——19. Does the greater or lesser angular direction in circular motion tend to an increased velocity?——20. What is the eccentricity of the earth's orbit?——21. Of Mercury's orbit?

The eccentricity of the orbit of Venus, being only half a million of miles, its perihelion varies but one million of miles from its aphelion.

The orbits of the comets being very elliptical, the irregularity of their motions must be exceedingly great. When near the sun, or their perihelion, the centripetal force must act powerfully on the comet, and that force must be equalled by the projectile force, hence they will then move with amazing celerity; but when arrived at their aphelion, where the influence of the sun is weak, their motion is exceedingly slow, and the sun must appear little more than a fixed star.

THE CENTRE OF GRAVITY.

LESSON XXVII.

The centre of gravity is that part of a body around which all its parts are so equally balanced, that if the body be suspended or supported by the centre of gravity, it will rest in any position. Take a book, and find, by trial, under what part the finger must be placed to keep the book from falling; that point is the centre of gravity to the book. Take a rod, and find that place about the middle of it, under which the finger being placed it will be balanced; that is the centre of gravity to the rod.

The centre of gravity always descends first. The cork of a shuttlecock always comes down before the feathers. Tie a weight of any sort to the end of a stick, and toss it into the air, that end will always come down first. It is for this reason that the point of an arrow is made heavier than the other end. The most ignorant savages soon find from experience that they must make the point of their darts heavier than the other end, that the point may always be straight forward when thrown at a wild beast or at an enemy.

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22. What is the eccentricity of the orbit of Venus?——23. What is the difference between the perihelion and aphelion from the centre of motion, in each of these planets?——24. Why is the irregularity of the motion of comets so great?——25. Why is the motion of comets so great, when in their perihelion?——26. How is their motion in the aphelion part of their orbits?

1. What is the centre of gravity?——2. How may the centre of gravity of a book be found?——3. In a rod how may it be found?——4. Which part of a body always descends first?——5. What are instances of this?——6. Why is the point of an arrow made heavier than the other end?

If there were two balls of equal size fastened to the two ends of a rod, the whole might be considered as one body, and their common centre of gravity would be the point equidistant from the two extremes. If one of the balls were greater than the other, the centre of gravity would be proportionally removed towards the larger one, till upon an ascertained point they would balance each other. Thus any two bodies suspended upon a point representing the common centre of gravity, may balance each other. These bodies may be connected together by an imaginary as well as by a real rod or line; and upon the same principle, instead of two bodies thus united, the number may be increased to three, ten, or an hundred, and all be considered but one, suspended or balanced, upon the point, which is their common centre of gravity.

Precisely in this way the planets of the solar system, including also the sun, have a common centre of gravity and balance each other. If there were but one body in the universe, provided it were of uniform density, the centre of it would be the centre of gravity, towards which all the surrounding portions would uniformly tend, and would thereby balance each other. Thus the centre of gravity, and consequently the whole body, would remain without any change of position.

Accordingly, if we suppose the sun to be this body, it would forever continue without change of place. Why should it move? Where could it move? If the portion of matter on one side of this immense globe were to incline it in one direction, the portion of matter on the other side would equally incline it in a contrary way. Consequently it would not move at all. It cannot be said or supposed that the sun, according to the usual mode of speaking, would fall *down*. On the supposition made, *up* and *down* would be relative terms. On which ever side of this vast spheroid or globe, the supposition were to be applied, *down* would mean towards the

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7. If two balls of equal size be fastened to the two ends of a rod, where will be their common centre of gravity?——8. How would the centre of gravity be situated if one ball were larger than the other?——9. May bodies balance each other, when connected by an imaginary as well as by a real line?——10. What is said of having a greater number of bodies than two thus balance each other?——11. What is there in nature precisely like this?——12. Where would be the centre of gravity in a body, provided there were no other body in existence?——13. Under what circumstances might a body remain without any change of position?——14. What is the course of reasoning when supposing the sun to be the only body in existence?——15. What is said of the terms up and down?——16. What might the term down in the supposition made be understood to mean?

centre of it. And as the sun and all the planets of the solar system may be viewed as one body, connected by imaginary lines, with a common centre of gravity, they of course balance each other, and forever will continue in the position they now occupy, unless moved therefrom by some other body or bodies existing in the regions of space.

If the earth were the only attendant on the sun, as its quantity of matter is computed to be 330,000 times as great as that of the earth, it would revolve in a circle a 330,000th part of the earth's distance, in the same time as the earth is making a revolution in its orbit, or in one year ; but as the planets in their orbits must vary in their positions, the centre of gravity cannot always be at the same distance from the centre of the sun.

The quantity of matter in the sun so far exceeds that of all the planets together, that even if they were all on the same side of it, astronomers assert that this luminary would never be more than its own diameter from its own centre of gravity. And since the sun is so little attracted from its own place, by the influence of the surrounding bodies in the system, it is very properly considered the centre of the system.

PERIODICAL CHANGE OF SEASONS.

LESSON XXVIII.

The variety of the seasons depends upon the length of the days and nights, and upon the position of the earth with respect to the sun. The orbit in which the earth revolves in its annual course round the sun is not, as stated in a previous lesson, a circle, but an ellipse or oval ; and we are more than three millions of miles nearer to the sun in December, about the winter solstice, than we are in June about the time of the summer solstice.

Now as heat and light from the sun are greater as the distance is less, it is manifest that this circumstance would occasion a variation

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17. How is it said the sun and planets may be viewed in relation to this subject ?——18. What supposition is made of the earth's being the only attendant on the sun ?——19. Why is the common centre of gravity to the solar system continually varying ?——20. How much might it vary if all the planets were to be on the same side of the sun ?——21. Why is the sun considered the centre of the system ?

1. On what depends the variety of the seasons ?——2. What is said of the orbit of the earth ?——3. When are we nearest to the sun ?——4. And how much ?

in the temperature of the air, like that of our seasons, if the equator always coincided with the ecliptic. But the seasons with us, in north latitude, are not in the least degree occasioned by this circumstance, but by the direction in which the sun's rays fall upon us. When they fall perpendicularly, or nearly so, the season is warmest; and when they fall most obliquely, or in a slanting manner, the season is coldest. The cause of the difference in the obliquity of the sun's rays, is the obliquity of the ecliptic, or the inclination of the earth's axis.

The axis of the earth inclines or leans to the plane of the ecliptic 23½ degrees. Figure 8, of Plate VI. represents the sun and the earth in four different parts of its orbit. When the earth is at B and D, the sun shines from pole to pole, causing days and nights of equal length, on the 20th of March, and the 23d of September. When at A, it represents the earth with the north pole turned away or inclined from the sun, as on the 23d of December. And when at C, it represents the north pole inclined towards the sun, as on the 21st of June. From figure 7, of Plate VIII. it will also be seen that a much smaller portion of winter than of summer rays will fall upon a given surface in consequence of the different degrees of obliquity with which they reach it.

The effect of obliquity in regard to the sun's rays, will be further evident from a very simple experiment. Let a piece of board be held perpendicularly before the fire. It will then receive a body of rays equal to its breadth. But if it be placed obliquely, at an angle of forty-five degrees, then only half the rays will fall on its surface, and the other half will pass over it; so it is with the surface of the earth in summer and winter.

The circumstance, also, that the days are longest, whether in north or south latitude, when the sun's rays fall in the greatest quantity and most directly at any place, contributes much to the warmth of summer and to the cold of winter. In northern countries, where the days are eighteen or twenty hours long, or where the sun is above the horizon for any number of days together, the heat of summer is equal to that of any part of the world.

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5. Are our seasons occasioned by this?——6. By what are they occasioned?——7. On what depends the obliquity of the sun's rays?——8. How much is the axis of the earth inclined?——9. What does figure 8, of Plate VI, represent?——10. How does the sun shine on the earth when at B and D?——11. What season is represented when at A?——12. And when at C, what one is represented?——13. What is explained by figure 7, of Plate VIII?——14. How is this illustrated by a piece of board?——15. How does the length of the days and nights affect the seasons?——16. What is said of countries where the sun is for several days together above the horizon?

Since the degree of heat from the sun increases as the earth's distance diminishes, and this distance is least when it is summer in south latitude, and greatest when it is summer in north latitude, a greater degree of heat, therefore, must be received in summer in south latitude, than in summer in north latitude. But to compensate for a less degree of heat, the inhabitants in north latitude have longer summers than those in south latitude. For as the sun is not in the centre of an ellipse but in one focus, the earth must move farther in its orbit in one part of its revolution than in the other. It moves slower also as it is farther from the sun; and our summers are found to be eight days longer than the summers in south latitude; that is, between the vernal and autumnal equinoxes there are eight days more than between the autumnal and vernal.

It is well known that the degree of heat is not greatest when the days are longest. We have the warmest weather in the latter part of July, and in the first of August; and our coldest month is January. To account for this it has been stated, that a body once heated does not grow cold again instantaneously, but gradually; now as long as more heat comes from the sun in the day than is lost in the night, the heat of the earth and the air will be daily increasing, and this must evidently be the case for some weeks after the longest day, both on account of the number of rays which fall on a given space, and also from the perpendicular direction of those rays. It is for the same reason, that the warmest part of the day is not, when the sun is at the meridian, but about two or three o'clock in the afternoon.

SUCCESSION OF DAY AND NIGHT.

LESSON XXIX.

By the daily motion of the earth on its axis, the same phenomena appear as if all the celestial bodies turned round it; so that in its rotation from west to east, when the sun or a star just appears above the horizon, it is said to be rising, and as the earth continues its revolution, it seems gradually to ascend till it has reached its

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17. In what proportion does the heat of the sun increase?——18. Why is a greater degree of heat from the sun received in southern than in northern latitudes?——19. How is this less degree of heat in northern latitudes compensated?——20. Why does the earth move faster in one part of its orbit than in another part?——21. How much longer are the summers in northern than in southern latitudes?——22. At what times in the year is our degree of heat the greatest? And greatest degree of cold?——23. Why is this?——24. Why is it warmer about two o'clock in the afternoon than when the sun is at meridian height?

1. What phenomena are exhibited from the daily motion of the earth?

meridian; here the object has its greatest elevation, and begins to decline till it set, or become invisible on the western side. In the same manner the sun appears to rise and run its course to the western horizon, where it disappears, and night ensues, till it again illuminate the same part of the earth in another diurnal revolution.

One half of the earth's surface is constantly illuminated, and by its regular diurnal motion, every place is successively brought into light and immersed in darkness. If the axis of the earth were always perpendicular to the plane of the ecliptic, the days would everywhere be of the same length, and just as long as the nights. For an inhabitant at the equator, and one on the same meridian towards the poles, would come into the light at the same time, and on the other side would immerge into darkness at the same time. And since the motion of the earth is uniform, they would remain in the dark hemisphere just as long as in the light; that is, their day and night would be equal—the plane of the ecliptic coinciding with the plane of the equator.

But as the ecliptic and equator make an angle with each other of twenty-three and a half degrees, or in other words, as the axis of the earth has such an inclination to the plane of its orbit, it is manifest that, except the earth be in that part of its orbit where the ecliptic cuts the equator, an inhabitant at the equator and one on the same meridian towards the poles, will not come into the light at the same time, nor, on the other side, immerge into darkness, at the same time. And since the axis of the earth always preserves the same inclination, they will, except at the points where the two great circles intersect each other, remain in the dark and light hemispheres at different times; that is, their day and night will be unequal.

The points where the equator cuts the ecliptic are the beginning of the signs Libra and Aries. The earth is at these points of its orbit, or, as is commonly said, the sun enters the sign Aries on the twentieth of March, and the sign Libra on the twenty-third of September. Hence at these periods, and at no others, the days and nights are equal all over the world; and on this account they

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2. How much of the earth's surface is constantly illuminated?——3. Is the same portion always illuminated?——4. How does it vary?——5. Under what circumstances would the days and nights everywhere be of the same length?——6. How is this explained?——7. How would then be situated the plane of the ecliptic in regard to the plane of the equator?——8. Why is not the day and night always equal to an inhabitant at the equator, and to one on the same meridian towards the poles?——9. How is this explained?——10. Since the axis of the earth is thus inclined, at what seasons will the days and nights be equal?——11. At what points does the ecliptic cut the equator?

are called equinoxes; the first, the vernal, and the second, the autumnal equinox.

At these seasons the sun rises exactly in the east at six o'clock, and sets exactly in the west at six o'clock; the light of the sun is then terminated by the north and south poles, and as all parts of the earth turn round once in twenty four hours, every place must receive the rays twelve hours, and be deprived of them for the same time. But at other seasons, where the rays of light are not terminated by the north and south poles, but extend over the one and do not reach the other, it must be manifest, from a moment's inspection of the circles drawn on globes, or common maps of the world, that day and night will be unequal in all places except those situated on the equator, where they will always be equal.

At the poles there is but one day and one night in a year, each of six months. The sun can never shine beyond a pole farther than twenty-three and a half degrees; for that is the extent of the declination; and when it has declination from the celestial equator either north or south, it must shine beyond one pole, and not to the other. The days, therefore, will be longest in one hemisphere when they are shortest in the other.

The subject of this lesson may be illustrated by hanging a small terrestrial globe or any other round body above or below the level of a candle, so as to correspond with the sun's declination. It will be seen, that the light shines over one pole, and does not reach the other. If the globe or ball be then turned, it will be observed, that the circles performed by any parts of the surface are unequally divided by the light; that it will be constant day or night near the north pole, as the ball is depressed or elevated, and that all the phenomena will be reversed in the other, or lower hemisphere.

The inhabitants of the polar regions are not in total darkness, even when the sun is absent. Twilight continues to enlighten them a great portion of the time. Besides this the moon is above the horizon of the poles, a fortnight together. And further to assist in mitigating the darkness, their full moons have the highest altitude, describing nearly the same track as their summer sun.

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12. Why are these points called equinoxes?——13. How are they distinguished from each other?——14. At what hour and where does the sun rise at this season?——15. At what hour and where does it set?——16. How long is day and night at the poles?——17. How far beyond the poles of the earth may the sun shine?——18. Why not more?——19. How do the lengths of the days and nights in different hemispheres correspond?——20. How may the subject of this lesson be illustrated?——21. Does the absence of the sun in polar regions cause the inhabitants to be in total darkness?——22. By what means is this prevented?

FORMS AND DIVISIONS OF TIME.

LESSON XXX.

Time, as measured by the heavenly bodies, is divided into years, months, weeks, days, hours, minutes, and seconds. Years are of two kinds, tropical and sidereal. A tropical year, which is also called the natural year, is the period which the earth takes in passing through the signs of the zodiac, and consists of 365 days, 5 hours, 48 minutes, and 51½ seconds. A sidereal year is the time that the sun apparently occupies in passing from a fixed star to its arrival at the same star again; and is 365 days, 6 hours, 9 minutes, and 12 seconds.

What is called the common or civil year, is usually reckoned at 365 days; and hence, as the tropical year consists of about 365¼ days, every fourth civil year must contain 366 days. The civil year is divided into twelve months; of which one has 28 days, seven have 31 days each, and four have 30 days each. Every fourth year the month of February has 29 instead of 28 days.

As the form of the year is various among different nations, so is its beginning. The Jews, like many other nations of the East, had a civil year, which commenced with the new moon in September; and an ecclesiastical year, which commenced from the new moon in March. The Jewish year consisted of 354 days, or twelve lunar months; and to every third year a month was added, so as to make the lunar and solar year coincide.

The Persians begin their year in the month answering to our June: the Chinese, and most of the inhabitants of India, begin it with the first new moon in March; and the Greeks with the new moon that follows the longest day. In England and America, the legal or civil year formerly commenced on the 25th of March, and the historical year on the first of January. But since the alteration of style, which took place in 1752, the civil year in both countries has likewise begun on the first of January.

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1. How is time divided, when measured by the heavenly bodies?——2. What is a tropical year?——3. What is a sidereal year?——4. How long is the civil year?——5. What comparison is made between the civil and tropical year?——6. How is the civil year divided?——7. What are the lengths of the different months?——8. What is the difference between the civil and ecclesiastical year of the Jews?——9. How long was their year?——10. When do the Persians begin their year?——11. When do the Chinese?——12. When do the Greeks?——13. How does the year begin in England and America?

Months are astronomical and civil. An astronomical month, which is also called the natural month, is measured by the motion of the earth or moon. If measured by the former, it is called the solar month. If measured by the latter, it is called the lunar month. A lunar month is the time the moon takes to revolve round the earth, being 27 days, 7 hours, and 43 minutes. A solar month is that period of time occupied in passing through one of the signs of the zodiac, and is found to contain 30 days, 10 hours, and 29 minutes. The length of time in a solar month, is ascertained by dividing the solar year into twelve equal portions.

Civil months are those which are established to answer the purposes of life, and do not greatly vary in length of time from astronomical months, whether solar or lunar. January received its name from Janus, a Roman deity; February, from Februa, a festival held in this month, by the Romans; March, from Mars, the god of war; April, from the Latin word aprilis or aperio, which means to open, the leaves and blossoms opening this month; May, from the Latin word Maius; June, from the Latin word Junius, or the goddess Juno; July, from Julius, the surname of Cæsar, the Roman Dictator; August, from Augustus Cæsar; September, from a Latin word, which means seven, it being the seventh month from March; October, from a Latin word, which means eight, it being the eighth month from March; November, from a Latin word, which means nine, it being the ninth month from March; and December, from a Latin word, which means ten, it being the tenth month from March.

Till the time of Augustus Cæsar, the sixth month was called Sextilis. In honor of that emperor, as already stated, it was changed to August. And, to increase the honor intended him, a day was taken from the last of February, and added to August. Previously to this time August consisted of but thirty days, and February, in a common year, had twenty-nine.

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14. What is the difference between a lunar and a solar month?——15. How long is the lunar month?——16. How long is the solar month?——17. How is the length of the solar month ascertained?——18. What are civil months?——19. From what did January receive its name?——20. From what did February?——21. From what did March?——22. From what did April?——23. From what did May?——24. From what did June?——25. From what did July?——26. From what did August?——27. From what did September?——28. From what did October?——29. From what did November?——30. From what did December?——31. What other honor was rendered the emperor Augustus Cæsar besides calling one of the months after his name?

The days of the week received their names in the following manner. The first day of the week was called Sunday, from the Sun, to which by the ancient heathens it was dedicated; Monday, from the Moon; Tuesday, from the Saxon word, *Tuisco*, and is the same as Mars; Wednesday, from a Saxon word, *Woden*, a heathen deity; Thursday, from the Saxon word, *Thor;* Friday, from *Friga*, a Saxon goddess; and Saturday, from two Saxon words, which signify the day of Saturn. Christians call the first day of the week Sunday, in honor of Jesus Christ the Saviour of the world, who is denominated the Sun of Righteousness.

The ancient Athenians and Jews began their day at sunsetting, which custom is followed by the modern Austrians, Bohemians, Silesians, Italians, and Chinese. The ancient Babylonians, Persians, Syrians, and most of the eastern nations, began their day at sunrise. The Egyptians and Romans began their day at midnight, and are followed by the English, the Americans, French, Germans, Dutch, and Portuguese. The Arabians begin their day at noon.

ON THE EQUATION OF TIME.

LESSON XXXI.

The natural or solar day is the time which the sun takes in passing from the meridian of any place till it comes round to the same meridian again; or it is the time from noon to noon. A sidereal day is the time in which the earth revolves once about its axis, as determined by the fixed stars. The rotation of the earth is the most equable and uniform motion in nature, and is completed in twenty-three hours, fifty-six minutes, and four seconds; for any meridian on the earth will revolve from a fixed star to that star again in this time. Sidereal days, therefore, are all of the same length; but solar or natural days are not. The mean length of a solar day is twenty-four hours, but is sometimes a little more, and sometimes a little less.

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32. How did the days of the week receive their names?——33. Why do Christians call the first day of the week Sunday?——34. What nations begin their day at sunsetting?——35. What ones at sunrise?——36. What ones at midnight?——37. By whom is the day begun at noon?

1. What is a natural or a solar day?——2. What is a sidereal day?——3. What is said of the rotation of the earth?——4. What is the mean length of solar days?

The reason of the difference between the solar and sidereal day is, that as the earth advances almost a degree eastward in its orbit, in the same time that it turns eastward round its axis, it must make more than a complete rotation before it can come into the same position with the sun that it had the day before; in the same way, as when both the hands of a watch or clock set off together, as at twelve o'clock, for instance, the minute hand must travel more than a whole circle before it will overtake the hour hand, that is, before they will be in the same relative position again. It is on this account that the sidereal days are found to be on an average, shorter than the solar ones by three minutes and fifty-six seconds.

As a clock is intended to measure exactly twenty-four hours, it is evident that, when a solar day consists of more than twenty-four hours, it will not be noon by the sun till it is past noon by the clock; in which case the sun is said to be slow of the clock. But when a solar day consists of less than twenty-four hours, it will be noon by the sun before it is noon by the clock; and the sun is then said to be fast of the clock.

The time measured by a clock is called equal or mean time, and that measured by the apparent motion of the sun in the heavens, or by a sundial, is called apparent time. The adjustment of the difference of time, as shown by a well regulated clock and a true sundial, is called the equation of time.

There are two reasons for the difference between the sun and a well regulated clock. One of these reasons is the inclination of the earth's axis to the plane of its orbit. The other is the inequality of the earth's motion in its orbit. This orbit is an ellipse, and the motion of the earth is quicker in its perihelion than in its aphelion. This inequality in the earth's motion causes our summer half year to be about eight days longer than the winter half year:

There are in the course of the year, as many mean solar days as there are true ones, the clock being as much faster than the sundial on some days of the year, as the sundial is faster than the

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5. What is the reason for the difference between the solar and sidereal days?——6. How is this illustrated by the hands of a watch?——7. How much shorter are sidereal days than solar days, on an average?——8. How is a clock intended to measure time?——9. When is the sun said to be slow of the clock?——10. And when fast of the clock?——11. What is called mean time?——12. What is called apparent time?——13. What is the equation of time?——14. What are the reasons for the difference between the sun and a well regulated clock?——15. How much longer is the summer half than the winter half of the orbit?——16. How does the number of mean solar days compare as to number with true ones?

clock on others. Thus the clock is faster than the sundial from the 24th of December to the 15th of April, and from the 16th of June, to the 31st of August; but, from the 15th of April to the 16th of June, and from the 31st of August to the 24th of December, the sundial is faster than the clock. On the 15th of April, the 16th of June, the 31st of August, and the 24th of August, the clock and sundial perfectly coincide, and the true solar day is exactly twenty-four hours.

Since the stars are found to gain three minutes and fifty-six seconds upon the sun every day, amounting in a year to one diurnal revolution, it follows that, in three hundred and sixty-five days, as measured by the sun, there are three hundred and sixty-six days as measured by the stars. This regular return of the fixed stars to the meridian affords an easy method of determining whether our clocks and watches keep true time. Make the trial in the following manner. Let a small hole be made through the window shutter; or in a thin plate of metal fixed for that purpose. Then observe at what time in the night a particular star disappears behind a chimney or some other object at a small distance. Do the same on the next night; and if it disappears, on the second night three minutes and fifty-six seconds sooner by the clock or watch than it did the night previous; do the same night after night, and if you continue to observe the same variation in the stars disappearing, it is certain that the timepiece goes right. But, if this result does not take place, it is certain that the timepiece is not accurate.

LEAP YEAR AND NEW STYLE.

LESSON XXXII.

In Lesson XXX, there has been given an account of the divisions of time. Julius Cæsar, finding that the lunar year was ten days shorter than the solar year, was induced to reform the calendar; and did accordingly introduce the system of computation which has borne his name to the present time. In this mode of reckoning time, the Julian year, as our year is called, consists of 365

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17. When is the clock faster than the sundial?——18. When is it slower than the sundial?——19. When do they perfectly coincide?——20. How does it appear that in a year measured by the stars, there is one day more than in a year measured by the sun?——21. How may the accuracy of clocks be determined?

1. From whom does the Julian year take its name?——2. Of what does this year consist?

days, and six hours. To allow for the six odd hours, every fourth year, a day was to be added to the month of February, the 24th of that month being reckoned twice. This year was thus made to consist of 366 days, and is called *leap year.*

The 24th of February being what the Romans called *sexto calendas Martii,* that is, the sixth of the calends of March, the additional or intercalary day was called *bis sexto calendas Martii,* that is, the second sixth of the calends of March, and hence in our almanacs leap year is denominated *Bissextile.* Instead of repeating the 24th of February, we place the additional day at the end of the month, which becomes the 29th day.

To ascertain the time when leap year or bissextile will return, divide the date of the year by four, and if there is no remainder, it is leap year. Thus, 1820, 1824, 1828, and 1832 are leap years, because when divided by four there is no remainder. When the year is divided by four, if one is the remainder, it is the first year after leap year, or bissextile; if the remainder is two, it is the second after; if the remainder is three, it is the third after. Hence 1829 would be the first year after leap year; 1830, the second after; and 1831, the third after.

The Julian year, consisting of 365 days and six hours, and the true solar year, as stated in a previous lesson, being a few minutes short of this, the difference amounts in a little less than 130 years, to a whole day. This difference at the time of Pope Gregory, who, in 1582, undertook further to improve the calendar, amounted to ten days. Accordingly, it was ordered that the 5th of October should be called the 15th. The style thus altered was called the Gregorian or new style. Though adopted and used in several countries of Europe, it was not received in England till the year 1752. The old style or Julian calendar still prevails in Russia. The difference between the old style and the new, in the present century, is twelve days.

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3. How did he provide for the six odd hours?——4. What is the year of 366 days called?——5. By what name is it called besides leap year?——6. Why is it called bissextile?——7. How is leap year determined?——8. What illustrations are given?——9. If the year divided by four has a remainder, what does that denote?——10. What are the three illustrations?——11. Is there any difference between the Julian year and the true solar year?——12. To what will this difference amount in 130 years?——13. Who further improved the calendar?——14. When?——15. How did he do it?——16. What is the improvement called?——17. When was new style received in England?——18. What country still retains the old style?——19. What is the present difference between new and old style?

In order to prevent a similar future discrepancy between the tropical and civil year, it was ordered, on the adoption of the Gregorian or new style, that bissextile shall be omitted three times in every four hundred years. When the centuries of the Christian era are divided by four, if nothing remain, the leap year is to be retained. But if there be a remainder, the year is to be reckoned common. Accordingly the closing year of every fourth century is bissextile. Thus 1600 and 2000 are leap years; but 1700, 1800, and 1900 are common years of 365 days. With this mode of computation it will require a period of nearly 5000 years in order to produce a difference of a single day between the civil and tropical year.

ON THE REFRACTION OF LIGHT.

LESSON XXXIII.

Whatever suffers the rays of light to pass through it, is called a medium, and the more transparent the body, the more perfect is the medium. But the rays of light do not pass through a transparent medium, unless they fall perpendicularly upon it, in precisely the same direction in which they were moving before they entered it. They are bent out of their former course, and this is called refraction.

When the rays of light pass out of a rarer into a denser medium, as from air into water or glass, they are always refracted towards a perpendicular to the surface, and the refraction is more or less, in proportion as the rays fall more or less obliquely on the refracting surface. In figure 3, of Plate VIII, the ray B C in passing into a denser medium is refracted to F, towards the perpendicular A E, instead of proceeding forward in a right line to D. But when the rays pass from a denser to a rarer, as from glass or water into air, they move in a direction further from the perpendicular. This is

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20. What method was adopted to prevent a similar discrepancy between the tropical and civil year?——21. What illustrations are given?——22. With the present improved Gregorian method of computation, how long a period will be necessary to make the difference of a day between the civil and the tropical year?

1. What is a medium?——2. On what does its quality depend?——3. What takes place when rays of light pass from a rarer to a denser medium?——4. In what proportion will they be refracted?——5. How is figure 3, of Plate VIII, to be explained?——6. What takes place when rays of light pass from a denser to a rarer medium?

represented in figure 2, of Plate VIII. The ray B C, if it proceeded forward in a right line, would reach the letter F; but by passing into a rarer medium, it is refracted from the perpendicular A E, to the point D.

If a piece of money is placed in an empty basin, and the spectator is stationed so far distant as not to be able to see it, no sooner is the basin filled with water, than the money will be distinctly seen. Here the rays of light pass from the air, a rarer, into water, a denser medium, and are refracted from the perpendicular, and thus meet the eye. This is illustrated in figure 6, of Plate VIII. The eye of the spectator is at A, the money is placed in the empty basin at C, and cannot be seen; but when filled with water it is seen at B.

It is an established maxim in optics, that we see everything in the direction of that line in which the rays approach us last. If you place a candle before a looking glass, and stand before it, the image of the candle appears behind it; but, if another looking glass be so placed as to receive the reflected rays of the candle, and you stand before this second glass, the candle will appear behind that; because the mind imagines every object to be in the direction from which the rays come to the eye last.

Rays of light, coming from a heavenly body, unless it be in the zenith, will be refracted or bent downward, in passing through our atmosphere. As the atmosphere is more and more dense, the nearer to the surface of the earth, these rays will be continually yielding to additional refraction. Thus the atmosphere represents different media, as A, B, C, and D, of figure 5, on Plate VI. On passing from one media to another, as b, c, d, and e, a new refraction of the ray a b will take place; but as the atmosphere is of an uniform variation in density, a ray of light passing through it, will proceed in a regular curve line, as m n, in that figure.

In consequence of this refraction, heavenly bodies, when in the horizon, appear higher than they are. The effect of this refraction is about six minutes of time, but the higher they rise, the less they are refracted; but when they are in the zenith, as already said,

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7. How is this explained by the figure?——8. What simple illustration is given of the refraction of light with a piece of money?——9. By which figure is this shown?——10. What established maxim in optics is named?——11. How is this shown by the candle and the looking glass?——12. What is said of rays of light coming from a heavenly body?——13. What does figure 5, of Plate VI, represent?——14. How is the figure to be explained?——15. What amount of time is this refraction?

they suffer no refraction. The sun is visible on this account about three minutes before it rises, and about the same time after it sets; making an increase of six minutes to the length of each day. In figure 4, of Plate VIII, E E represent a portion of the earth's surface, and the small dots denote the atmosphere. Although the sun is below the horizon, at S, yet a ray of light coming from the centre of it, on reaching the atmosphere at A will be refracted to B, and will thereby cause the sun to appear in the horizon at C.

In figure 8, of Plate VIII, the same phenomena are displayed. D E F represent the earth, and A B C the atmosphere. The sun being below the horizon at T, a ray of light T I, when falling on the atmosphere is turned out of its direct, or rectilineal course, and is so bent down to the eye of the observer at D, that the sun appears in the direction of the refracted ray at S, above the horizon, H D. On the same account, a star in the heavens at a, will appear at b to the eye of the spectator, D.

TWILIGHT, OR CREPESCULUM.

LESSON XXXIV.

Twilight, also called crepesculum, is the time from the first dawn in the morning, to the rising of the sun; and again, between the setting of this luminary and the last remains of day. By means of the atmosphere it happens that though none of the sun's direct rays can come to us after it is set, yet we still enjoy its reflected light for some time, and night approaches by degrees; for after the sun is hidden from our eyes, the upper regions of our atmosphere remain for some time exposed to the sun's rays, and from thence the whole is illuminated by reflection.

It is usually computed that the twilight commences and terminates when the sun is about eighteen degrees below the horizon. Hence in high latitudes, during that part of the year in which the sun is never eighteen degrees below the horizon, there is continual

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16. What is said of the sun's being visible below the horizon?——17. How is this explained by figure 4, of Plate VIII?——18. How is the same shown by figure 8, of Plate VIII?——19. How is the difference between the real and apparent situation of a star shown by that figure?

1. By what other name is twilight called?——2. What is twilight?——3. How is it occasioned?——4. At what time does it commence and terminate?——5. What is said of twilight in high latitudes?

twilight, from sunsetting to sunrising. This appears to be one of the beneficent allotments of the Deity, for mitigating the darkness of polar nights.

As the twilight depends much on the quantity of matter in the atmosphere fit to reflect the sun's rays, the duration of it will be somewhat various. The height of the atmosphere, also, has an influence in determining the period of its continuance. For instance, in winter, when the air is condensed with cold, and the atmosphere upon that account lower, the twilight will be shorter; and in summer, when the limits of the atmosphere are extended by the rarefaction and dilatation of the air of which it consists, the duration of the twilight will be greater. And for the like reason, the morning twilight, (the air being at that time condensed and contracted by the cold of the preceding night,) will be shorter than the evening twilight, when the air is more dilated and expanded.

It is entirely owing to the reflection of the atmosphere, says Dr. Kiell, that the heavens appear bright in the day time. For without it, only that part of the heavens would be luminous in which the sun is placed; and, if we could live without air, and should turn our backs to the sun, the whole heavens would appear as dark as in the night. In this case, also, we should have no twilight, but a sudden transition from the brightest sunshine to dark night, immediately upon the setting of the sun.

In such a case as this, even in the day time, during the shining of the sun, the least stars would be seen as plainly as in the darkest night, because there would be nothing to reflect the sun's rays to the eyes; and all the rays that do not fall upon the surface of the earth, passing by us, would either illuminate the planets and stars, or, spreading themselves out in infinite space, would never be reflected back to us. But as the atmosphere surrounds the earth, which is strongly illuminated by the sun, it reflects the light back to us, and causes the whole firmament to shine with such splendor, as to obscure the faint light of the stars, and render them invisible.

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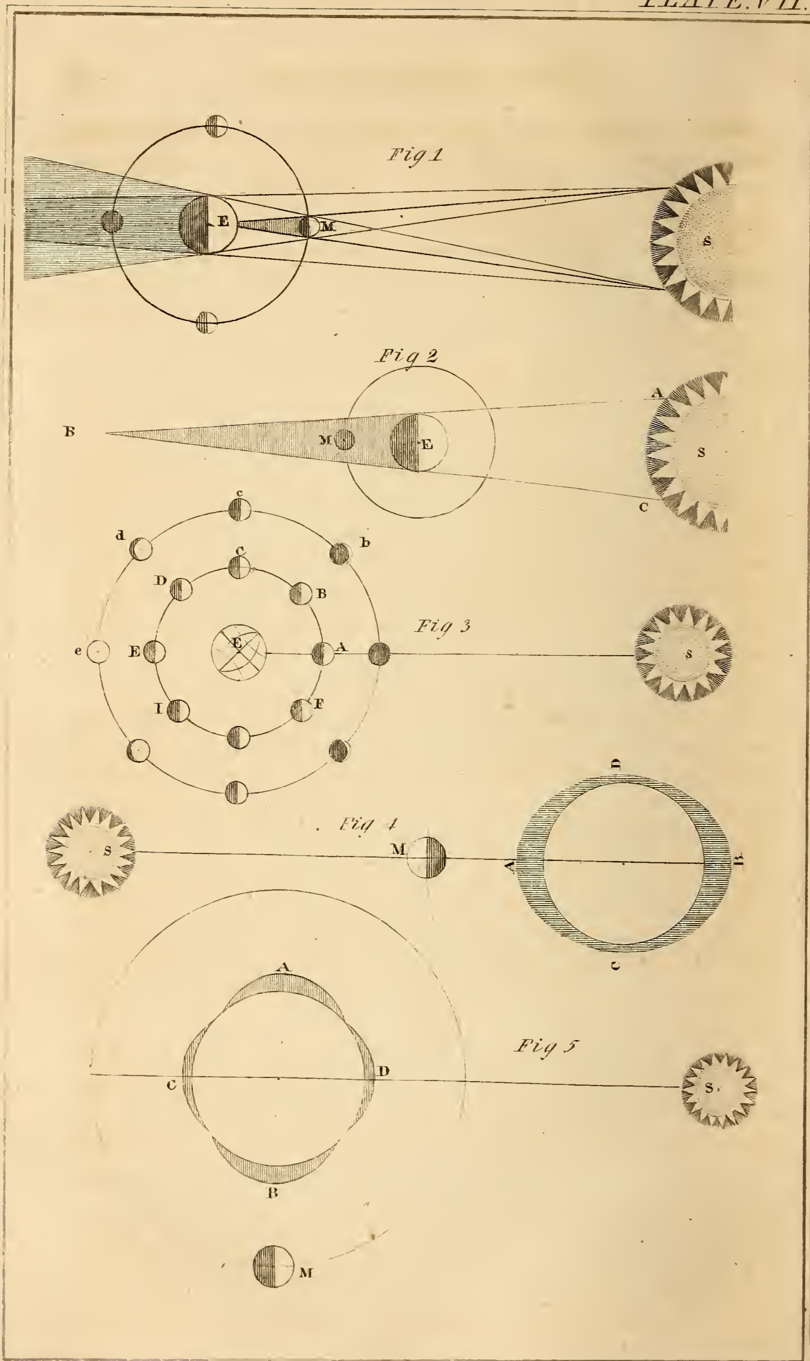
6. What is the advantage of it in high latitudes?——7. On what does twilight much depend?——8. Why is twilight short in winter?——9. And more extended in summer?——10. Why is the morning twilight longer than evening twilight?——11. How would the heavens appear, if it were not for the reflection of the atmosphere?——12. How would be the change from day to night, and from night to day?——13. Under what circumstances might the stars be seen in the day time?——14. Why are they not seen in the day time?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Kepler supposed that twilight might be caused by the luminous matter about the sun. This may lengthen the time of its continuance, by illuminating the air, when the sun is too low to reach it with its own light; but that the twilight is occasioned, as has been stated, by the refraction of the atmosphere, is too evident to admit a doubt.

LUNAR AND SOLAR ECLIPSES.

LESSON XXXV.

The earth being a dark or opaque body enlightened by the sun, necessarily projects a shadow into the regions of space in a contrary direction. When it so happens that the moon, in the course of its revolution about the earth, falls into the earth's shadow, it loses the sun's light, and appears to us *eclipsed.* As this happens when the earth passes between the sun and the moon, a lunar eclipse can of course take place only when the moon is full or in opposition. This may be illustrated by figure 2, of Plate VII.

But the moon is not eclipsed every time it is full, or in opposition to the sun, because its orbit does not coincide with the plane of the earth's orbit, one half being about five degrees and a third above it, and the other half as much below it; and therefore, unless the full moon happen in or near one of the nodes, that is, in or near the points in which the orbits intersect each other, it will pass above or below the earth's shadow, in which case there can be no eclipse. If the moon be within twelve degrees from the node at the time when it is full, there will be a partial or total eclipse, according as a part, or the whole of its disc falls into the shadow of the earth. See figure 4, of Plate VI.

As the shadow of the earth is considerably wider than the diameter of the moon, an eclipse of the moon sometimes may continue for several hours. It is by knowing exactly at what distance the moon is from the earth, and of course the width of the earth's

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15. What did Kepler suppose might cause the twilight?

1. How is an eclipse of the moon occasioned?——2. At what time can the moon be eclipsed?——3. Which figure represents a lunar eclipse?——4. How may that figure be explained?——5. Why is not the moon eclipsed at every time of being full?——6. How near the node must the moon be in order to be eclipsed?——7. By which figure is this illustrated?——8. Why does an eclipse of the moon continue so long?——8. How is it that eclipses can be calculated with so much accuracy?

shadow at that distance, that eclipses are calculated with the greatest accuracy, many years before they happen. Lunar eclipses are visible over every part of the earth that has the moon at that time above the horizon; and the eclipse appears of the same magnitude to all, from the beginning to the end.

An eclipse of the moon is *partial*, when only a part of its disc is within the shadow of the earth; it is *total*, when all its disc is within the shadow; and it is *central*, when the centre of the earth's shadow falls upon the centre of the moon's disc. The faint reddish color, which the moon exhibits in the midst of an eclipse, is supposed to proceed from the rays of light which are refracted by the earth's atmosphere, and fall upon the surface of the moon.

An eclipse of the sun is caused by an interposition of the moon between the sun and the earth. See figure 1, of Plate VI. This can happen only at the new moon, or when the moon at the time of conjunction is near one of its nodes; for unless the moon is in or near one of its nodes, it cannot appear in the same plane with the sun, or seem to pass over the sun's disc. In every other part of its orbit it will appear above or below the sun. If the moon is in one of its nodes, having no altitude, it will, in most cases, cover the whole disc of the sun, and produce a total eclipse; if it be anywhere within about sixteen degrees of a node, a partial eclipse will be produced.

When a bright luminous ring appears round the dark body of the moon during an eclipse of the sun, it is called an *annular* eclipse. An annular eclipse is occasioned by the moon being at its greatest distance from the earth at the time of an eclipse; in which situation the vertex, or point of the cone of the moon's shadow, does not reach the surface of the earth. If the moon, when new, is in one of its nodes, the eclipse of the sun will be central; and if so, it will also be annular, provided the distance of the moon from the earth at the time of the eclipse be greater than its mean distance.

A total eclipse of the sun is a very curious and uncommon spectacle; and total darkness cannot last more than three or four minutes. Of one that was observed in Portugal more than one hun-

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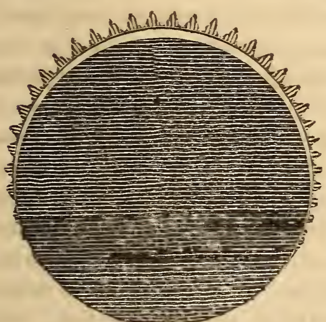
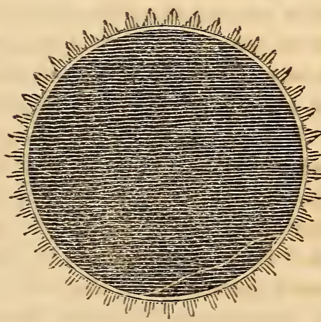
10. Where are lunar eclipses visible?——11. When is a lunar eclipse partial?——12. When total?——13. When central?——14. To what is the faint reddish color of the moon, in time of its being eclipsed, owing?——15. How is an eclipse of the sun occasioned?——16. Which figure represents it?——17. When can an eclipse of the sun happen?——18. When will it be partial, and when total?——19. When is an eclipse of the sun annular?——20. How is it occasioned?——21. What is said of a central annular eclipse?

dred and fifty years ago, it is said that the darkness was greater than that of night; that some of the largest stars made their appearance; and that birds were so terrified that they fell to the ground. A very remarkable total eclipse took place in New England, June 16, 1806. The day was clear; several stars were visible; the beasts were greatly agitated; and a gloom spread over the landscape. The first gleam of light contrasted with the previous darkness, seemed like the usual meridian day. On the 12th of February, 1831, was seen in various parts of the United States, an annular eclipse, which awakened a most intense feeling of curiosity. The types of this eclipse may be seen in the annexed wood cuts.

Appearance of the sun, at the greatest obscuration, at Natches, Nashville, Washington, Baltimore, Philadelphia, New York, New Haven, Hartford, Boston, New Bedford, Portsmouth, Portland, and all other places where the sun was about 11½ digits eclipsed on his S. limb.



Appearance of the sun, at the apparent conjunction of the sun and moon, in the Eclipse of the 12th of February, at Petersburg, Va. Cahawba, Siasconset, Halifax, and all other places where the sun was centrally, or very nearly centrally eclipsed.



Eclipses were formerly beheld by mankind with terror and amazement; and were looked upon as prodigies which portended calamity and misery. Such fears and the erroneous opinions that produced them, originated in ignorance. The illiterate, in all ages, have beheld eclipses with a kind of terror; and, not having been able to account for the obscuration of any of the celestial bodies, super-

22. What is said of a total eclipse of the sun which happened in Portugal?——23. And of that which took place in New-England in 1806?——24. And of that which took place February 12th, 1831?——25. At what places in the United States was it annular?——26. How were eclipses formerly considered?——27. What is said of the illiterate in relation to them?

stition has invented a thousand ridiculous stories to account for this seeming wonderful phenomenon.

The natives of Mexico keep fasts during eclipses, imagining the moon has been wounded by the sun in a quarrel. Other nations have thought, that in an eclipse of the sun, that body has turned away its face with abhorrence from the crimes of mankind; and, by fasting, they think to appease the excited wrath. This ignorance and superstition were greatly serviceable to the celebrated navigator, Columbus.

When he arrived at St. Domingo, on his fourth voyage of discoveries, in the year 1502, he had the mortification to find the Spanish governor, who resided there, would not allow his ships to anchor, because he was jealous of the favors which Columbus had received from Isabella, then queen of Spain. This obliged him to put to sea in search of some more hospitable harbor. After he had searched in vain for a passage to the Indian ocean, he returned, and was shipwrecked on the coast of Jamaica.

Being driven to great distress, in consequence of the natives withholding a supply of provisions, he had recourse to a happy artifice, which not only produced the desired success, but heightened the favorable ideas the Indians had originally entertained of the Spaniards. By skill in astronomy he knew there would shortly be an eclipse of the moon. He assembled all the principal persons of the district the day before the eclipse happened; and having reproached them for their caprice, in withholding their assistance from men whom they had so lately and so highly respected, he told them the Great Spirit was so offended, at their want of humanity to the Spaniards, that as a sign he intended to punish them with extreme severity, and that his vengeance was ready to fall on them, he would cause the moon, *that very night*, to conceal its light, and appear of a bloody hue, the certain emblem of Divine wrath.

This artifice was a most successful one. It led to the speedy supply of all his wants. Some of these poor ignorant creatures did indeed hear his threat with indifference, while others listened to it with a degree of astonishment; but when the moon began gradu-

28. And of the natives of Mexico?——29. Why did not the Spanish governor of St. Domingo allow Columbus to remain at the island?——30. Under what circumstances was he brought upon the island of Jamaica?——31. Did the natives of Jamaica receive him kindly?——32. By what means did he manage so as to induce them to furnish him with the needed supplies?——33. How did they receive his threat?

ally to be darkened, all were struck with fear. They immediately ran with consternation to their houses, and returned instantly, loaded with provisions.

Plutarch mentions, that at Rome it was not allowed to talk publicly of any natural causes of eclipses, the popular opinion running so strongly in favor of their supernatural production, at least those of the moon; for as to those of the sun, the Romans had some idea that they were caused by the interposition of the moon between the sun and the earth. It could not, however, be imagined that there could be any body to pass between the earth and the moon, which was thought must be the case, if the eclipses of that luminary were produced by natural causes.

An eclipse of the moon with us is an eclipse of the sun to the inhabitants of the moon; because the portion of the moon which appears dark to us during an eclipse is actually deprived of the light of the sun, by the interposition of the earth. On this account the eclipsed portions of the moon are prevented from seeing a portion of the sun. The sun, therefore, appears eclipsed to them.

PHENOMENA OF THE TIDES.

LESSON XXXVI.

The sea is observed to flow for a certain time from the east towards the west. In this motion, which lasts about six hours, the sea gradually swells; so that entering the mouths of rivers, it drives back the waters towards their source. After a continual flow of six hours, the sea seems to rest for about a quarter of an hour; it then begins to ebb, or retire back again from west to east for six hours more; and the rivers again resume their natural course. Then, after a seeming pause of a quarter of an hour, the sea again begins to flow, as before, and thus alternately. This regular alternate motion of the sea constitutes the tides.

The tides are occasioned chiefly by the attraction of the moon; but are affected by that of the sun. There are two tides in about

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34. How were they affected when the eclipse began to appear?——35. What does Plutarch say was not allowed to be done at Rome?——36. How did the Romans think eclipses of the sun might be effected?——37. And of those of the moon what did they think?——38. When will the sun be eclipsed to the inhabitants of the moon?

1. What regular motion is observed in the sea?——2. For what length of time does it flow back and forth?——3. By what are the tides occasioned?

twenty-five hours; and the time of high and low water is every day fifty minutes later than on the preceding day. The moon is supposed to draw the earth towards itself, and to act upon the solid parts of it in the same manner as if its whole weight were in a single point in or near the centre. Now the waters at any place over which the moon is passing, will be more attracted than the earth, and therefore will be heaped up under the moon. But the waters on the opposite side of the globe will be less attracted than the earth; consequently, the earth is drawn away from them; and they are heaped up, or in other words, it is high water there.

When the waters are elevated at the side of the earth under the moon, and at the opposite side also, it is evident they must recede from the intermediate points, and thus the attraction of the moon will produce high water at two places, and low water at two places, on the earth, at the same time. In figure 4, of Plate VII, let S represent the sun, M the moon, and A B C D the earth. Here it will be seen that at A and B, the points of the earth nearest and most distant from the moon is a high tide, while at the intermediate points C and D, there is a corresponding depression, or low tide.

The tide is fifty minutes later every day, because it is twenty-four hours and fifty minutes before the same meridian on our globe returns beneath the moon. The earth revolves on its axis in about twenty-four hours; if the moon, therefore, were stationary, the same part of our globe would return beneath it, every twenty-four hours; but as during our daily revolution the moon advances in its orbit, the earth must make more than a complete revolution in order to bring the same meridian opposite to the moon; we are fifty minutes in overtaking it, and the tides are retarded for the same reason that the sun rises later on one day than on the preceding day.

The tides, though constant, are not equal; but are greatest when the moon is in conjunction or opposition with the sun, or at the time of new and full moon; and least when in quadrature. This increase and diminution constitute what is called the *spring* and

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4. In what length of time are there two tides?——5. How does the time of high tide vary from day to day?——6. How is the operation of the moon in causing the tides described, particularly that on the side of the earth most distant from the moon?——7. What must evidently take place at the intermediate points, when the moon causes a high tide at the two opposite sides of the earth?——8. How is figure 4, of Plate VII, illustrated?——9. Why is the tide fifty minutes later every day?——10. How is this explained?——11. Are the tides always of equal height?——12. When are they highest?——13. When least?——14. What is this increase and diminution of the tides called?

neap tides. In figure 4, of Plate VII, will be seen exhibited the spring tides; and in figure 5, of that Plate, will be seen the neap tides, where the effect of the moon's attraction on the earth in the production of them is partly counteracted by the attraction of the sun.

The attraction of the sun does not raise tides; its only effect is to increase or diminish those raised by the moon. The tides are highest when both luminaries are in the equator, and the moon at the least distance from the earth. This happens at the time of the equinoxes. The tide is at the greatest height, not when the moon is in the meridian, but sometime afterwards; because the force by which the moon raises the tide continues to act after it has passed the meridian. The regular tides are greatly affected by strong winds. Continents also stop them in their course, and in narrow rivers they are frequently very high and sudden, on account of the resistance from the banks.

The above, in connection with other minor causes, occasion a great diversity in the tides. Thus, upon the coasts of France, which border the British channel, the flux being confined in a basin, and at the same time repelled by the coasts of England, rises to an enormous height; at St. Malœs, even to fifty feet. The ordinary tide in the gulf of Hamburg is from six to eight feet; but when the wind blows with violence from the northwest, the tide rises to 18 feet, sometimes even to more than 20 feet. In the bay of Fundy, actual observation has proved that tides rise at some points to the enormous height of seventy feet.

In small collections of water, the moon acts at the same time on every part; diminishing the gravity of the whole mass. On this account there are no tides in lakes, they being generally so small that when the moon is vertical, it attracts every part alike; and by rendering all the waters equally light, no part can be raised higher than another part. The Mediterranean and Baltic seas have very small elevations, partly on the above account, and partly because the inlets by which they communicate with the ocean are so narrow, that they cannot in so short a time either receive or discharge enough sensibly to raise or sink their surfaces.

15. How are the spring and neap tides explained by the figures?——16. At what periods in the year are tides the highest?——12. Why is the high tide a short time after the moon passes the meridian of a place?——18. By what are the regular tides affected?——19. What is said of the tides on the coasts of France which border on the British channel?——20. And in the gulf of Hamburg?——21. And in the bay of Fundy?——22. Why are the tides small in lakes and other small collections of water?——23. Why are they small in the Mediterranean and Baltic seas?

From the resistance of the banks, in narrow rivers, the tides rise to a great height. In the river Severn, it is high water at the mouth of it and at London, while it is low tide between those places. A similar phenomenon is exhibited in the river Amazon, of South America. Here are to be seen no less than seven high tides in the course of five hundred miles, the distance to which the tide ascends, with low water between each one of them.

Kepler was the first who ascertained that the tides are occasioned by the attraction of the moon. The great Newton, as in other departments of science, pursued the hint thus given, and has reduced this interesting subject to a perfect system. To the philosophical mind the tides appear as evincing wisdom and goodness in the Deity which should excite our love and admiration. Were it not for this constant motion the vast ocean might become stagnant, and the great fountain of contagion and death.

ATMOSPHERE AND WIND.

LESSON XXXVII.

The air in which we live surrounds the earth to a considerable height, revolves with it in its diurnal and annual motion, and, together with the clouds and vapors that float in it, is called the atmosphere. The height to which the atmosphere extends has never been ascertained; but at a greater height than forty-five miles, it ceases to reflect the rays of light from the sun. The air is invisible because it is perfectly transparent; but it may be felt on moving the hand in it, or when it moves and produces what we call wind.

The air is found on experiment to be about nine hundred times lighter than water. The weight of a column of air reaching from the top of it to the surface of the earth, is known to be equal to a column of water of the same size, thirty-three feet high, for that is the height to which water will rise in a pump. On the surface

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24. What is said of tides in narrow rivers?——25. In the river Severn? 26. In the river Amazon?——27. Who first ascertained that tides were occasioned by the moon's attraction?——28. Who made improvements on his discovery?——29. How does the Christian philosopher view the tides? ——30. What would be the consequence were it not for them?

1. What composes the atmosphere?——2. To what height does it rise?——3. Why is it invisible?——4. How may it be felt?——5. How much lighter than water is it?——6. How is the weight of the air determined?

of the earth the pressure of the atmosphere, upon every square inch is fifteen pounds. It has been computed that the pressure of the atmosphere on the whole surface of the earth is equal to a globe of lead sixty miles in diameter. We find no inconvenience from this great weight, because the pressure is alike on every part.

Although the atmosphere is the great reservoir for the numerous vapors and effluvia which float about us, still without it vegetable and animal life could not exist. Insinuating itself into all the pores of bodies, it becomes the great spring of almost all the mutations in material nature of which we are the witnesses. Without it the constitutions and principles of matter would be totally changed.

As a proof that atmospheric air is necessary for the support of animal life, it may be mentioned that animals put under the receiver of an air-pump soon expire when the air is extracted. If a number of persons are met in a small apartment, they soon find an inconvenience from the want of fresh air, unless by the opening of doors or windows a fresh supply can be admitted. Some years since, the Nabob of Calcutta confined, for a night, one hundred and forty-six Englishmen in an apartment called the Black-hole, but only twenty-three of them survived till the next morning.

Were the atmosphere not elastic, but everywhere equable, its height would be determined from its density. By this means it would appear to be about fifty-five miles in height; but the air being very elastic, and the more it is compressed, the less space it occupies, it follows that in the upper regions, as it ascends, it must become more rarefied, till it extends to an immeasurable, or comparatively infinite height. At the height of three and a half miles the density of the atmosphere is twice as much rarefied as at the earth's surface; and at seven miles elevation, four times as much; and so on in a geometrical progression.

Air is also the medium through which sound is conveyed to us. The organs of speech, or any sonorous body, make an impression on the air, and that is conveyed to the ear. The particles of air

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7. On the surface of the earth what is the amount of its pressure to a square inch?——8. What has been the estimated amount of the whole pressure of the atmosphere upon the earth?——9. Why do we find no inconvenience from the pressure of the atmosphere?——10. Of what use is the atmosphere?——11. How is it shown that the atmosphere is necessary to the support of animal life?——12. What is the consequence if a number of persons be confined in a close small room?——13. What took place at Calcutta?——14. Under what circumstances might the height of the atmosphere be accurately determined?——15. At what height is its density only half of what it is at the surface of the earth?——16. At what height is it only a quarter of that density?——17. How is sound produced?

set in motion by a sounding body communicate that motion to those next to them, those particles to others, and so on, until the particles of air are reached which are within the drum of the ear. The air then acts upon that membranè by communicating to it its own vibrations, which are transmitted to the auditory nerve, and by that nerve to the brain. Hence results the sensation of sound.

As the air is a fluid, its natural state is undoubtedly that of rest, which it endeavors always to keep, or to retrieve, by an universal equilibrium of all its parts. When this equilibrium of the atmosphere is destroyed in any part, there necessarily follows a motion of all the circumjacent air towards that part to restore it; and it is this motion of the air which is called *wind.* Wind may be produced by a variety of causes; but the most general are these two—heat and cold. Heat rarefies and expands the air, making it lighter in some places than it is in others, and cold by condensation makes it heavier.

There are some winds which blow constantly in the same direction. Of this kind, there are two general currents of the atmosphere—that which follows the course of the sun in the torrid zone; and that flowing from the cold regions around the poles, towards the equator, which is chiefly felt in the temperate zones. Other winds are periodical, or blow at only certain periods of the day, or the year; but these, as well as the constant winds, are chiefly confined to warm climates.

The *periodical winds*, or *monsoons*, as they are denominated, prevail chiefly in the Indian ocean, blowing six months from the southeast, and then from the northwest the same length of time. The change of the periodical winds from one to a contrary direction, is generally attended with severe storms of thunder and lightning, and sometimes with hurricanes. These winds extend over the whole of India and the sea coast of East Persia.

In islands and places near the sea in warm climates, particularly between the tropics, there is usually a wind blowing during the latter part of the night and the forenoon from the land to the water; and during the latter part of the day and the first part of the night, from the water to the land. These are called *land* and *sea breezes.*

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18. What is the natural state or tendency of the atmosphere?——19. What is the consequence when its equilibrium is destroyed?——20. How does heat and cold tend to produce wind?——21. What two constant winds are there? ——22. What are periodical winds?——23. Where do they mostly prevail? ——24. What takes place when they change their direction?——25. What winds are common on islands and places near the ocean?——26. What are they called?

The most dreadful of all storms is that called a *hurricane*, with which hot countries are sometimes afflicted. It is a sudden and violent storm of wind, rain, thunder, and lightning, attended with a furious swelling of the sea, and sometimes with an earthquake; in short, with every circumstance which the elements can assemble, that is terrible and destructive. Hurricanes are most frequent in the West Indies.

The qualities of winds are affected by the countries over which they pass; and they are sometimes rendered pestilential by the heat of deserts, or the putrid exhalations of marshes and lakes. Thus from the deserts of Africa, Arabia, and the neighboring countries, a hot wind blows called the Samiel or Simoon, which sometimes produces instant death. A similar wind blows from the Sahara, upon the western coast of Africa, called Hermattan, producing a dryness and heat which are almost insupportable, and scorching like the blasts of a furnace.

The velocity of wind, in a small breeze, is about four miles an hour; in a fresh gale, twenty or thirty miles an hour; in a violent storm, fifty or sixty miles an hour; and in a hurricane, from eighty to an hundred miles an hour.

TEMPERATURE OF THE ATMOSPHERE.

LESSON XXXVIII.

The presence of the sun is undoubtedly one of the principal sources of heat, as its absence is of cold; but if those affections of the atmosphere depended solely on these two causes, an equal temperature would, at the same seasons, prevail in all places situated under the same parallels. This, however, is far from being the case; for the temperature of the eastern coasts of America is far colder than that of the western shores of Europe, in the same latitudes; and the same observation may, with some degree of variation, be extended to the whole of these two continents.

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27. What are hurricanes?——28. Where do they mostly prevail?——29. How are the qualities of winds affected?——30. What is said of the wind called Samiel or Simoon?——31. And of that called Hermattan?——32. What is the velocity of wind in a small breeze?——33. In a fresh gale?——34. In a violent storm?——35. In a hurricane?

1. What is a principal cause of heat and of cold?——2. If the sun were the only cause of heat what would be the consequence?——3. What instances are named of places in the same latitudes having a different temperature?

It is equally observable, that the tropical heats of Africa are far greater than those of the West India Islands, and some other parts of America, situated in the torrid zone; and indeed, an abundance of proofs might be adduced to show that the temperature of the air in different countries depends on a variety of circumstances besides geographical position.

One great source of heat exists in the earth; but whether this arises from any central fire, or from elementary heat diffused through the whole mass, is a problem of no easy solution. The warmth which the earth imparts to the atmosphere, tends greatly to moderate the cold; and it has, by various observations, been found that the same degree of heat exists in all subterraneous situations at the same depth, or at least, that the variations are extremely small. The condensation of vapor also is another cause of heat, of which, it is well known, that vapor contains a great quantity. This condensation is often formed by the attraction of an electrical cloud, and hence arises that sultry heat which in summer is often felt before rain, and particularly before a thunder storm.

As the earth is the source of heat, distance from the earth must, consequently, be a cause of cold; and, in confirmation of this theory, it is invariably found that cold increases in proportion to our elevation in the atmosphere. Hence we find, even under the equator, mountains of a certain height have their tops covered with snow. An elevation of 500 yards produces the same effect as a distance of 5,000 miles from the equator. Accordingly, at an elevation of 13,000 feet we find the frosts of the frozen zone; and at 15 and 16,000 feet, the mountains, based upon the most scorching plains, are capped with perpetual snow and ice.

The heat of the atmosphere is further augmented by the accumulation of the sun's rays at the surface of the earth. The rays are then reflected into the air and to surrounding objects; so that the reflected heat is often greater than the direct heat of the sun. On this account, the heat in valleys, where the heat is reflected by hills and mountains, is sometimes very great. In an elevated val-

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4. What is the first source of heat named besides the sun?——5. What has been found as to the temperature of the earth on descending below the surface?——6. What is said of the condensation of vapor as an instrument in affecting the temperature of the air?——7. How is this condensation formed? 8. How is this known?——9. How is the temperature affected in rising above the surface of the earth?——10. What is evidence of this?——11. How does an elevation above the surface compare with distance from the equator as to temperature?——12. How is temperature affected by the reflection of the sun's rays?——13. What is said of heat in valleys?

ley in Switzerland, the heat is so much increased by reflection, that in the centre there is a spot of perpetual verdure, in the midst of perpetual snow and glaciers; and there are plains on the Himmaleh mountains, 15,000 feet above the level of the sea, which produce fine pasturage; and at the height of 11,000 feet, which is above the region of perpetual snows on the Andes, in the same latitude, barley and wheat are known to flourish.

From these and various other considerations, it is evident that some parts of the globe are, from the nature of the soil, and other topographical circumstances, exclusive of their geographical position with respect to the equator and the poles, better adapted for the reception and communication of heat than several others in the same latitudes. Stones and sands cool and heat more readily, and to a greater degree than mould or clay. From this cause proceeds, in a great measure, the excessive heats in the sandy deserts of Arabia and Africa, and the intense cold of Terra del Fuego and other stony countries in high latitudes.

Countries that are uncultivated and covered with wood, are much colder than those which are open and cultivated; as the former prevent the access of the solar rays to the earth or to the snow which they may conceal, and also present a greater number of evaporating surfaces than the latter. To be convinced that the air of woody countries is rendered colder by the evaporation from the trees and shrubs, it is only necessary to observe that a thick shade of trees is cooler than the shelter of buildings.

As the land is capable of receiving and retaining much more heat or cold, than water can imbibe, the vicinity of the sea is also a circumstance which considerably affects the temperature of the air. The sea therefore moderates the heat in warm climates, and the cold in higher latitudes. When the rays of the sun strike upon the water, they will penetrate six or seven hundred feet, if there be that depth; and the heat will be diffused through the whole mass remaining till carried off by evaporation. Consequently in hot climates, the body of the ocean is much cooler than the land; and in cold ones it is warmer.

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14. Of a valley in Switzerland?——15. And of some plains on the Himmaleh mountains?——16. What is evident from the above and other considerations?——17. What is said of stones and sand as affecting temperature?——18. By reference to what places is this confirmed?——19. What is said of cultivated and uncultivated countries in relation to this subject?——20. What is mentioned as proof that the evaporation from trees affects temperature?——21. What comparison is made between the land and water as affecting temperature?

Thus, too, countries which abound with rivers, lakes, and marshes, are also less subject to the extremes of heat and cold, than those which are dry. Islands which participate in the temperature of the sea, are generally cooler in summer, and warmer in winter, than continents in the same parallels; and in regard to the latter the same comparison will hold good between the maritime parts and the interior. The difference between the heat of the day and the night is also less at sea than on land, especially in low latitudes; and consequently less in islands and maritime places than in countries remote from the coast.

The irregular intersection of the surface of the earth, by seas and mountains, branching out in a thousand different directions, and exhibiting a variety of appearances, numerous and multiform, beyond all the ideas that imagination can conceive, may to a superficial observer appear fortuitous, and present to the eye of ignorance the view of an immense ruin; but to the physical geographer, it points out the agency of an all-wise provident Hand, in the architecture of an immense fabric. When the apparent irregularities on the surface of the globe are inspected with the eye of philosophy, they are found not only beneficial, but absolutely necessary to the welfare of the inhabitants.

CLOUDS, RAIN, SNOW, AND HAIL.

LESSON XXXIX.

Clouds are a collection of misty vapors suspended in the air. These vapors consist of water, particles of earth, nitre, sulphur, salts, and all other substances which the heat of the sun, and the action of terrestrial bodies, cause to rise above the surface of the globe. The lightest clouds are seldom more than two miles in height; the more dense range within one mile; and the most dense, surcharged with electricity, generally float within half a mile of the ground.

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22. What is said of countries abounding with rivers, lakes, and marshes? ——23. What comparison is made between islands and continents?——24. So far as the temperature of day and night is affected, what is said concerning seas and lands?——25. What is said of the physical irregularities on the face of the earth?

1. What are clouds?——2. Of what do they consist?——3. To what height do they extend?

Among the advantages afforded us by the existence of clouds, they serve as screens between the scorching rays of the sun and the earth. So intense oftentimes are these rays, that were they not thus obstructed, vegetable life could scarcely be sustained. In the less discoverable operations of nature, where the electric fluid is concerned, clouds have a principal share; and particularly serve as a medium for conveying that subtile matter from the atmosphere to the earth, and from the earth to the atmosphere.

The various colors and appearances of clouds are owing to their particular situation in regard to the sun, to the different reflections of the sun's rays, and to the effects produced on them by heat. On being run together, or condensed into drops by the influence of cohesive attraction, fall by their own weight, and are called *rain.*

The annual average is about three feet in depth, to the whole surface of the earth. This quantity, however, is not very equally distributed. It is most abundant in tropical regions, and decreases in proportion to the distance from the equator to the poles. Within the tropics, the rains, like the winds, occur regularly at certain seasons of the year. In the northern tropic, they begin in April, and end in September. In the southern, they begin in September, and end in April. In the West Indies, the average is nearly ten feet, while at the parallels of seventy degrees of latitude, and upwards, the annual stock is not above ten inches. In some countries, as in Egypt, and a part of Peru and Chili, there is little or no rain.

The economy of nature is very beautiful. Vapors arise from the seas, pass in clouds over the lands, and then, by their own weight descend upon the earth to water and to fertilize it. Dr. Halley attempted to estimate the vapor drawn from the Mediterranean, during one sunny day; and by calculating the surface of that sea, and making an experiment on a small quantity of water, he was led to suppose that it might be at least 5,280 millions of tons.

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4. What are the uses of them?——5. To what are the various colors and appearances of clouds owing?——6. How is rain produced?——7. What is the annual depth of rain on the whole surface of the earth?——8. Is it equally distributed?——9. Where is it most abundant?——10. What is said of the rains between the tropics?——11. When do they begin in the northern tropic?——12. When in the southern tropic?——13. What is said of rain in the West Indies, and at the distance of seventy degrees of latitude?——14. In what places is there little or no rain?——15. What quantity of water did Dr. Halley suppose was evaporated daily from the Mediterranean sea?

It has been supposed by Sir Richard Phillips, that the quantity of rain falling upon particular portions of the earth might be varied by artificial means. According to his hypothesis, the leaves of vegetables and particularly of trees, disturb the electricity of the clouds, and cause it to rain. Hence he concluded that more perfect metallic conductors raised to greater heights in the atmosphere might be so combined as to produce more certain results.

Pursuing this idea, he traces to the cutting down of trees in civilized countries their ultimate sterility, and conceives that to this cause solely is to be ascribed the present sterility of Syria, Chaldea, and Barbary, once the most fertile regions in the world; and he ascribes the *oases* of the deserts to the circumstance of a few trees being accidentally suffered to grow on them. He imagines, that those countries might now be restored by erecting on their elevated surfaces a sufficient number of metallic rods to arrest the clouds and produce sufficient rain to sustain vegetation, and refill the almost exhausted rivers.

As fanciful as this theory of Sir Richard appears, it is confirmed by what is taking place in nature. Thus, the first lands over which prevailing winds blow from the ocean are always the best watered; and those farther off are less watered in proportion to their distance. The western countries of Ireland, Ireland itself with respect to England, and the western counties of England with reference to the eastern ones, prove the powers of the innumerable spicula of vegetation and minerals to disturb the electricity of the clouds, and make them fall in rain. From like causes, according to Sir William Young, the value of estates in several of the West India Islands has been greatly diminished by the cutting down of the trees. The phenomena of Peru and Chili, in the neighhorhood of the elevated natural conductors of the Andes, where it rains almost perpetually, afford also a lesson to man, whenever the state of society enables him to adopt it.

Clouds being condensed into drops by cohesive attraction, and then congealed or frozen by the cold as they are falling to the ground, produce what is called *hail.*

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16. What did Sir Richard Phillips suppose as to the quantity of rain?—— 17. How did he suppose it might be done?——18. What does he say of cutting down trees?——19. What cases of illustration does he mention?—— 20. To what does he attribute the oases of deserts?——21. How does he suppose that steril countries might be restored to fertility?——22. Is the theory of Sir Richard probable?——23. What reason is mentioned in favor of it?——24. What is said of Ireland and England in support of this theory? ——25. What fact is affirmed relating to the subject from Sir William Young? 26. Of Peru and Chili what is said in confirmation of this theory?——27. How is hail produced?

Natural historians furnish accounts of surprising showers of hail, in which the hailstones were of extraordinary magnitude. Dr. Halley mentions one, which occurred in the north of England, 1697, killing fowls and other small animals, spliting trees, knocking down men and horses, and even ploughing up the earth to a considerable depth. The hailstones were of various forms, some of them weighing five ounces, and a few even half a pound. Another occurred five days later, even more disastrous. In this the hailstones were much larger than the other, and killed several persons, their bodies being beaten in a most shocking manner.

Different particles of clouds touching each other, and freezing without being condensed into drops, produce what is called snow. In Lapland, Siberia, and other northern regions, snow falls to the depth of ten and twelve feet. By this means, as it is a preservative against the effects of the frost, vegetable substances are kept alive to adorn the season of summer. In Labrador, during winter, the natives make houses under the surface of the snow, where they reside. Capt. Cartwright and the Moravian Missionaries describe them as warm and comfortable habitations.

In Sicily, Naples, and Malta, the inhabitants preserve snow, and use it to cool their wines and other drink, as we do ice. It is kept in the caverns, in Mount Etna and other high mountains, so as to be secure from melting in that mild climate. The Sicilians carry on considerable trade in snow, which affords employment to some thousands of mules, horses and men.

THEORY OF THUNDER AND LIGHTNING.

LESSON XL.

The surface of the earth, and of all bodies with which we are acquainted, is supposed to contain or possess a power of exciting or exhibiting a certain quantity of an exceeding subtile agent, called the electric fluid. The quantity usually belonging to any surface is called its natural state, and it then produces no sensible effects;

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28. What account does Dr. Halley give of a hail storm?——29. How is another hail storm described, said to be still more disastrous?——30. How is snow produced?——31. What is said of snow in Lapland, Siberia, and other northern regions?——32. What is the use of snow?——33. What is said of it in Labrador?——34. What is said of it in Sicily, Naples, and Malta?

1. What is electricity?——2. What is the natural state of a body when spoken of in relation to electricity?

but when any surface becomes possessed of more, or less, than its natural quantity, it is electrified, and it then exhibits a variety of peculiar and surprising phenomena ascribed to the power called electric.

If you take a stick of sealing-wax and rub it on the sleeve of your coat, it will have the power of attracting small pieces of paper, or any other light substances, when held near them. If a clean and dry glass tube be briskly rubbed with the hand, or with a piece of flannel, and then presented to any small light substances, it will immediately attract and repel them alternately for a considerable time. The tube is then said to be excited. If an excited glass tube, in a dark room, be brought within about half an inch of the finger, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise, and a peculiar sensation of the finger. Dry flannel clothes, when handled in the dark, frequently exhibit a sparkling appearance, attended with the same kind of noise that is heard in the experiment of the glass tube.

When any body is possessed of more than its natural quantity of electricity, it is said to be positively electrified; and when possessed of less than its natural quantity, it is said to be negatively electrified. If two substances come in contact, one charged positively and the other negatively with electricity, so much of the fluid passes from the former to the latter, as to produce an equilibrium. Certain bodies have the power of transmitting electricity from one surface to another, and are hence called conductors; others not possessing this power are called non-conductors. Metals, ores, and fluids in their natural state, excepting air and oils, are conductors; vitrified and resinous substances, amber, sulphur, wax, silk, cotton, and feathers, are non-conductors.

From the similarity between lightning and the electric fluid, it had long been supposed, that they were one and the same thing; but it was left for Dr. Franklin to prove the truth of this supposition. When the clouds and the different terrestrial objects, over which they pass, are charged, one positively and the other negative-

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3. When is a body said to be electrified?——4. What experiment is made with the sealing-wax?——5. What one with a glass tube?——6. What is said of dry flannel clothes in illustration of the subject?——7. When is a body positively electrified?——8. When is it negatively electrified?——9. What takes place when two substances come in contact, one charged positively and the other negatively?——10. What substances are called conductors?——11. Why are they so called?——12. What ones are called nonconductors?——13. Why are they so called?——14. Who first proved that lightning and electricity are the same thing?

ly, in the passage of this fluid from the former to the latter, there is presented what we call lightning. So likewise, where two clouds come in contact, differently charged, the same result takes place. Thunder is the report which accompanies the taking place of this electrical union. It is occasioned by the rarefaction or displacing of the air, and its sudden return to its original position. Thunder and lightning bear the same relation to each other, as the flash and report of a cannon.

The experiment of Dr. Franklin, to prove, that lightning and electricity were the same thing, was exceedingly simple. He took a boy's kite covered with a silk handkerchief instead of paper, and then fastened some wire to the upper part which served to collect and conduct the fluid. When he had raised this machine into the atmosphere, he drew electric fluid from the passing clouds, which descended through the flaxen strings of the kite as a conductor, and was afterwards drawn from an iron key, which he tied to the line at a small distance from his hand. This important discovery immediately led to the formation of conductors to secure buildings from the effects of lightning. Thunder is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place where the report is heard from the point of the discharge.

In summer when the earth is dry, and the day is warm, droughty and serene, the atmospheric electricity increases from sunrise till mid-day, when it arrives at its maximum ; it then remains stationary for two hours, and afterwards diminishes until the fall of the dew. Towards midnight it revives, to be again almost entirely extinguished. In winter, the maximum of electricity is at eight o'clock in the evening, being weaker through the day. In all these variations atmospherical electricity seems very exactly to follow up the development of hydrogen gas, which is more or less considerable at different periods of the day.

Electrical phenomena are more prevalent in some quarters of the globe than others. Towards the poles, the disengagement of hy-

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15. How is lightning produced?——16. What is thunder?——17. How is it caused?——18. To what is the relation between thunder and lightning compared?——19. With what experiment did Dr. Franklin make the discovery that lightning and electricity are the same?——20. To what did his discovery lead? ——21. By what is the duration and intensity of thunder affected?——22. What is said of electricity in the season of summer?——23. And in winter?——24. In these variations what is it said that atmospherical electricity exactly follows? ——25. Are electrical phenomena equally prevalent in all quarters of the globe?

drogen gas is extremely scanty, and there is also no continual friction between the earth and the atmosphere. Thunder, accordingly, is rarely observed in those regions; it is only a weak decrepitation. As we advance towards the equator, hydrogen gas becomes more abundant, and at the same time storms are most violent. It is under the equinoctial line that we meet with that vast extent of sea, where thunder storms almost constantly prevail.

Storms, notwithstanding the calamities which they frequently occasion, and which the thunder rod cannot infallibly prevent, deserve to be considered as one of the greatest benefits our Creator has bestowed. They diffuse freshness through the atmosphere when it is in a confined and sultry state; the plants resume their lively green, the flowers raise their drooping heads, when their thirst has been quenched by the rain; the crops and fruits penetrated by new warmth, ripen more rapidly, and man silently adores the great Being whose power has been displayed.

EXPLANATION OF THE RAINBOW.

LESSON XLI.

The Rainbow is a meteor in form of a party colored arch, or semicircle, exhibited only at the time when it rains. It is always seen in that point of the heavens which is opposite to the sun, and is occasioned by the refraction and reflection of the sun's rays in the drops of falling rain. There is likewise, though not always distinctly visible, a secondary rainbow, much fainter than the primary one, and at some distance from it.

The different colors of the rainbow are owing to the refraction and reflection of the sun's rays thus produced. These colors appear the more vivid, as the clouds which are behind them are darker, and the drops of rain fall closer. The drops continually forming produce a new rainbow every moment, and as each spectator observes it from a particular situation, it happens that scarcely two men, strictly speaking, see the same rainbow; and this appearance can only last whilst the drops which fall are succeeded by others.

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26. What is said of them in polar regions?——27. And in the equatorial regions?——28. What is said of storms?——29. What advantage results from them?

1. What is the rainbow?——2. In what part of the heavens is it seen?——3. What is said of the secondary rainbow?——4. To what are the colors of the rainbow owing?——5. Do different persons see the same rainbow?

As evidence that rainbows are occasioned in the manner stated, it may be observed that artificial rainbows are easily produced. Cascades and fountains, whose waters, in their fall, are divided into drops, will exhibit rainbows to a spectator, properly situated, during the time of the sun's shining. This appearance is also seen by moonlight, though seldom sufficiently vivid to render the colors distinguishable. Colored bows have been seen on grass formed by the refraction of the sun's rays in the morning dew.

Artificial rainbows may also be produced by a candle light on the drops of water ejected by a small fountain. But the most natural and pleasing is by means of the air fountain, the jet of which is perforated with a great number of very fine holes from which the water spouts so as to form a kind of fluted column. The rainbow is formed by the sun's rays, for the spectator has only to place the spouting streams directly in the sun's beams, with his own back to the sun, and being in a direct line with the sun and the centre of the jet, by stooping his head to a certain degree, he will discover the beautiful appearance of the natural prismatic colors, and a small rainbow, on the same principle as those which are seen in the time of rain and sunshine.

PARALLAX OF THE HEAVENLY BODIES.

LESSON XLII.

The parallax is an arc of the heavens intercepted between the true place of the moon, or any other heavenly body, and its apparent place. The true place of the moon, or star, is the point of the heavens in which it would be seen by an eye placed in the centre of the earth. And the apparent place, is that point in the heavens where the moon, or star, appears to an eye on the surface of the earth.

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6. Can artificial rainbows be produced ?——7. What is said of those produced by cascades ?——8. What is said of them when seen by moonlight ?——9. And of the colored bows seen on the grass ?——10. How may artificial rainbows be produced by candle-light ?——11. How are the most natural and pleasing ones produced ?——12. How is the appearance described ?

1. What is the parallax of a heavenly body ?——2. What is the true place of the moon or a star ?——3. What is the apparent place of it ?

In figure 9 of Plate VIII. to a spectator at G the centre of the earth, the moon at E would appear among the stars at I; but seen from A on the surface of the earth, it would appear at K. The place I is its true situation, and K its apparent situation; and the difference between them is its parallax.

The parallax is greatest when the heavenly body is in the horizon, and decreases as the body ascends towards the zenith, at which place it is nothing. Thus it may be seen, from the figure named in the preceding paragraph, that when the moon rises above the horizon to D, it will have a less parallax than when at E; and when at the zenith F, there will be to it no parallax.

The nearer a body is to the earth the greater is its parallax; hence the moon on this account has the greatest parallax, and the fixed stars, from their immense distance, have no parallax, the semidiameter of the earth appearing at that distance, no more than a point. Thus, if the moon were at the small e, the parallax would be less than if it were at the capital E.

What is termed annual parallax is the difference in the apparent place of a heavenly body, as seen from opposite points in the earth's orbit. This orbit is about one hundred and ninety millions of miles in diameter. Hence an object, unless immensely distant as seen from one part, must appear in a very different place in the heavens, from the same object as seen from the opposite part.

It is seen, from what is said above, and from the lesson on the refraction of light, that refraction and parallax both make bodies appear where they are not; but refraction elevates them and parallax depresses them. They are both greatest in the horizon, and vanish entirely at the zenith.

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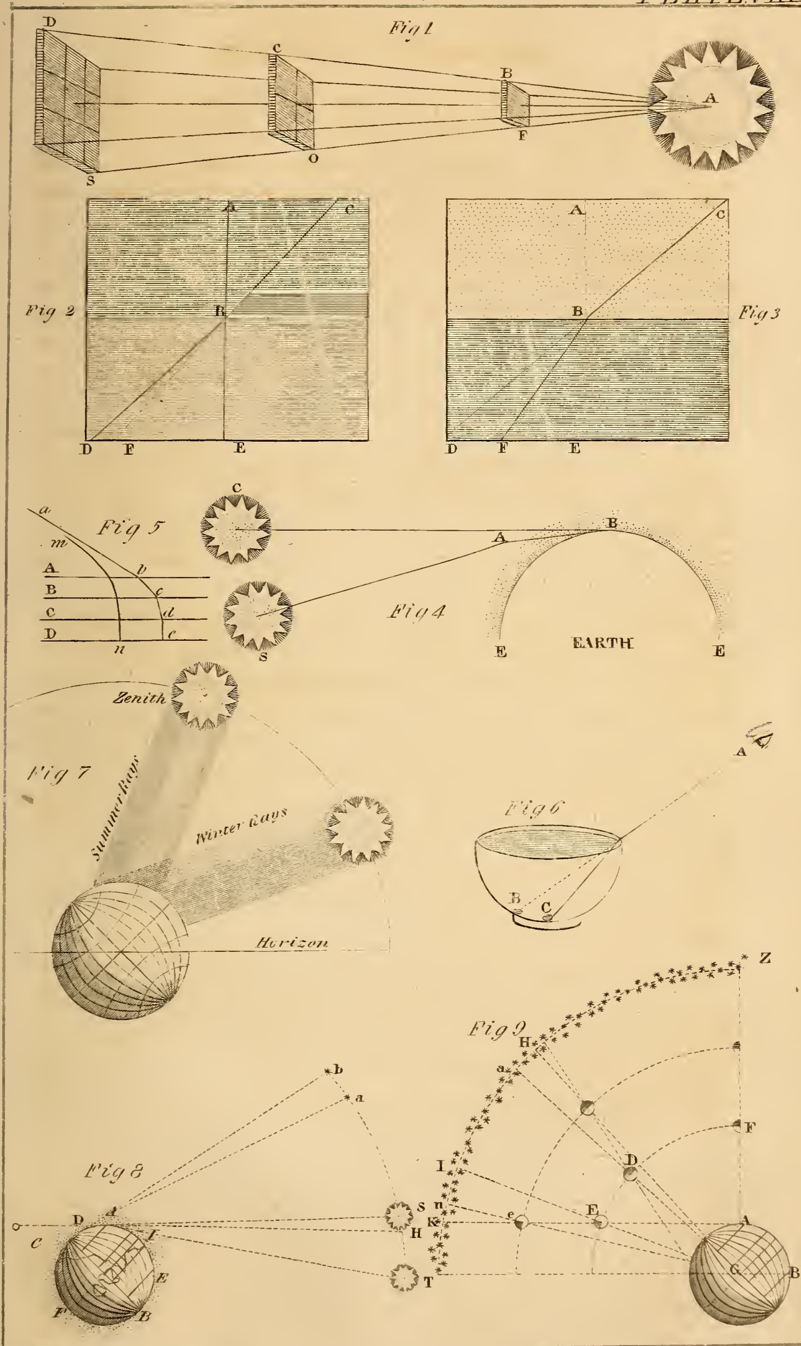
4. Which figure illustrates the parallax?——5. How is the illustration given by the figure?——6. Where is the parallax greatest?——7. How is it altered in rising above the horizon?——8. How is this explained by the figure?——9. How is the parallax affected by distance from the earth?——10. And how is this shown from the figure?——11. What is the annual parallax?——12. What is said of bodies seen from the earth in different parts of its orbit?——13. What comparison is made between refraction of light and parallax?

PLATE VIII.



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PROBLEM I, ON THE TERRESTRIAL GLOBE.

LESSON XLIII.

The Method of finding the Latitude and Longitude of any given Place.

PROCESS. Find the given place on the globe, and bring it to the graduated edge of the brazen meridian. Then, the degree on this meridian, immediately over the place, will be the latitude sought; and the degree on the equator, which corresponds with the graduated edge of the brazen meridian, will be the longitude of the given place.

Note. If the latitude is north of the equator, it is called north latitude; if south of the equator, it is called south latitude. If the longitude is east of the first meridian, it is called east longitude; if west of the first meridian, it is called west longitude.

QUESTIONS FOR PRACTICE.

1. What is the latitude and longitude of Philadelphia?——2. What is the latitude and longitude of the island St. Helena?——3. What is the latitude and longitude of Quito?——4. What is the latitude and longitude of Nankin?——5. What is the latitude and longitude of Charleston, S. C.?——6. What is the latitude and longitude of Cape Horn?——7. What is the latitude and longitude of Batavia?——8. Of Quebec?——9. Of Archangel?——10. Of Gibralter?——11. Of Buenos Ayres?——12. Of Calcutta?——13. Of Mexico?——14. Of Canton?——15. Of the island of Chiloe?——16. What place has no latitude or longitude?

PROBLEM II, ON THE TERRESTRIAL GLOBE.

LESSON XLIV.

Method of finding the Difference in Latitude between any two given Places.

PROCESS. Bring the places successively to the meridian, and note the latitude of each. If the latitudes thus found be both north, or both south, subtract the less from the greater, and the remainder is the difference between them. If one of them be north latitude, and the other be south latitude, they are to be added together, and their sum is the difference required.

QUESTIONS FOR PRACTICE.

1. What is the difference between the latitude of Baltimore and Mexico?——2. What is the difference between London and Rome?——3. What is the difference between Boston and Buenos Ayres?——4. Between Constantinople and Cape Town?——5. Between Lima and Philadelphia?——6. Between Canton and Paris?——7. Between Quito and New Orleans?——8. Between New York and Valparaiso?——9. Between Archangel and St. Petersburg, in Russia?——10. Between Portland and St. Salvador?

PROBLEM III, ON THE TERRESTRIAL GLOBE.

LESSON XLV.

Method of finding the Difference in Longitude between any two given Places.

Process. Find the longitude of each place, subtracting the less from the greater, if they be both east, or both west longitude, and the remainder will be the difference sought. If one place be east, and the other west longitude, they are to be added together, and the product will be the difference required.

QUESTIONS FOR PRACTICE.

1. What is the difference of longitude between Vienna and Calcutta?——2. Between Cincinnati and Savannah?——3. Between Boston and Rome?——4. Between St. Louis and New Haven?——5. Between Lisbon and Genoa?——6. Between Warsaw and Dublin?——7. Between Cork and Adrianople?——8. Between Cadiz and Berlin?——9. Between Baltimore and Cadiz?——10. Between Copenhagen and Astrachan?——11. Between Oporto and Bourdeaux?——12. Between London and Washington?

PROBLEM IV, ON THE TERRESTRIAL GLOBE.

LESSON XLVI.

The Method of finding a Place, when the Latitude and Longitude are given.

Process. Look on the equator for the given longitude, and bring it to the brazen meridian. Then find the given latitude on the meridian, and directly under it is the place required.

QUESTIONS FOR PRACTICE.

1. What city is situated thirty degrees east longitude, and thirty-one degrees north latitude?——2. What island lies six degrees west longitude, and sixteen degrees south latitude?——3. What city is situated ninety degrees west longitude, and thirty degrees north latitude?——4. What one 116° east longitude, and 40° north latitude?——5. What one 77° west longitude, and 12° south latitude?——6. What island lies 5° west longitude, and 16° south latitude?——7. What one 63° west, and between 32° and 33° north?——8. What one 156° west, and 19° north?——9. What one 121° east, and 15° north?——10. What one 81° east, and 8° north?

PROBLEM V, ON THE TERRESTRIAL GLOBE.

LESSON XLVII.

Method of rectifying the Globe to the Latitude, to the Zenith, and to the Sun's Place.

Process. Elevate the pole above the horizon, till its altitude is equal to the latitude of the place. If the place is in north latitude, the north pole is to be elevated; if it is in south latitude, the south pole is to be elevated. When this is done, fix the quadrant of altitude on the brazen meridian, at the zenith, which is directly over the latitude of the place. The globe should also be placed so that the poles may stand due north and south, corresponding with the poles of the earth.

The globe having been thus rectified to the latitude and the zenith, let the given day of the month be found in the outer circle of the wooden horizon, and against it, in the middle circle, is the sun's place in the ecliptic. Then find the same sign and degree in the ecliptic, bringing it to that part of the meridian numbered from the equator to the poles; at the same time putting 12 on the hour circle to the said meridian. The globe is now rectified as required.

EXAMPLES FOR PRACTICE.

Let the globe be rectified for New York on the 15th of May. New York being about 40° north, the north pole must be raised 40° above the horizon, and the quadrant of altitude fastened directly over the latitude. Then find on the horizon the 15th of May, which answers to the twentieth of Taurus. This being done, bring the twentieth of Taurus on the ecliptic, to the meridian, and set the index to the hour circle at 12, and the globe is rectified. For the latitude and zenith of all other places, the globe may be rectified in the same way. From a similar examination of the horizon to the globe, it will be seen the 1st of June corresponds to the 10th of Gemini; the 10th of August to the 18th of Leo; and the 15th of April to the 26th of Aries.

QUESTIONS FOR PRACTICE.

1. How is the globe rectified to the latitude of a place?——2. And to the zenith?——3. And to the sun's place?——4. Where is the sun's place on the ecliptic, on the 5th of July?——5. On the 12th of January?——6. On the 25th of December?——7. On the 14th of September?——8. On the 20th of May?——9. On the 4th of April?——10. On the 22d of November?

PROBLEM VI, ON THE TERRESTRIAL GLOBE.

LESSON XLVIII.

The Method of finding the Distance between any two given Places.

Process. Bring one of the places to the brazen meridian, over which fix the quadrant of altitude; then extend it over the other place, and the number of degrees on the quadrant, contained between, is the distance in degrees. This being done, multiply the number of degrees by 69½, and the product will be the number of English miles. If multiplied by 60, the product will be the number of geographical miles.

QUESTIONS FOR PRACTICE.

1. What is the distance in English miles between Boston and New Orleans? ——2. Between London and Paris?——3. Between Vienna and Rome?——4. Between Philadelphia and Savannah?——5. Between Pekin and Constantinople?——6. Between Berlin and Madrid?——7. Between Archangel and Moscow?——8. Between Baltimore and Lexington, Ky.?——9. Between New York and Montreal?——10. Between Calcutta and Canton?

PROBLEM VII, ON THE TERRESTRIAL GLOBE.

LESSON XLIX.

The Method of finding the Hour of the Day at a required Place, when the Day and Hour at another Place are given.

Process. Bring the given place to the meridian, set the index to the given hour; then turn the globe till the required place comes under the meridian, and the index will point out what the hour is at that place. Thus when it is 12 o'clock, at noon, in London, it is 7 o'clock in the morning at Philadelphia; and 4 o'clock in the afternoon at the island Mauritius.

QUESTIONS FOR PRACTICE.

1. When it is 10 o'clock in the morning at Boston, what will be the hour at Cincinnati?——2. When it is noon at Boston, what will be the hour at Paris? ——3. When it is noon at London, what will be the hour at Constantinople? ——4. When it is noon at St. Petersburg, what will be the hour at New York? ——5. When it is noon at Rome, what will be the hour at Canton?——6. When it is noon at Baltimore, what will be the hour at New Orleans?——7. When it is noon in Boston, where is it midnight?——8. At Washington, when it is 6 o'clock in the evening, where is it noon?——9. When it is noon at Quebec, what will be the hour at the mouth of the Columbia river?

PROBLEM VIII, ON THE TERRESTRIAL GLOBE.

LESSON L.

Method of finding at what Hour the Sun rises and sets, and the Length of the Day and Night, at any Place, on any given Day of the Year.

Process. Find the latitude of the place, and rectify the globe for the latitude; find the sun's place in the ecliptic, bring it to the brazen meridian, and set the index of the hour circle at the upper

12; turn the globe on its axis eastward until the sun's place is level with the horizon, and the index will point to the hour of the sun's rising. Turn the globe on its axis westward, until the sun's place is level with the western edge of the horizon, and the index will point to the hour of the sun's setting.

The hour of the sun's rising being doubled, shows the length of the night; and the hour of the sun's setting being doubled, shows the length of the day.

QUESTIONS FOR PRACTICE.

1. At what time will the sun rise and set at New-York, on the 20th of December?——2. What will be the length of the day and of the night?——3. At what time will the sun rise and set at Boston, on the 20th of September?——4. And what will be the length of the day and of the night?——5. At what time will the sun rise and set, at St. Petersburg, on the 10th of January?——6. And what will be the length of the day and the night?——7. At what time will the sun rise and set at London on the 22d of June?——8. And what will be the length of the day and the night?——9. At what time will the sun rise and set at New Orleans, on the 5th of August?——10. And what will be the length of the day and the night?

PROBLEM IX, ON THE TERRESTRIAL GLOBE.

LESSON LI.

Method of finding those Days of the Year on which the Sun will be Vertical at any given Place in the Torrid Zone.

Process. Bring the given place to the brass meridian, and mark its latitude; then turn the globe on its axis, and observe those two points of the ecliptic, which pass under that degree of latitude; look for these points of the ecliptic, in the circle of signs on the horizon, against which, in the circle of months, are the days required.

QUESTIONS FOR PRACTICE.

1. When will the sun be vertical at Calcutta?——2. At Sierra Leone?——3. At Mexico?——4. At Lima?——5. At Canton?——6. At Quito?——7. At St. Helena?——8. At Rio Janeiro?——9. At Havanna?——10. At the Sandwich Islands?——11. At the Pelew Islands?——12. At the Friendly Islands?

PROBLEM X, ON THE TERRESTRIAL GLOBE.

LESSON LII.

Method of finding all those places on the Globe which will have a vertical Sun, the Month and the Day of the Month being given.

Process. Find the sun's place in the ecliptic, as directed in a previous problem, and bring it to the meridian; turn the globe round, and all the places that pass under that degree of the meridian, will have a vertical sun on that day.

QUESTIONS FOR PRACTICE.

1. What places will have a vertical sun on the twenty-second of February? ——2. What ones on the tenth of June?——3. What ones on the fourteenth of August?——4. What ones on the sixteenth of September?——5. What ones on the eighth of May?——6. What ones on the fourth of July?——7. What ones on the twentieth of November?——8. What seas will have a vertical sun on the ninth of May?——9. What large rivers will be affected by a vertical sun on the first of June?——10. What large rivers will be affected by a vertical sun on the first of March?

PROBLEM I, ON THE CELESTIAL GLOBE.

LESSON LIII.

The Method of finding the Latitude or Longitude of any given Star.

Process. Screw the quadrant on the pole of the ecliptic, bring the star to the meridian, and the degrees of the quadrant, between the ecliptic and star, show the latitude, and the degree of the ecliptic under the graduated edge of the quadrant, is the longitude.

Note. Latitude, on the celestial globe, is reckoned from the ecliptic, north and south. *Longitude* is reckoned on the ecliptic, from the first point of Aries round the globe.

QUESTIONS FOR PRACTICE.

1. What is the latitude and longitude of Arcturus? Ans. Latitude is 31° north; longitude is 201°.——2. What is the latitude and longitude of Regulus? ——3. Of Vega, in the Harp?——4. Of Medusa's Head?——5. Of Sirius?—— 6. Of Pollux, in Gemini?——7. Of Antares, in Scorpio?——8. Of Altair, in Aquila?——9. Of Argol, in Perseus?——10. And what is the latitude and longitude of Canis Minor?

PROBLEM II, ON THE CELESTIAL GLOBE.

LESSON LIV.

Method of finding the Declination and Right Ascension of the Sun or a Star.

Process. Bring the place of the sun or the given star to the brass meridian, and the degree above it will be its declination; and the number of degrees on the equinoctial under the meridian, reckoning from Aries eastward, is the right ascension.

Note. Declination is reckoned from the equinoctial, north and south. *Right Ascension,* is reckoned on the equinoctial from the first point of Aries round the globe.

QUESTIONS FOR PRACTICE.

1. What is the declination and right ascension of the sun on the 19th of April? Ans. Declination, 11° 19′; right ascension, 27° 30′.——2. What is the declination and right ascension of the sun on the 2d of December?——3. On the 18th of February?——4. On the 4th of March?——5. On the 10th of May?——6. Of the star Rigel, in Orion?——7. Of Aldebaran, in Taurus?——8. Of Rastaben, in Draco?——9. Of Algol, in Perseus?——10. Arcturus, in Bootes?

PROBLEM III, ON THE CELESTIAL GLOBE.

LESSON LV.

Method of finding the Place of a heavenly Body on the Globe, when the Latitude and Longitude are given.

Process. Place that part of the quadrant of altitude marked 0, on the given longitude in the ecliptic, and the upper end over the pole of the ecliptic; and under the given latitude will be found the star required.

QUESTIONS FOR PRACTICE.

1. What is the star whose longitude is 201°, and its latitude 31° north? Ans. Arcturus, in Bootes.——2. What star is that which has a longitude of 299°, and a latitude of 29° north?——3. That which has a longitude of 85°, and a latitude of 16° south?——4. That which has a longitude of 300° and a latitude of 44° north?——5. That which has a longitude of 79° and a latitude of 32° north?——6. That which has a longitude of 334°, and a latitude of 21° south?——7. That which has a longitude of 107°, and a latitude of 10° north?——8. And that which has a longitude of 66½°, and a latitude of 5½° south?

PROBLEM IV, ON THE CELESTIAL GLOBE.

LESSON LVI.

Method of finding the Place of a heavenly Body on the Globe, when the Right Ascension and Latitude are given.

Process. Bring the given degree of right ascension to the graduated edge of the brass meridian, and note the degree. Then immediately under the given declination, on the brass meridian, will be found the place of the star required.

QUESTIONS FOR PRACTICE.

1. What is the star whose declination is thirty degrees and forty minutes south, and right ascension 341° 38′? Ans. Formalhaut, in the southern Fish.——2. What one has a right ascension of 129°, and a declination of 7° north?——3. What one has a right ascension of 83°, and a latitude of 34° south?——4. What one has a right ascension of 26°, and a latitude of 20° north?——5. What one has a right ascension of 54°, and a latitude of 23½° north?——6. What one has a right ascension of 113°, and a latitude of 28½° north?——7. What one has a right ascension of 99°, and a latitude of 16½° south?——8. What one has a right ascension of 76°, and a latitude of 8½° south?——9. What one has a right ascension of 46½°, and a latitude of 10° south?——10. What one has a right ascension of 110½°, and a latitude of 32° north?

PROBLEM V, ON THE CELESTIAL GLOBE.

LESSON LVII.

Method of finding the Distance in Degrees between any two given Stars on the Globe.

PROCESS. Lay the quadrant of altitude over the two given stars; and the number of degrees between them as reckoned on the quadrant, will be their distance as seen from the earth. Or, extend a thread over any two given stars; apply the distance found to the equator, and count the number of degrees.

QUESTIONS FOR PRACTICE.

1. What is the distance between Altair, in the Eagle, and Sega, in Lyra?——2. Between Pollux, in Gemini, and Altair?——3. Between Spica and Regula? ——4. Between Castor and Pollux?——5. Between Rigel and Aldebaran?——6. Between Sirius and Procyon?——7. Between Arcturus and Procyon?——8. Between Vega and Rastaben?——9. Between Sirius and Deneb?——10. Between Regel and Sirius?

DICTIONARY OF ASTRONOMICAL TERMS.

A.

Aberration, is an apparent motion of the celestial bodies, arising from the progressive motion of light, and the earth's annual motion in its orbit.

Absolute Equation, is the sum of the optic and eccentric equations.

Acceleration. The diurnal Acceleration of the Fixed Stars, is the time which the stars, in one diurnal revolution, anticipate the mean diurnal revolution of the sun; which is 3° 55′ 9″.

Acceleration of a Planet. A planet is said to be accelerated when its real diurnal motion exceeds its mean diurnal motion.

Acceleration of the Moon, is a term used to express the increase of the moon's mean motion from the sun, it being somewhat greater now than formerly.

Acherner, a star of the first magnitude, in the constellation Eridanus, right ascension, $22\frac{3}{4}$°, Dec. 58° 17′ S.

Achronycal, is said of a star, or planet, when it is opposite to the sun. A star *rises achronycally*, when it rises at sunset; and *sets achronycally* when it sets at sunrise.

Acubene, a star of the fourth magnitude, in the southern claw of Cancer, marked *a*.

Acteraimin, a star of the third magnitude, in the left shoulder of Cepheus, marked *a*.

Adhil, a star of the sixth magnitude, on the garment of Andromeda.

Aldebaran, a star of the first magnitude, in the sign Taurus. Right ascension 4 h. 25′ 35″. Dec. 16° 8′. This star frequently suffers an occultation by the moon, when the ascending node is in Virgo.

Aldhafera, a star of the third magnitude, in Leo.

Algenib, a star of the second magnitude, on the right side of Perseus.

Algol, or *Medusa's Head*, a variable star in the constellation Perseus.

Algorab, a star of the third magnitude, in the right wing of Corvus.

Allioth, a star of the third magnitude, in the tail of the Great Bear.

Almacantars, are circles of altitude, parallel to the horizon.

Almanac, a calendar, wherein the days of the month, festivals, lunation, motions of the heavenly bodies, eclipses, &c. are set down for each year.

Alpheratz, a star of the second magnitude, in the head of Andromeda.

Altitude of a Celestial Body, is the arc of a vertical circle, measured from the horizon.

Amphiscii, or *Amphiscians*, are the people who inhabit the torrid zone, so called because they have their shadows at noon, turned sometimes one way, and sometimes another, or north and south.

Amplitude, is an arc of the horizon intercepted between the east or west point, and the centre of the sun or star, at its rising or setting.

Analemma, is a projection of the sphere on the plane of the meridian made by straight lines and ellipses, the eye being supposed at an infinite distance, and in the east and west points of the horizon.

Andromeda, a northern constellation, containing, according to Flamstead, sixty-six stars.

Angle, is the inclination of two lines, or planes, meeting in a point, and may be any quantity less than 180°.

Angle of Commutation, is the angle at the sun, formed by two lines, one drawn from the earth, and the other from the place of the planet reduced to the ecliptic, meeting in the sun's centre.

Angle of Elongation, is the angle formed by two lines drawn from the earth, the one to the sun, and the other to the planet, or it is the difference between the sun's place and the geocentric place of the planet.

Angle of Evection, is an inequality in the motion of the moon, by which, at or near her quadratures, she is not in the line drawn through the centres of the earth and sun, as she is at the syzygies, but makes an angle with that line of about 2° 51′.

Angular Motion, is the motion of the planets about the centre of the sun, or it is that of the satellites about the centres of their primaries.

Annual, *yearly*, something that returns or ends with the year.

Annual Argument, is an arc of the ecliptic comprehended between the sun's place and that of the moon's apogee.

Annual Epact, is the excess of the solar year above the lunar, which is 10 d. 21 h. 11 m. or nearly 11 days, which shows that the moon changes so much sooner in any month of the subsequent year, than it did the year before.

Annual Equation, is the difference between the planet's mean and true place.

Anomalistical Year, is the time from the sun's leaving its apogee, till it returns to it again, which is 365 d. 6 h. 15 m.

Anomaly, is the distance of a planet in degrees, minutes, and seconds, from the aphelion or apogee.

Anse, or *Anses*, signify the seemingly prominent parts of the ring of Saturn, which are seen at its opening.

Antarctic Circle, is a small circle parallel to the equator, and 23° 28′ from the south pole.

Antarctic Pole, is the south pole, or the southern extremity of the earth's axis.

Antares, the Scorpion's heart, a star of the first magnitude, in the constellation Scorpio.

Antecedentia, a term made use of to signify that a planet moves retrograde, or contrary to the order of the signs, that is, from east to west.

Antieci, or *Antecians*, are those who live under the same meridian, and at the same distance from the equator, but one having north, and the other south latitude.

Antipodes, are the people of two places diametrically opposite to each other; they differ in longitude 180°, and one has the same latitude north, as the other has south.

Aphelion, is that point in the orbit of the earth or planet, which is at the greatest distance from the sun.

Apogee, is that point in the moon's orbit, which is farthest from the earth.

Apparent, that which is visible or evident to the eye.

Apparent conjunction of the planets, is when they have the same geocentric longitude. The apparent conjunction of the moon with any of the heavenly bodies, is their conjunction as seen from the surface of the earth.

Apparent diameter of the heavenly bodies, is their angular diameter, as seen from the earth, measured with a micrometer.

Apparent distance of two celestial bodies, is their angular distance as seen from the earth. *Apparent* horizon is that circle which limits our sight, and has its plane parallel to the true horizon, passing through the centre of the earth.

Apparent Place and *Time*. See Place and Time.

Appulse, means the near approach of two celestial bodies to each other in angular distance, so as to be seen, for instance, within the field of a telescope.

Apses, or *Apsides*, are the two points in the orbits of the planets, or satellites, which at the greatest and least distance from the centre of motion. And a line joining these two points is called the line of the apses.

Apus, a constellation in the southern hemisphere, containing eleven stars.

Aquarius, one of the zodiacal constellations, containing one hundred and eight stars.

Aquila, *the eagle*, a northern constellation containing (with Antinous) seventy-one stars.

Ara, *the altar*, a southern constellation, containing nine stars.

Arc, is a part of a curve line, or circle; for example, the latitude and declination are arcs of the meridian, and longitude is the arc of the equator or parallel circle.

Arc of Direction, is that arc which a planet appears to describe when its motion is direct or progressive.

Arc of Retrogradation, is that which a planet describes whilst moving contrary to the order of the sign, or from east to west.

Arctic Circle. A small circle surrounding the north or arctic pole, and distant from it 23° 28′; it passes through the north pole of the ecliptic; this and the *Antarctic Circle*, are called *Polar Circles*.

Arcturus, a star of the first magnitude in the constellation Boötes.

Argo Navis, a southern constellation, containing sixty-four stars.

Argument, is an arc given, by which another may be found in some proportion to it.

Argument of Latitude, is an arc of the orbit of a planet, intercepted between the ascending node, and the place of the planet from the sun, according to the order of the signs.

Aries, the Ram, one of the northern constellations of the zodiac; it contains sixty-six stars.

Arietis, a star of the second magnitude, in the head of the Ram.

Armillary Sphere. A name given to an artificial sphere, representing the several circles of the system of the world.

Ascending, a term denoting any star, degree, or any point of the heavens, rising above the horizon.

Ascending Latitude, is the latitude of the moon or planet when going northward.

Ascending Node, is that point of a planet's orbit, where it cuts the ecliptic in going northward; it is marked ☊.

Ascension. See Oblique and Right.

Ascensional Difference, is the difference between the right and oblique ascension, or descension; or it is the interval of time the sun rises or sets, before or after six o'clock.

Ascii, are the inhabitants of the torrid zone, who at certain times of the year have no shadow.

Aspect, is the situation of the stars or planets with respect to each other. There are reckoned five aspects, viz. *Conjunction*, ☌; *Sextile* ⚹; *Quartile*, □; *Trine*, △; *Opposition*, ☍. A☌ $=0^\circ=0^s$, *a*⚹ $=60^\circ=2^s$, *a*□ $=90^\circ=3^s$, *a*△ $=120^\circ=4^s$, and ☍ $=180^\circ=6^s$.

Astrolabe, signifies a stereographic projection of the sphere upon the plane of one of the great circles. The *Sea Astrolabe*, is an instrument used for the altitude of the sun and stars.

Astrology, a pretended art of foretelling future events by the aspects and positions of the stars.

Astronomy, from *Aster*, a star, and *Nomos*, a law, is the science by which we are taught the motions, magnitudes, distances, &c. of the heavenly bodies.

Astrocope, an astronomical instrument, invented by W. Shuckhard.

Atair, a star of the first magnitude, in the constellation Aquila.

Atmosphere, is that elastic invisible fluid which surrounds the globe, and causes the refraction and twilight.

Attraction, according to the Newtonian philosophy, is that innate principle of matter, by which bodies mutually tend towards each other.

Auriga, the Waggoner, a northern constellation containing 66 stars.

Aurora, the morning twilight. See Twilight.

Aurora Borealis, or *Northern Lights*, a kind of meteor of a pale colour, sometimes seen in the northern parts of the heavens, supposed to be an electrical phenomenon.

Austral, southern. The six signs of the zodiac, which are south of the equinoctial, are called *Austral signs.*

Autumn, the third quarter of the year, which begins when the sun enters *Libra*, that is, about the 21st or 22d of September, when it is equal day and night.

Autumnal Equinox, is the time when the sun enters Libra, or the descending point of the ecliptic, called also the *Autumnal point.* The signs *Libra*, *Scorpio*, and *Sagittarius*, are called autumnal signs.

Axis of the World, is an imaginary line passing through the centre of the earth, and extending both ways to the sphere of the fixed stars, around which they appear to perform their diurnal revolutions, by the motion of the earth upon this axis.

Axis of the Circles of the Sphere, are right lines supposed to be drawn through their centres, perpendicular to their planes.

Azimuth, of the celestial bodies, is an arc of the horizon intercepted between the meridian and a vertical circle passing through the body.

Azimuth Compass, an instrument for finding the magnetic azimuth, or amplitude of a celestial body.

B.

B, in the astronomical tables, stands for Bissextile, or Leap Year.

Back Staff, an instrument invented by Captain John Davis, a Welchman, about the year 1590; it was used for taking the sun's altitude at sea.

Barometer, an instrument for showing the gravity of the atmosphere; it is commonly used for foretelling the changes of the weather; but is useful for ascertaining the altitude of mountains, and for correcting the variation of the refraction arising from the changes in the density of the atmosphere.

Bear, the name of two constellations near the north pole. See Ursa Major and Minor.

Beard of a Comet, are the rays which it emits from its head in the direction of its motion.

Bellatrix, a star of the second magnitude in the left shoulder of Orion.

Binocle, or *Binocular Telescope*, a telescope by which the object can be viewed with both eyes at the same time.

Bissextile, or *Leap Year*, is a year consisting of 366 days, which happens every fourth year. The reason for adding a day every fourth year, is because the *tropical* year exceeds the *civil* year six hours. To find *Leap Year*, divide the year by four, and if nothing remains, it is Leap Year. For instance, 1818 divided by 4, gives the quotient 454, and the remainder is two, which shows that the year 1818 is the second after Bissextile or Leap Year, and that 1820 will be Leap Year.

Boötes, a northern constellation, containing fifty four stars.

Boreal Signs, are those on the north side of the equinoctial, viz. Aries, Taurus, Gemini, Cancer, Leo, and Virgo.

C.

Calendar. See Almanac. There are a great many different calendars, adapted to the various uses of common life, viz. the *Roman calendar*, the *Gregorian calendar*, the *Julian*, the *Reformed*, and the *French new calendar*, &c.

Cancer, *the Crab*, one of the constellations of the zodiac; when the sun enters this sign it has the greatest declination northward; it contains eighty-three stars.

Canis Major, or the *Great Dog*, is a southern constellation, that contains Sirius, one of the brightest fixed stars in the heavens; the number of stars in this constellation is thirty-one.

Canis Minor, the *Little Dog*, a northern constellation consisting of fourteen stars.

Canopus, a star of the first magnitude, in the rudder of Argo, the ship; its right ascension is 95° and dec. 52° 36′ south, and therefore is not visible in the latitude of London.

Capella, or *the Goat*, a bright star of the first magnitude, in the left shoulder of Auriga; right ascension 75° 49′, declination 45° 48′.

Cardinal Points, are the north, south, east, and west points of the horizon.

Cardinal Signs, are Aries, Cancer, Libra, and Capricorn. The beginning of these signs are in the Cardinal points of the ecliptic.

Cassiopeia, a northern constellation, consisting of fifty-five stars.

Castor, the name of a star of the first magnitude, in the constellation Gemini.

Catalogue of the Stars, is a table of the fixed stars, arranged according to their right ascensions, or longitudes, with their declinations, or latitudes, together with their annual variations and magnitudes.

Cauda Capricorni. See Dineb Algedi.

Cauda Ceti. See Dineb Haetos.

Cauda Cygni. See Dineb Adigege.

Cauda Delphini, a star of the third magnitude on the tail of the Dolphin, marked E.

Cauda Draconis, *the Dragon's tail*. The moon's descending node. See Descending Node.

Cauda Leonis, sometimes called *Lucida Cauda*. See Dineb Eleced.

Cauda Ursæ Majoris, a star of the third magnitude, near the end of the Great Bear's tail, called also *Benenath*.

Cauda Ursæ Minoris. See Pole Star.

Centaurus, one of the southern constellations, which contains thirty-five stars.

Centrifugal Force, is that force by which all bodies moving about a central body, or force, endeavour to fly off in tangent lines.

Centripetal Force, is that by which a body moving round another, tends towards it; this, and the centrifugal force acting upon the planets, cause them to describe curvilinear orbits about the sun.

Ceres, or *Piazzi*, a primary planet moving between the orbits of Mars and Jupiter; it was discovered on the 1st of January, 1801, by M. Piazzi.

Cetus, *the Whale*, a southern constellation, containing ninety-seven stars.

Characters, are certain marks used in this science, as abbreviations. The astronomical characters are the following: *The twelve signs of the zodiac*, are ♈ Aries, the Ram; ♉ Taurus, the Bull; ♊ Gemini, the Twins; ♋ Cancer, the Crab; ♌ Leo, the

Lion; ♍ Virgo, the Virgin; ♎ Libra, the Balance; ♏ Scorpio, the Scorpion; ♐ Sagittarius, the Archer; ♑ Capricornus, the Goat; ♒ Aquarius, the Water bearer; ♓ Pisces, the Fishes. *The Planets.* ☉ The sun; ☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; ⚶ Vesta; ⚵ Juno; ⚳ Ceres; ⚴ Pallas; ♃ Jupiter; ♄ Saturn; ♅ Uranus. *The Aspects.* ☌ Conjunction; ⚹ Sextile; □ Quartile; △ Trine; ☍ Opposition. *The Nodes.* ☊ Ascending node; ☋ Descending node. *Motion* and *Time.* ° Degree; ′ minute; ″ seconds: h hour; m minute; s second; A. M. Ante Meridian, or before noon; P. M. Post Meridian, or afternoon. Sometimes M. is put for morning, and A. for afternoon.

Charles's Wain, seven conspicuous stars in Ursa Major, or the Great Bear.

Chronometer, an instrument contrived for the purpose of measuring small portions of time; or watches used for finding the longitude, are generally called by this name, or Time-keepers.

Circle, a plane figure, bounded by a curve, equally distant from a point called the centre; and all lines drawn from this point to the circumference, are equal.

Circles of the Sphere, are those whose planes pass through the sphere, and have their circumference upon its surface. If the plane pass through the centre of the sphere, it is called a great circle, if not, it is called a less circle. The equator and ecliptic are great circles: the polar circles and the parallels of latitude or declination, are small circles.

Circles of Altitude. See Vertical Circles.

Circles of Declination, are great circles perpendicular to the equinoctial.

Circle of Illumination, is that imaginary circle which divides the enlightened hemisphere of the earth from the darkened.

Circles of Latitude, or *secondaries to the ecliptic*, are great circles perpendicular to the ecliptic, and intersecting in its poles.

Circles of Longitude. See Longitude.

Circles of perpetual Apparition, are small circles parallel to the equator, and touching the horizon of any given place.

Circles of perpetual Occultation, are also small circles parallel to the equator, and touching the lower part of the horizon, or never appearing above it.

Circles of Position, are great circles of the sphere, passing through the common intersection of the meridian and horizon, and through any degree of the ecliptic, or centre of a star or planet.

Circular Velocity, is the velocity of a revolving body, measured by an arc of a circle.

Circumpolar Stars, are such as revolve round the pole, without setting in a given latitude.

Civil Day, the time allotted for day in civil purposes; it begins differently in different nations; it is divided into twenty-four hours.

Civil Month, is the same as given in the common almanacs.

Civil Year, is that which is appointed by any government, to be used within its own dominions.

Clock, a well known machine for measuring time, regulated by the uniform motion of a pendulum. Common clocks are made to show mean solar time, but those used at observatories, for the purpose of observing the time of the stars transiting the meridian, show sidereal time.

Columba Noashi, Noah's dove, a small constellation in the southern hemisphere, consisting of ten stars.

Colures, are two great circles, which intersect each other at right angles, in the poles of the world, dividing the ecliptic into four equal parts, denoting the four seasons of the year; the one passing through Aries and Libra, is the Equinoctial Colure; and the other, passing through Cancer and Capricorn, the Solstitial Colure.

Coma Berenices, or *Berenice's Hair*, a northern constellation, consisting of forty-three stars.

Comet, a celestial body, frequently called a blazing star, moving in a very eccentric orbit, having a vapour-like appendage. The comet moves in the planetary regions, appearing and disappearing at very uncertain intervals of time.

Cometarium, a machine showing the motion of a comet about the sun.

Commutation. See Angle of Commutation.

Complement of an Arc or an Angle, is what it wants of 90°; thus we say, the complement of altitude or coaltitude, which is the zenith distance; the complement of latitude or declination, which is the polar distance.

Conjunction of two celestial bodies, is when they have the same degree of longitude. See Apparent and True Conjunction.

Consequentia, in astronomy, is when the planets move according to the order of the signs.

Constellation, is a number of stars contained within some assumed figure, as a Lion, an Eagle, a Bear, &c.

Cor Caroli, an extra constellated star of the second magnitude, its right ascension and declination at the beginning of 1818, was right ascension 191° 52½′ declination 39° 18½′ N.

Cor Hydræ, the heart of Hydra. A star of the second magnitude in the constellation Hydra.

Cor Leonis, or *Regulus*. A star of the first magnitude in the constellation Leo.

Cor Scorpionis. See Antares.

Corona Borealis, the *Northern Crown*, a constellation containing 21 stars.

Corona Meridionalis, the *Southern Crown.* This constellation contains 12 stars.

Corvus, the Raven, a constellation in the southern hemisphere, containing nine stars.

Cosmical Rising and Setting, is when a star rises or sets at the time of sunrise.

Cosmography, a description of the world, showing the structure of the heavens, with the disposition of the stars, and parts of the earth.

Crater, the Cup, a southern constellation consisting of thirty-one stars.

Crepesculum. See Twilight.

Culmination, the transit or passage of a star over the meridian.

Curtate Distance of a planet from the earth or sun, is the distance of the earth or sun from that point where a perpendicular passing the planet cuts the ecliptic.

Cycle, a certain period of time, in which the same revolutions begin again, a periodical space of time.

Cycle of Indiction, or Roman Indiction. This cycle has no connection with the celestial motions; it is a period of 15 years. To find this cycle, add three to the given year, and divide the sum by fifteen, and what remains is the indiction.

Cycle of the moon, or the *Lunar Cycle*, is a period of nineteen years, in which the new and full moons return on the same days as they did nineteen years before; this cycle is called the *Golden Number*, for the finding of which, see Golden Number.

Cycle of the Sun, is a period of 28 years, in which time the days of the month return again to the same days of the week, &c. See Solar Cycle.

Cygnus, the Swan, a constellation of the northern hemisphere, containing eighty-one stars.

D.

Day, is that portion of time from the appearance of the sun, to its disappearance; this is called an artificial day.

Day, Astronomical. The Astronomical day begins at apparent noon, and is counted twenty-four hours to the following noon.

Day, Civil. See Civil day.

Day, Natural; the natural day is either *Astronomical* or *Civil.* See these articles.

Day, Siderial. See Siderial day.

Dechotomized. See Quadratures.

Declination, is the distance of the sun, moon, or stars from the equinoctial, either north or south.

Declination Circles, or *Circles of Declination*, are great circles perpendicular to the equinoctial, and passing through its poles.

Degree, the 360th part of a circle, or the 30th part of a sign.

Delphinus, the Dolphin, a northern constellation, containing 18 stars.

Deneb, the Arabic term for tail; the name of several fixed stars. See *Cor.*

Depression of the Poles, is to advance towards the equator.

Depression of the Sun or Star, is its vertical distance below the horizon.

Descending Node, is that point of a planet's orbit, where it cuts the ecliptic, proceeding southward, marked ☋.

Descension. See Oblique and Right.

Dial. An instrument to show the hour of the day by the sun.

Digit, the twelfth part of the sun or moon's diameter, and is used to show the degree of obscuration in an eclipse.

Direct. See Consequentia.

Disc, is the face of the sun, or moon, as it appears to the eye.

Disc of the Earth, is the difference between the horizontal parallax of the sun and moon; and is used in the construction of solar eclipses.

Distance of the Sun, Moon, and Planets, is the real distances of any of these as found by their parallaxes.

Diurnal, of or belonging to the day.

Diurnal Arc, is the arc described by the celestial bodies from their rising to their setting.

Diurnal Motion, is the degrees, minutes, or seconds, a celestial body describes in twenty-four hours.

Diurnal Motion of the Earth, is its rotation on its axis.

Dog. See Canis Major and Canis Minor.

Dominical Letter, one of the first seven letters of the alphabet, wherewith the Sundays are marked in the almanacs with a red letter throughout the year. To find the Sunday letter for any year, for instance, 1820; $20\times\frac{20}{4}\times2=27$, this ÷ by 7=3 six-sevenths, and 7—6=1, which is A; as 1820 is leap year, this will be the Sunday letter from the end of February, to the end of the year; but from the beginning of the year to the end of February, the dominical will be B, so that the Sunday letters for 1820, are B and A.

Draco, the Dragon, a northern constellation, containing, or consisting of, eighty stars.

Dubhe, or *α Ursa Major*, a star between the first and second magnitude, the most northern of the pointers.

E.

Earth, or *Terra*, one of the planets; its orbit lies between Venus and Mars. Its diameter is 7914 miles, and observation proves it to be inhabited.

East, one of the cardinal points, being that on which the sun rises at equinoxes.

Eclipse, a privation of light of the sun or moon, by the interposition of some opaque body.

Ecliptic, a great circle of the sphere, or orbit of the earth; it is inclined to the equator, or equinoctial, at an angle of about 23° 28′. The sun appears to describe this circle in the heavens every year.

Elements, in Astronomy, are those principles deduced from observation, by which tables of the planetary motions are computed.

Elevation of the pole or star, is the height of the pole or stars in degrees above the horizon.

Elongation. See Angle of Elongation.

Emersion, is the reappearance of a celestial body after having been eclipsed; when a satellite reappears after having been eclipsed by the shadow of the planet, it is called the emersion.

Epact. See Annual and Menstrual Epacts.

Ephemeris, tables containing the computations of the places of the heavenly bodies for every day at noon.

Epoch, the same as Era, which see.

Equation of the Centre. See Annual Equation.

Equation of the Moon's mean Motion, depends upon the situation of the moon's apogee and nodes with respect to the sun.

Equation of Time, is the difference between apparent and mean time, or between the sun's mean motion and right ascension.

Equatoral, a very useful instrument in Astronomy, for taking the altitude, azimuth, right ascension, &c. of the heavenly bodies.

Equinoctial, in the heavens, or equator on the earth, is one of the great circles of the sphere, whose poles are the poles of the world.

Equinoctial Colures. See Colures.

Equinoctial Points, are *Aries* and *Libra*, and when the sun enters either of these points it is called the equinox.

Era, or *Epoch*, means a fixed point of time from which to begin the computation of the ensuing years.

Eridanus, the river, a southern constellation, consisting of eighty-four stars.

Evection. See Angle of Evection.

Eccentric. See Annual Equation, and Anomaly.

Eccentricity, is the distance of the centre from the foci of the elliptical orbit of the planet.

F.

Facule, are certain bright spots, frequently seen upon the disc of the sun.

Falcated. The moon or a planet is said to be falcated, when the enlightened part appears of a crescent form like the Moon or Venus, when near the sun.

Fixed Signs of the Zodiac, are Taurus, Leo, Scorpio, and Aquarius; they are so called because the season is considered to be more settled when the sun passes through these signs, than at any other times of the year.

Fixed Stars, are such as do not appear to change their relative situations. They are properly called stars, in contradistinction to planets and comets.

Fomahaut, a fixed star of the first magnitude, in the mouth of the southern fish.

Fore Staff, an instrument used at sea for raking the altitudes of the celestial bodies. It is now superseded by the use of more perfect instruments.

G.

Galaxy, is that whitish track which appears to encompass the heavens; it is very visible of a bright night, when the moon is absent. Dr. Herschel found it to consist of innumerable small stars and nebulous matter.

Gemma, α Corona Borealis, or *Alphacea*, a star of the second magnitude in the Northern Crown.

Gemini, a zodiacal constellation in the northern hemisphere, containing eighty-five stars.

Geocentric Place of a planet, is its place as seen from the earth.

Geocentric Latitude of a planet, is its perpendicular distance from the ecliptic as seen from the earth.

Geocentric Longitude of a planet, is its elliptical distance from the first point of Aries, as seen from the earth.

Gibbous, is a term used for the figure of the enlightened parts of the moon, from the time of the first quarter to the full, and from that of the full to the last quarter.

Gnomon, an apparatus used by the ancients for finding the altitudes and declinations of the celestial bodies.

Golden Number, or *Cycle of the Moon*, which see. To find the Golden Number for any year, for example, 1819: First, 1819+1=1820; this divided by 19, gives 95, and 15 for the remainder, which is the Golden Number, as required.

Gravitation, or *Gravity*. See Attraction.

Great Bear, a northern constellation. See Ursa Major.

Great Circles. See Circles of the Sphere.

Gregorian Calendar, is the reformed calendar now in use, which takes its name from Pope Gregory the XIIIth.

Gregorian Epoch, is the time when the Gregorian computation first took place, which was in the year 1582.

Gregorian Telescope, is a reflecting telescope, having a hole in the centre of the great speculum, through which the image is thrown by the small reflector to the eye. The distinctness of the object seen through this telescope is somewhat diminished by the hole in the great speculum.

Gregorian Year, the year now in use, called the new style; it consists of 365 days for three years, and 366 every fourth year, the same as the Julian account; but as this exceeds the tropical year by about eleven minutes and one twentieth, and which in Pope Gregory's time amounted to ten days, he ordered so many days to be struck out of the calendar; and to prevent the like anticipation in future, it was ordered that every century not divisible by four, to be reckoned common years, which in the Julian account are bissextile.

H.

Halo, a very conspicuous circle of about 45 degrees in diameter, surrounding the sun or moon, supposed to arise from the refraction of light in passing through the thin vapours of the atmosphere; they are most commonly visible in stormy weather.

Heaven, is the infinite expanse in which the stars, planets, and comets, are situated, or perform their respective revolutions.

Heliacal rising and setting of a Star, is, properly, when it rises or sets with the sun. Or a star is said to rise heliacally when it is first seen after conjunction with the sun, and to set heliacally when it is so near the sun as to be hid by his beams.

Heliocentric place of a planet, is its latitude and longitude, or place in the heavens, as seen from the sun. The heliocentric motion of a planet is always direct, the sun being its centre of motion.

Heliometer, a kind of micrometer for measuring the diameter of the sun, moon, and stars.

Hemisphere, is the half of a globe or sphere divided by a plane passing through its centre. The equator or equinoctial divides the sphere into two equal parts, called the northern and southern hemispheres.

Hercules, a northern constellation, containing one hundred and thirteen stars.

Heterocii, are the inhabitants of the two temperate zones, whose shadows at noon are always projected the same way with regard to themselves, or always contrary ways with respect to each other.

Horizon, is a great circle of the sphere, dividing the heaven and the earth into two equal parts, called the upper and lower hemisphere. See Apparent.

Horizontal, something relating to, or parallel to the horizon.

Horizontal Parallax, is the parallax of a celestial body, when in the horizon. See Parallax.

Hour, is the 24th part of a natural day, answering to 15° of the equator.

Hydra, a constellation of the southern hemisphere, containing 60 stars.

I.

Immersion, in an eclipse, is the beginning; the term is frequently used in reference to Jupiter's satellites; when the satellite enters the shadow of the planet, it is called the immersion. When a star or planet is so near the sun that it cannot be seen, it is called an immersion.

Inclination of the orbit of a planet, is the angle which the plane of the planet's orbit makes with the plane of the ecliptic, or earth's orbit.

Indiction. See Cycle of Indiction.

Informed Stars, are such as were formerly not included in constellations; but modern astronomers have contrived to include all the unformed stars.

Ingress, is the sun's entering any of the twelve signs, or other parts of the ecliptic.

J.

Julian Year, is the year establised by Julius Cæsar, now called the old style. See Gregorian Year.

Juno, or *Harding Planet*, one of the newly discovered planets, and the sixth in order from the sun; it was first discovered in 1804.

Jupiter, one of the superior planets, the largest in the solar system; its diameter is 91,000 miles.

L.

Latitude, in geography, is the height of the pole; or it is an arc of the meridian, intercepted between the zenith and the equator, and is north or south, according as the place is on the north or south side of the equator.

Latitude of the Moon, is her perpendicular distance from the plane of the ecliptic; and it is north latitude, when she is on the north side of the ecliptic, and south latitude when on the south side. It is *north ascending*, from the ascending node, to her northern limit; and *north descending*, from the northern limit to the descending node. It is *south ascending*, from her southern limit to the ascending node; and *south descending*, from the descending node to her southern limit. And the like is to be understood of the planets.

Leap Year. See Bissextile.

Leo, the Lion, a northern and zodaical constellation, containing ninety-five stars.

Leo Minor, or *Little Lion*, a modern constellation, in the northern hemisphere, containing fifty-three stars.

Lepus, the Hare, a southern constellation, containing nineteen stars.

Libra, the Balance, or Scales, a zodaical constellation, containing fifty-one stars.

Librations of the Moon, are periodical irregularities in her motion, by which the same face is not always turned towards the earth.

Limit of a Planet, signifies its greatest heliocentric latitude.

Longitude of a celestial Body, is the distance of that point of the ecliptic, cut by a secondary to it, passing through the body from the beginning of Areis.

Lunar Distance, is a term used in nautical astronomy, for the distance of the moon from the sun, or fixed stars; the measurement of which, whereby the true distance can be computed, is found to be of the greatest use in determining the longitude.

Lupus, the Wolf, a constellation in the southern hemisphere, containing twenty-four stars.

Lynx, a modern constellation in the northern hemisphere, of forty-four stars.

Lyra, the Harp, a northern constellation, containing twenty-one stars.

M.

Maculæ, are dark spots that are frequently seen upon the disc of the sun.

Magnitudes. The fixed stars, according to their size or brightness, are divided into magnitudes; the brightest are called stars of the first magnitude; the next in brightness, stars of the second magnitude; and so on to the sixth or seventh magnitudes, which are the smallest that can be seen with the naked eye.

Marcab, or *α Pegasus*, a fixed star of the second magnitude, near the wing of Pegasus.

Mars, a superior planet, and fourth in order from the sun.

Mean Anomaly of a planet, is its angular distance from the aphelion or perihelion, supposing it to revolve in a circle with its mean velocity.

Mean Conjunction of the Sun and Moon, is the conjunction of their mean longitudes.

Mean Distance of a planet, is the semi-transverse diameter of its orbit.

Menknar, or *α Cetus*, a star of the second magnitude, in the head of the Whale.

Mercury, an inferior planet, the nearest to the sun.

Meridian, a great circle of the sphere, passing through the poles of the world.

Micrometer, is an instrument fitted to a telescope, for the purpose of measuring small angles, such as the diameters of the celestial bodies.

Mid-Heaven, called also *Medium Cœli*, is that point or degree of the ecliptic, which is upon the meridian at any time.

Milky Way. See Galaxy.

Minute, the 60th part of a degree, or of an hour.

Mirach, or *β*, *Andromeda*, a star of the second magnitude, in the constellation Andromeda.

Monoceros or the *Unicorn*, a northern constellation, consisting of thirty-one stars.

Month, the 12th part of a year. A *lunar month* is the time the moon takes to describe the whole circle of the ecliptic, and is $27^d\ 7^h\ 43^m$. A *synodic month*, is the time between two conjunctions of the sun and moon, and is $29^d\ 12^h\ 44^m\ 3^s$. A *solar month* is the mean time of the sun's passing through one entire sign of the ecliptic, which is about $30^d\ 10^h\ 29^m$.

Moon, the satellite of *Terra*, and which is nearest to the earth of all the heavenly bodies.

Mutual Aspects, are such as the primary planets make among themselves.

N.

Nadir, is that point in the heavens directly under our feet.

Napoleon, a name given to the constellation Orion.

Nebulæ, is a term applied to those telescopic stars that have a cloudy appearance.

Nocturnal Arc, is that arc described by a celestial body during the night.

Nodes, are the two opposite points where a planet's orbit cuts the ecliptic.

Nonagisimal Degree, is the highest point of the ecliptic above the horizon, and is equal to the angle which the ecliptic makes with the horizon. It is of great use in calculation of eclipses.

North, one of the cardinal points on the compass; that opposite the south.

Number of Direction, is a number not exceeding thirty-five, which number is the limit of Easter day, always falling between the 21st of March and 25th of April.

Nutation of the Earth's Axis, is a kind of vibratory motion, by which its inclination to the plane of the ecliptic is subject to a small variation.

O.

Oblique Ascension, is that point of the equinoctial which rises with a celestial body in an oblique sphere.

Oblique Descension, is that point of the equinoctial which sets with a celestial body in an oblique sphere.

Oblique Sphere, is that position of the sphere in which the equator and its parallels cut the horizon obliquely.

Observatory, a place or building fitted up with proper instruments for observing the celestial bodies.

Occidental, westerly. A planet is said to be occident when it sets after the sun.

Occultation, is the obscuration of a star or planet by the interposition of the moon.

Opposition, is that aspect of the celestial bodies when they are 180° from each other.

Orbus Magnus, a term formerly used to signify the orbit of the earth.

Orbit, is the curvilinear tract in which the planets perform their respective revolutions round the sun.

Oriental, easterly. A planet is said to be oriental, when it rises before the sun.

Orion, a constellation situated upon the equinoctial, containing seventy-eight stars.

Orrery, a machine for exhibiting the various motions of the planetary bodies. It is more properly called a *Planetarium*.

Ortive Amplitude, is the eastern amplitude of a heavenly body.

P.

Pallas, or *Olbers*, one of the newly-discovered planets, and the eighth in order from the sun.

Parallax, is the angle formed at the centre of a star by two lines, one drawn from the centre, and the other from the surface of the earth.

Parallax, in altitude, is the difference between the true and apparent altitude of the body; or the difference between the altitude at the surface and centre of the earth.

Parallax Horizontal. See Horizontal Parallax. As the altitude of a body is affected by parallax, so is its right ascension, declination, latitude, and longitude.

Parallel Sphere, is that position of the sphere in which the equator is parallel to the horizon.

Parallels of Altitude, are small circles parallel to the horizon.

Parallels of Declination, or *Parallels of Latitude*, are small circles parallel to the equinoctial or equator.

Parhelion, a mock sun.

Pegasus, a northern constellation, containing eighty-nine stars.

Penumbra, is a faint shade surrounding the perfect shadow, in an eclipse.

Perigee, is that point of the moon's orbit which is nearest to the earth.

Perihelion, is that point of a planet's orbit which is nearest to the sun.

Periœci, are those who live under the same parallel of latitude, whether north or south, but on opposite meridians.

Periscii, are the inhabitants (if any) that live within the polar circles.

Perseus, a northern constellation, containing fifty-nine stars.

Phases, are the different appearances of the enlightened parts of the Moon, Venus, and Mercury.

Phenomenon, any singular appearance in the heavens, as an eclipse, comet, &c.

Phœnix, a southern constellation, containing thirteen stars.

Pisces, the last of the zodiacal signs, which contains 113 stars.

Place of a Celestial Body, is simply its situation in the heavens, and is usually expressed by its latitude and longitude.

Planet, is a celestial body revolving about the sun. The planets may be known from the fixed stars, by their change of situation in the heavens.

Pleiades, or *Seven Stars*, a cluster of stars on the neck of the Bull.

Poles, are the extremities of the axis of the world; one called the north, and the other the south pole.

Pollux, one of the twins, also the name of a star of the second magnitude, in the constellation Gemini.

Precession of the Equinoxes. This is a very slow motion of the equinoctial points in *antecedentia* or from east to west; this motion is about 50″ in a year.

Primary Planets, are those that have the sun for their centre of motion.

Procyon, or α *Canis Minor*, a star of the first magnitude in the constellation Canis Minor.

Q.

Quadrant, the fourth part of a circle, or 90°. Also an instrument, variously constructed, for the purpose of taking the altitude and angular distances of the heavenly bodies.

Quadrature, is that position of the moon when she is 90 degrees from the sun.

Quartile, Aspect. See Aspect.

R.

Radius Vector, is that imaginary line connecting the planet and sun, and which, as the planet moves round the sun, describes equal areas in equal times.

Reduction, is the difference between the planet's orbit, place, or argument of latitude, and ecliptic place.

Ras-algethi, α *Hercules.*

Ras-alhague, α *Ophinchus.*

Rastaban, γ *Draco.*

Refraction, is the bending of the rays of light, in passing through the atmosphere, thereby causing the heavenly bodies to be more elevated above the horizon, than they really are.

Regulus. See Cor Leonis.

Reticula, an instrument invented for ascertaining the quantity of an eclipse.

Retrograde. See Antecedentia.

Revolution, is the period of any celestial body.

Rigel, a star of the first magnitude, on the left foot of Orion.

Right Ascension, is that point of the equinoctial which comes to the meridian with any celestial body, and is reckoned from the first point of Aries. The degree of the equinoctial, that rises with any celestial body in a right sphere, is called its *right ascension*, and the degree of the equator which sets with any celestial body in the said sphere, is called its *right descension*.

Right Sphere, is that on which the equator and its parallels, cut the horizon at right angles.

Rising of a Celestial Body, is its appearance above the eastern horizon.

Rotation. See Revolution.

S.

Sagitta, the Arrow, a northern constellation, containing eighteen stars.

Sagittarius, the Archer, one of the zodiacal constellations, containing sixty-nine stars.

Saros, called also the *Chaldean Saros*, is a period of 223 lunations, in which the same eclipse returns again, within an hour or two, but not with the same degree of obscuration.

Satellites, or *Secondary Planets*, are those celestial bodies that revolve round some primary planet; the moon, is a secondary planet, as are those small stars that accompany Jupiter, Saturn, and Herschel.

Saturn, one of the superior planets, and was formerly considered the most distant in the solar system; it is the tenth in order from the sun.

Scheat, or *β Pegasus*, a star of the second magnitude in the constellation Pegasus.

Scorpio, the Scorpion, a zodiacal constellation, containing 44 stars.

Seasons, are the four quarters of the year, viz. Spring, Summer, Autumn, and Winter. The first quarter begins when the sun enters Aries; the second, begins when the sun enters Cancer; the third, when he enters Libra; and and the 4th, when he enters Capricorn.

Second, the 60th part of a minute, either of time or of motion.

Secondary Circles, or *Secondaries*, are all those circles which intersect one of the six great circles of the sphere, at right angles.

Secondary Planets. See Satellites.

Serpens, a northern constellation, called the Serpent of Ophinchus; it contains sixty-four stars.

Serpentarius, a northern constellation, containing seventy-four stars.

Setting, is the going down, or disappearance of a celestial body, in the western horizon.

Sextant, the sixth part of a circle; or the name of an astronomical instrument, used for the same purpose as a quadrant.

Sextile, Aspect. See Aspect.

Sidereal day, is the time in which a star appears to revolve from any meridian to the same again, which is equal to the time of the earth's performing one entire revolution upon its axis, $23^h\ 56^m\ 4{\cdot}1^s$, of mean solar time.

Sidereal Year, is the time in which the earth or sun makes one complete revolution in its orbit: that is, from any given star to the same again.

Sign, is the 12th part of the zodiac, or ecliptic, which contains 30 degrees.

Sirius, the Dog-Star, one of the brightest stars in the heavens; in the constellation Canis Major.

Solar Year, is of two kinds, Tropical and Sidereal, which see.

Solstices, is the time when the sun enters the tropical points, Cancer and Capricorn.

Solstitial Points, are Cancer and Capricorn.

South, one of the four cardinal points of the compass; when the sun is on the meridian, in northern latitudes, it is then directly south.

Sphere, Armillary. See Armillary Sphere, Oblique, and Right Sphere.

Spica, a star of the first magnitude, in the constellation Virgo.

Stars. See Planet and Fixed Stars.

Stationary. A planet is said to be stationary, when it appears to have no motion among the fixed stars.

Summer. See Seasons.

Sun, or *Sol*, the great and central luminary of the planetary system.

Syzygy, means either the conjunction or opposition of a planet with the sun.

T.

Taurus, the Bull, a zodiacal sign, containing 141 stars.

Telescope, a most useful optical instrument, of which there are two kinds, the reflecting and refracting, the latter of which is best for observing the heavenly bodies.

Telescopical Stars, are those stars which are not visible to the naked eye, and can be only seen with a telescope.

Terminator. See Circle of Illumination.

Thermometer, an instrument showing the degrees of heat and cold. It is used conjointly with the barometer, for correcting the variation in the refraction, from the change of temperature and specific gravity of the atmosphere.

Tides, the periodical flux and reflux of the waters of the sea, supposed to be caused by the action of the sun and moon upon the ocean.

Time, is a certain measure of duration, depending upon the motion of the heavenly bodies.

Transit, is the passing of a planet, just before or over the disc of another star or planet, as the passing of Mercury or Venus over the sun's disc, is called a transit; the same is said of a planet or star when it passes the meridian.

Tropics, are two lesser circles of the sphere parallel to the equinoctial, and 23° 28′ distant from it, being the limits of the sun's greatest declination north and south.

True Place of a Planet. See Heliocentric Place.

Twilight, is that partial light which is observed in the morning before sunrise, and in the evening, for a short time after he is set, which is caused by the refraction and reflection of the rays of light in passing through the at mosphere.

V.

Vector. See Radius Vector.

Vega, or *Lyra*, a star of the first magnitude in the Harp.

Venus, one of the inferior planets, and at times appears the brightest star in the heavens.

Vertex, is that point in the heavens directly over our heads, called the zenith.

Vertical Circle, is a great circle perpendicular to the horizon, and passing through the zenith, and nadir of any place.

Vesta, one of the newly discovered planets, and the fifth in order from the sun.

Via Lactea. See Galaxy.

Vindemiatrix, a star of the third magnitude in the constellation Virgo.

Virgo, a zodiacal constellation, containing 110 stars.

U.

Umbra, the total shadow of the earth, moon, and planets.

Unicorn. See Monoceros.

Uranus, or *the Herschel Planet*, a superior planet, and the most remote in the solar system.

Ursa Major, the Great Bear, a northern constellation, consisting of eighty-seven stars.

Ursa Minor, the Little Bear, a constellation near the north pole, which contains twenty-four stars, one of which is called the pole star.

W.

Week, a division of time consisting of seven days.

X.

Xiphias, the Sword Fish, a southern constellation, containing six stars.

Y.

Year. See Sidereal, and Solar, &c.

Z.

Zenith. See Vertex.

Zodiac, a belt or girdle surrounding the heavens, in the middle of which runs the ecliptic; it is about 18 degrees in breadth.

Zones, are five large divisions of the globe, viz. the Torrid, two Temperate, and two Frigid Zones.

Zubenelg, or *β Libra*, a star of the second magnitude in the constellation Libra.

Zubenesch, or *α Libra*, a star of the second magnitude in Libra, right ascension 220° 10′, declination 15° 16′ S.

Besides the terms commonly used in Astronomy, this Glossary contains all the constellations with the number of stars in each, from Mr. Flamstead's catalogue; likewise the names of the most noted stars, with their situations in the heavens. To render this glossary as complete as possible, the names of different astronomical instruments are also introduced; and although the explanations of the different articles are but short, yet they will be found sufficient to give the learner a just idea of the term he seeks.

DIRECTION TO THE BINDER FOR THE PLATES.

PLATE I, To face the Title Page.

„ II, To face page 6.

„ III, IV, V, VI, VII, and VIII, to be placed in their order, at the end of the book; and each one to face towards the left hand.