ILLUSTRATED

COMMON SCHOOL ASTRONOMY.

WITH

EXPLANATORY NOTES,

AND

QUESTIONS FOR EXAMINATION.

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"The heavens declare the glory of GOD, and the firmament showeth His handywork."

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PREFACE.

Of the multitudes that crowd our Common Schools, it is not to be expected that many will devote themselves to the science of Astronomy. By far the greater number will be immersed in the active concerns of life; and yet, perhaps, all of this numerous class would willingly add to the stores of general knowledge they are amassing, the great facts and principles of Astronomy, if they enjoyed opportunities and facilities for so doing.

For the aid of such, this little work has been prepared. It simply aims to render familiar the important truths and facts of the science, avoiding cumbrous details.

It may be used alone, or as an introduction to some more extended work on the subject, such as the "Elements of Astronomy."

Hartford, *May 4th*, 1857.

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ASTRONOMY.

INTRODUCTORY CHAPTER.

1. ASTRONOMY is that branch of NATURAL SCIENCE which treats of the MAGNITUDES, DISTANCES, CONSTITUTIONS, and MOTIONS of the HEAVENLY BODIES, and the LAWS which regulate them.

2. THE HEAVENLY BODIES consist of *moons*, *planets*,[1] *comets*,[2] and *suns;* and possibly a fifth class exist called *nebulæ*.[3] To moons, planets, and suns, the general name of *stars* is often given.

3. The mode of union existing among the heavenly bodies is the following: One or more moons *revolve about a planet;* several planets with their attendant moons *revolve about a sun*, around which, likewise, sweeps a numerous train of comets. A sun with its assemblage of planets and comets constitutes a *system.*

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1. *Planet*, from the Greek word *planetes*, signifying a *wanderer:* a star that changes its place in the heavens.

2. *Comet*, from the Latin word *coma*, *a head of hair*, this body presenting a hairy appearance.

3. The name of *nebulæ* is given by astronomers to certain objects in the distant heavens which appear like small clouds, or specks of mist. True nebulæ are supposed to be vast collections of unformed matter, thinly diffused through space. Nebulæ is a Latin word, signifying *mists*, or *clouds*.

What is Astronomy? What do the heavenly bodies consist of? What is the mode of union between heavenly bodies?

4. The investigations of astronomers tend to prove that these systems are not fixed in space, but revolve like planets about some common central point, or body. And we have reason for believing that this mode of arrangement extends throughout all space, groups of systems rising one above the other in magnitude; the lesser circling around the greater, until at length their vast aggregate embraces and completes the Universe.

5. Solar System. The sun with his train of planets, moons, and comets, forms the Solar System.

6. The number of planets already known is *fifty*. Thirty-nine of these have been discovered within the last twelve years, and others will doubtless be detected. The names of the planets are given in the following table, in the order of their distances from the sun, beginning with the nearest.

TABLE OF THE PLANETS.

MERCURY, (nearest), EARTH, VENUS, MARS.

The Asteroids, between Mars and Jupiter.

FLORA,	PHOCEA,	POMONA,	CALLIOPE,
HARMONIA,	MASSALIA,	PROSERPINE,	PYSCHE,
ISIS,	HEBE,	FIDES,	THEMIS,
MELPOMENE,	LUTETIA,	EUNOMIA,	HYGEIA,
CLIO,	FORTUNA.	THALIA,	EUPHROSYNE,
EUTERPE,	PARTHENOPE,	JUNO,	
URANIA,	THETIS,	CIRCE,	
VESTA,	AMPHITRITE.	CERES,	LEUCOTHEA,
POLYMNIA,	EGERIA,	LÆTITIA,	ATALANTA,
METIS,	ASTREA,	PALLAS,	LEDA,
IRIS,	IRENE,	BELLONA,	DAPHNE.

JUPITER, SATURN, HERSCHEL, or URANUS, NEPTUNE (most distant).

What is a system? What is the solar system? How many planets are now known? How many have been discovered within the last twelve years? Give the names of the planets.

7. All the planets between Mars and Jupiter are termed *Asteroids*.[1] In the annexed cut, Fig. 1, a view of the solar system is presented. The Roman numeral, I, represents the orbit[2] of Mercury; II, that of Venus; III, that of the Earth; IV, that of Mars; V, the orbit of the nearest asteroid; VI, that of the most remote asteroid; VII, is the orbit of Jupiter; VIII, of Saturn; IX, of Herschel; and X, of Neptune. In the cut the distances of the several planets from the sun bear the same relation to each other as their actual distances.

8. The Mode of Conducting Astronomical Investigations. When an artisan wishes to ascertain the dimensions of a stick of timber, he does so by means of a rule, the length of which he *knows*, and thus he obtains the solidity of the log in feet and inches.

When, likewise, we wish to determine the speed of a locomotive, we measure by the aid of a watch the time taken to pass over a known number of miles. Thus *unknown* magnitudes and motions are ascertained by comparing them with such as are *known*.

9. In astronomical investigations we pursue a like course, and begin with determining the *size*, *motions*, and *form* of the Earth, with other important particulars that are within our reach. We thus obtain *fixed standards* of measurement, whereby we are ena-

1. Asteroids. From two Greek words: aster, *a star*, and eidos, *like*. *Like a star*, because all these planets are very small.

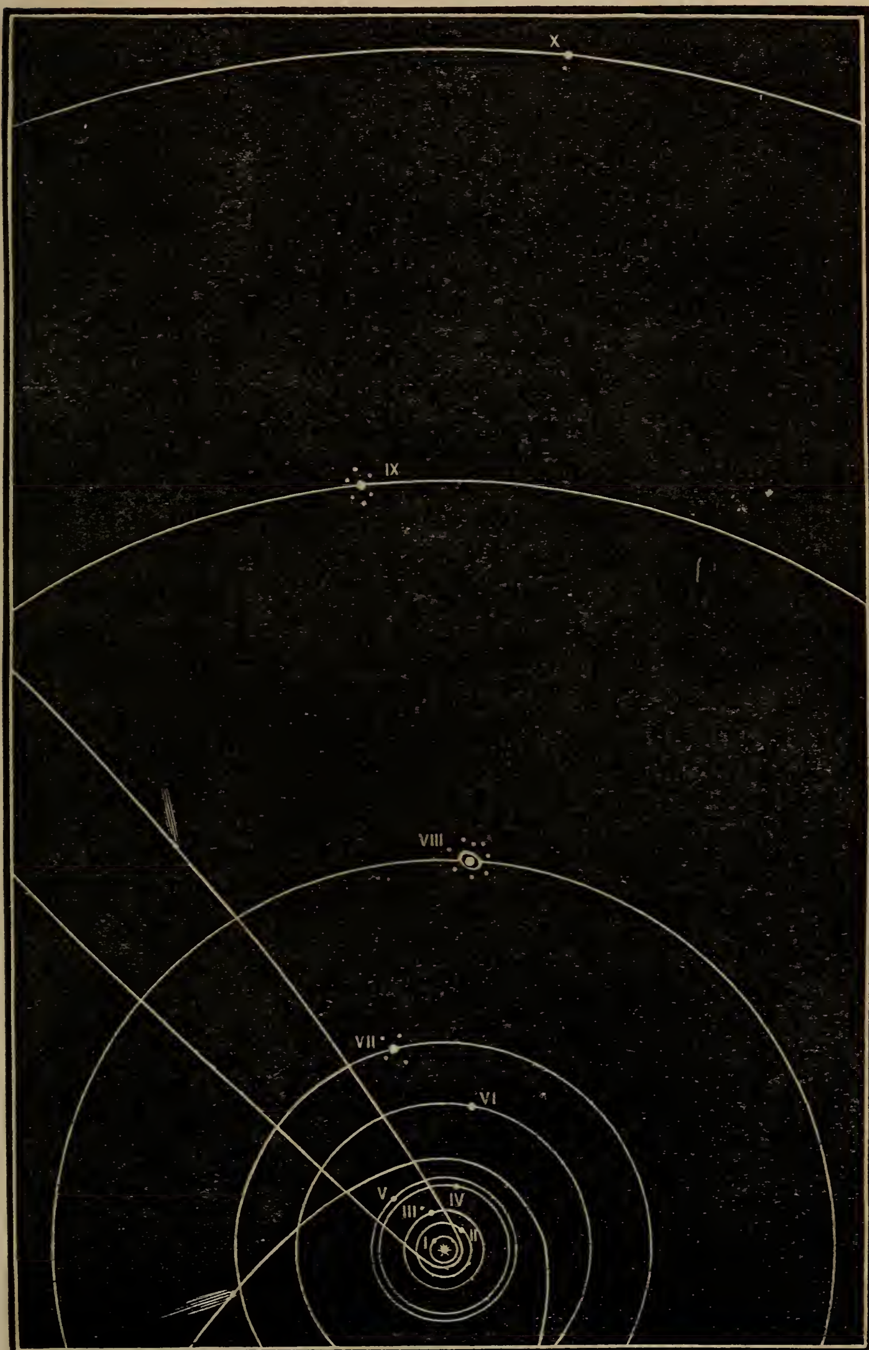
2. Orbit means the path of a planet about the sun. So called from the Latin word, *orbis*, *a circle*, *a circuit*.

What are the Asteroids, and where situated? Explain the figure. In what manner are astronomical investigations conducted?

bled to push our inquiries beyond the earth, and to compute the distances, times, motions, and velocities of many of the bright orbs[3] that glitter about us, and the extent of the vast spaces through which they move. In the study of Astronomy our attention is, therefore, directed *First* to the EARTH in its relation to the rest of the heavenly bodies. *Secondly*, to the SOLAR SYSTEM. *Thirdly*, to the STARRY HEAVENS, of which this system is a part.

3. The stars are frequently called *orbs*, from their round figures. (Latin,) *a circle.*

FIG. 1.



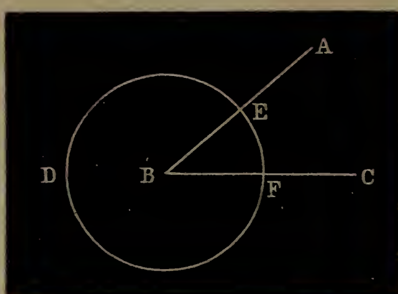
SOLAR SYSTEM.

EXPLANATORY CHAPTER.

10. In learning Astronomy it is necessary for the pupil at the outset to know the meaning of certain mathematical and philosophical terms and expressions which are constantly occurring in the discussion of astronomical subjects. These must be mastered in order to obtain a clear understanding of the science, and yet they are by no means difficult to comprehend. The most important of these are explained in the present chapter. The meaning of other terms and phrases will be given as they occur in the book.

11. Angle. An angle is the *opening or inclination between two lines that meet each other*; thus, in Fig.

FIG. 2.



AN ANGLE.

2, the line AB meets the line BC, and the opening between them is called the *angle* B, or the *angle* ABC; the letter at the point of meeting always being placed in the middle.

The size of an angle is computed as follows. The

In learning astronomy, what is it necessary for the pupil to do at the outset? What is an angle? How is its size computed? Describe from the figure.

circumference of any circle being divided into 360 equal parts, each part is called a *degree;* a degree being divided into 60 equal parts, each part is called a *minute;* a minute being divided into 60 equal parts, each part is called a *second.* If, now, we take the point B, as the centre of a circle, and describe the circumference DEF, cutting the two lines, AB and CB in any two points, as E and F, the *number of degrees, minutes, and seconds* contained in the part of the circumference, EF, included between the two lines, AB and CB, gives the *value of the angle,* ABC. For example, if the length of the circumference, DEF, was 360 *inches,* and the part, EF, contained 40 *inches and nine-sixtieths* ($40\frac{9}{60}$) of an inch, ABC would be an angle of *forty degrees and nine minutes* ($40° 9'$.) *Degrees* are denoted by the following character, °; *minutes* thus, ′; *seconds* thus, ″.

12. A Right Angle. A right angle contains 90°, and can be thus constructed. Draw two diameters through any circle, dividing the circumference into

FIG. 3.

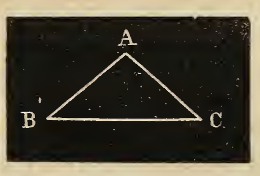
RIGHT ANGLE.

How are degrees, minutes, and seconds denoted? What is a right angle, and how is it constructed?

four equal parts, and each of the angles at the centre will be a right angle, for since the whole circumference contains three hundred and sixty degrees, *one-fourth* of it contains *ninety degrees*. Thus, in Fig. 3, the two diameters, AB and DE, dividing the circumference of the circle, A, D, B, E, into four equal parts, make each of the angles at the centre, right angles, viz., ACD, DCB, BCE, and ECA.

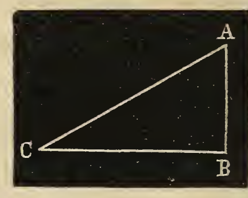
13. Triangles. A triangle is a figure that is bounded by *three lines*, either curved or straight, and contains *three angles:* hence its name, derived in part from a Latin word, *tres*, meaning *three*. The sum of the

FIG. 4.



A RECTILINEAR TRIANGLE.

FIG. 5.



A RECTILINEAR RIGHT-ANGLED TRIANGLE.

three angles of any rectilinear[1] triangle is always equal to 180°. Fig. 4 represents any such triangle, and the sum of its angles is equal to 180°. A right-angled rectilinear triangle is one that contains one right angle. Thus, Fig. 5 is a right-angled triangle, since it contains a right angle, viz., ABC.

14. Similar Triangles. Similar triangles are those which have *all the angles of one triangle equal to*

1. Rectilinear, from rectus, *straight*, and linea, *a line*, (Latin,) STRAIGHT-LINED.

What is a triangle? How many degrees does it contain? Refer to figure. What is a right-angled triangle? Refer to figure. What are similar triangles? Explain from figure.

those of the other, each to each, and the sides forming the equal angles proportional ; thus, in Figs. 6 and 7, the triangles, $A^1B^1C^1$ and ABC, are similar, because

FIG. 6.

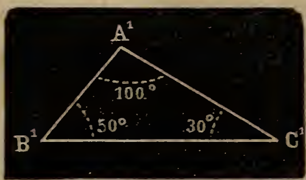
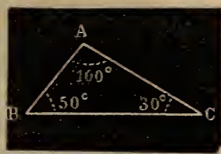


FIG. 7.



SIMILAR TRIANGLES.

the angle B^1 equals B, A^1 equals A, C^1 equals C, and the side $A^1B^1 : AB :: A^1C^1 : AC$; and so of the other sides.

15. A Plane Surface. A plane surface is such that if any two points in the surface are connected by a straight line, every part of that straight line touches the surface. To illustrate: The surface of tranquil water in a pond is a plane surface, because if any two points on the surface are taken, and are connected by a perfectly straight rod, every part of the lower side of the rod touches the water. Such a surface is sometimes termed a *plane*. Thus, the surface of this page, when pressed flat, is a plane surface, or plane.

16. A Plane Figure. A plane figure is one whose bounding line or lines are situated in the same plane. The flat cover of this book is a plane figure.

17. Ellipse. An ellipse is a plane figure, bounded by a curved line, and so constructed that if two straight lines are drawn from two points within, called the *foci*, to *any point* in the curve, the *sum* of

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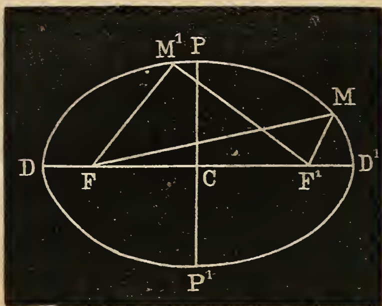
What is a plane surface? What a plane figure? What is an ellipse? Describe it from figure.

these lines is invariably the same for the *same* ellipse. Thus, the annexed figure is an ellipse. F and F^1, the foci, and if straight lines are drawn to any points, as

FIG. 8.



AN ELLIPSE.

M and M^1; FM added to F^1M equals FM^1 added to F^1M^1, and so of lines drawn to any other point. The line DD^1, drawn through the foci and terminated by the curve, is called the *major axis* of the ellipse. The line PP^1, drawn through C, the middle of DD^1, or the centre of the figure, is the *conjugate axis.*

18. To Construct an Ellipse. Stick two pins into a piece of paper, at a short distance from each other, as at F and F^1, and pass over them a loop of thread, place a pencil in the loop, and keeping the thread tight, a triangle will be formed like FMF^1, the pencil being at M. Passing the pencil completely round F and F^1, its point will mark out an ellipse. For since in making the circuit, the length of the loop does not change, neither the distance between F and F^1, it necessarily follows that the sum of the distances from the pins to the pencil: viz., F^1M, FM, &c., is invariable.

Construct an ellipse.

19. Eccentricity. Ellipses differ among themselves. If the foci are near the centre of the ellipse, the ellipse approaches the form of a circle; but if the foci depart widely from it the length of the conjugate axis is small in proportion to that of the major axis, and the ellipse is said to be very eccentric.[1]

The distance from the centre to either focus, viz., FC, or F¹C, is termed the *eccentricity of the ellipse.*

FIG. 9.

FIG. 10.

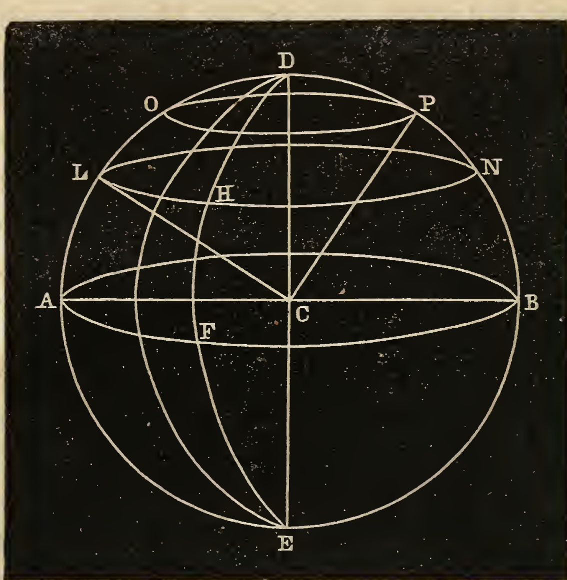
In Figs. 9 and 10, two ellipses are exhibited which differ greatly in their eccentricity—one being almost a circle, and the other very oval.

20. A Sphere. A sphere is a solid, bounded by a curved surface, *every point of which is equally distant from a point within, called the centre;* every line passing through this centre, and limited by the surface, is a *diameter.* The half of this line is a *radius* of the sphere. Thus, in Fig. 11, representing a

1. *Eccentric,* from ex, *out of,* and centrum, *centre,* (Latin) *out of the centre.*

What is meant by the term eccentricity?
What is a sphere? Describe it from the figure with its lines and sections.

FIG. 11.



A SPHERE WITH ITS SECTIONS.

sphere, the points D, O, L, A, E, H, N, &c., are all equally distant from the centre C. DE and AB are diameters, and CP, CL, CA, CB, &c., are each a radius.

If a plane passes through a sphere, any section it makes with the sphere is a circle. A *great circle* passes through the centre of the sphere, all other circles are small circles. Thus, in the figure, AFB is a *great circle*, and LHN and OP *small circles.*

21. Poles of a Circle of a Sphere. The *poles* of a *circle of a sphere* are *points* on the *surface of a sphere, equally distant* from *every point in the circumference of that circle.* Thus, D is the pole of the circle LHN, because the curved lines DH, DN, and

What are the poles of a circle of a sphere? Explain from figure.

DOL, and all others drawn to the circumference LHN, are equal to one another. For the same reason D is the pole of the circles OP and AB. It will also be seen that the point E is situated like D, with respect to these circles, since the curved lines EBN and EAL are equal, as likewise ELO and ENP. Each circle of a sphere has therefore *two poles.*

In a great circle the poles are each *ninety degrees* distant from the circumference of the circle ; thus, in the great circle AB, the poles E and D are each ninety degrees from its circumference AFB.

PART FIRST.

THE EARTH IN RELATION TO OTHER HEAVENLY BODIES.

CHAPTER I.

ITS FORM, SIZE, AND ROTATION.

22. Its Form. The earth appears to our view to be nothing more than a vast broken plain, rising into mountains, sinking into valleys, and spreading out into lakes, seas, and oceans; but a careful investigation removes this erroneous impression, and proves, *First*, that the general surface of the earth is *curved; Secondly*, that the mass itself is *nearly spherical* in form; *Thirdly*, that it *rests upon nothing.*

23. The facts are established by several independent proofs. *In the first place*, when a vessel sails from the shore, the spectators upon the strand, as they watch her lessening in the distance, at length perceive the hull gradually sinking below the line of the horizon;[1] next the lower sails disappear, and the last objects that are seen are the tops of the masts, on a level with the distant waters; and this is the case in

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1. Horizon, a *boundary*. It here means the line that apparently divides the surface of the earth from the sky and limits our view. Its full meaning is explained in Arts. 27, 28, 29.

What does Part First treat of? What does Chapter First treat of? What appearance does the earth present? What facts have been proved by careful investigation? State the several proofs of these facts.

whatever direction the vessel sails. *Secondly*, navigators have repeatedly sailed around the earth, by advancing constantly in the same direction; arriving at length at the port from whence they departed.

Thirdly. The horizon is *circular*, which would not be the case unless the earth was spherical.

Fourthly. When the sun, earth, and moon are so situated that they are all in the same straight line, the earth being in the middle, the latter casts a shadow upon the moon, causing an *eclipse.* This *shadow* is seen to be *circular in form*, thus proving that the earth is round.

Fifthly. Since the sun, and the nearest heavenly bodies are seen to be *round*, we naturally infer that the earth does not constitute an exception, but has also a similar form.

Sixthly. From observations and actual measurements, mathematicians are able to compute the distances of places on the earth's surface from its centre; in numerous places widely differing in latitude and longitude; these distances *have been computed*, and are found to be in all instances *nearly equal.* This fact proves the spherical shape of the earth, since a sphere alone of all solid bodies possesses the property, that the distance from the centre to any point on its surface is everywhere the same.

In view of all these facts we conclude that the earth is a body *having a curved surface that is* nearly *spherical* in shape, and *that it rests upon nothing.*

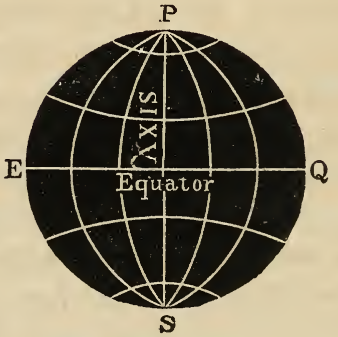
24. We say *nearly spherical*, for according to the best calculations of astronomers, the earth swells out at the equator, the diameter which passes through

the centre and the poles,[1] being about one three hundredth part ($\frac{1}{300}$th) shorter than any diameter that passes through the equator. To such a solid geometricians have given the name of *oblate spheroid*.

25. SIZE OF THE EARTH. The length of the polar diameter of the earth is 7,899 miles, and that of the equatorial diameter 7,925½; the latter being longer than the former by 26½ miles. Thus in Fig. 12, if PS represents the polar diameter, and EQ the equatorial, EQ is longer than PS by 26½ miles.

The distance around the earth, that is, its circumference, is about 25000 miles.

FIG. 12.



THE EARTH.

1. The *polar diameter* of the earth is the imaginary line or axis about which the earth rotates, like a wheel on an axle. Its extremities are the poles of the earth. A diameter drawn at right angles, to the polar diameter, and passing through the centre of the earth, is an *equatorial diameter*. See Fig. 12, where P and S are the poles of the earth, and PS the polar diameter.

Is the earth exactly spherical? How much shorter than the equatorial diameter is the polar? What is the geometrical name of a solid body shaped like the earth? What is the length of the polar diameter of the earth? What of the equatorial? What is the distance around the earth?

26. Rotation of the Earth. To every one who can see, it is one of the most familiar sights in nature to behold the sun ascend the eastern sky, attain its noontide splendor, and at length set beneath the western horizon. And when night approaches, the stars appear moving in the same order; rising successively above the eastern horizon, and passing over to the west. This motion of the celestial bodies can be explained in *two ways*, either by supposing that the earth is *at rest*, and all the luminaries of the sky actually revolve about it, or that their motion is only *apparent*[1], the earth itself really rotating while the celestial orbs remain immovable.

The first theory was received as the truth for ages, until the discoveries of scientific men at length showed its falsity, and established, by undeniable proofs, the fact of the *rotation of the earth on its axis.* The period of rotation, as we shall hereafter see, is divided into twenty-four equal parts, called *hours.*

1. When a person sails from the shore with a steady wind, the shore apparently moves backward, while the ship seems to be stationary, though the observer knows all the while that the true state of the case is exactly the reverse. The ship moves, but the shore is fixed.

In how many ways can the motions of the celestial bodies be explained? What are those ways? Which one for ages was received as true? Has it been proved false? How is the period of rotation divided?

CHAPTER II.

THE HORIZON.

27. Horizon is an astronomical term derived from the Greek word *orizon*, signifying *boundary*, and of these boundaries there are *two.*

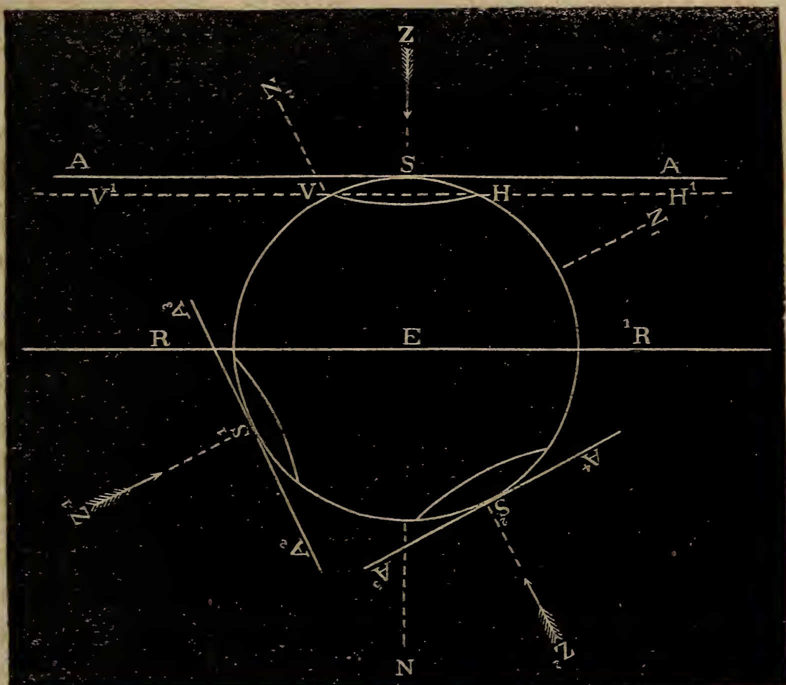
28. Sensible Horizon. The first is the *sensible* or *visible horizon*, of which we have already spoken. It is the line apparently separating the earth and sky, and which a spectator upon the expanse of ocean, or on a vast unbroken plain, perceives to be a *circle.*

The plane of the visible horizon is regarded as touching the earth at the point where the spectator stands, though strictly speaking this is not the case, since on acccount of the depression of the visible horizon the point where the spectator stands is a little above its plane. This is evident by referring to Fig. 13, where the circle E, represents a section of the globe, S the place of the spectator, and the circular line VH, a part of his visible horizon. Now it is evident at a glance, that owing to the curvature ot the earth the plane of the visible horizon, which takes the direction V^1VHH^1, is necessarily below the parallel plane that touches the earth at S, the place of the spectator, and takes the direction of ASA^1. Nevertheless the difference in distance between the two planes is usually so small that they are generally regarded as coinciding; the plane of the horizon being supposed to pass through S.

What does Chap. II. treat of? What is the meaning of the term *horizon?* Give the meaning of the term *sensible* horizon, and explain from Fig. 13.

29. Rational Horizon. The second or *rational horizon* is a vast imaginary circle whose plane passes

FIG. 13.



HORIZON EXPLAINED.

through the centre of the earth and reaches to the sky, dividing the earth and sky into two hemispheres, and is parallel to the plane of the visible horizon. It is also represented in direction in Fig. 13, by the line RR¹.

30. Plane of the Horizon not fixed in Space. We have said that the plane of the horizon touches the surface of the earth at the point where the spectator

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What is the *rational* horizon?
Is the plane of the horizon fixed in space?

stands, or in other words, is at right angles at this point to a plumb-line[1] passing through this same point. Now the direction of the plumb-line varies at every point of the earth's surface. Consequently, there are as many horizons, both sensible and rational, as there are such points; and the planes of these horizons take all possible directions. Thus, in Fig. 13, if S, S^1, S^2, represent the stations of different spectators upon the earth's surface, it is clear that the planes of the horizons of each, viz, AA^1, A^2A^3, A^4A^5, take different directions.

31. Zenith and Nadir. The point in the heavens, in the direction of the plumb-line, exactly over the head of an observer, is the *zenith;* and the point in the heavens beneath him in the opposite direction is the *nadir.* Thus, in Fig. 13, Z is the *zenith* of the place S, and N. its *nadir.*

Since the horizon of an observer changes at every step, it necessarily follows that his zenith and nadir also change. The zenith of the place directly beneath us on the opposite side of the earth is our nadir, and its nadir our zenith. In Fig. 13, Z is the zenith at S, and N the nadir. At S^1, Z^1 is the zenith and N^1 the nadir. At S^2, Z^2 is the zenith and N^2 the nadir.

32. Changing Aspect of the Heavens arising

1. If a ball of lead is tied to one end of a string, and the other end held up so that the ball can swing freely, the direction the string takes when the ball is at rest is the direction of the plumb-line. *Plumbum* is the Latin word for lead.

How many horizons are there? Explain from figure.
What is meant by zenith and nadir? Explain the changing aspect of the heavens arising from the rotation of the earth.

from the Rotation of the Earth. Having learned the fact of the rotation of the earth, and of the full meaning of the term horizon, we will now contemplate the aspect of the starry sky, remembering all the while that we are not stationary, but standing on the surface of a rolling ball.

33. If, in our latitude, upon a clear evening, we take a position upon some commanding eminence, we perceive the whole of the overarching sky studded with multitudes of glittering stars, down to the very line which separates the earth from the heavens. Some bright cluster may perhaps be seen just hanging above the western horizon, while another may arrest our attention in the eastern sky. After a short time, when we turn our eyes again towards the western group it is no longer visible, but has sunk beneath the horizon, while the cluster in the east has attained a loftier elevation.

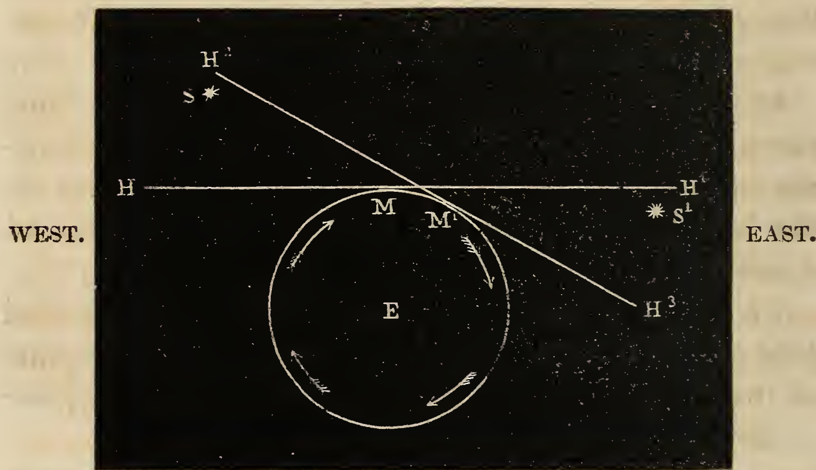
34. By a longer and closer observation we find that all the stars have this common motion from east to west, and that they appear to move in *circular paths.*

35. Our knowledge of the rotation of the earth renders these appearances perfectly intelligible. The stars are not *really* in motion, but only *appear* to be, for the earth in its rotation from west to east is constantly depressing the eastern part of the horizon and elevating the western, so that a star *rises* in consequence of the eastern horizon being carried *below* it, and *sets* because the western horizon is carried up to it and *above* it.

36. This point is illustrated in Fig. 14, where circle

E represents the earth rotating from west to east, as shown by the direction of the arrows. If a person is at M, on the surface of the earth, the plane of his horizon is in the line HH^1, and the star S is above his western horizon, and the star S^1 below his eastern horizon. But when the earth in its rotation brings the person into the position M^1, the plane of his horizon has been so changed as to take the direction H^2H^3, and the star S has set below the western horizon, while the star S^1 has risen above the eastern.

FIG. 14.



CHANGING HORIZONS.

37. Why the Stars appear to describe Circles. The *apparent circular paths* of the stars is the result of our own circular motion on the surface of the earth; for, not perceiving ourselves to move, these orbs appear to have the kind of motion that really belongs to us. This illusion is the same as that which happens when two trains of cars coming from opposite

Explain why the stars appear to describe *circles*.

directions stop side by side in a depôt, and a passenger in one looks out at the opposite stationary train, the moment his own starts; unconscious of his own motion, the train at his side appears to him to move in a contrary direction to that in which he himself is actually proceeding. If his own train moves in a *straight line*, the other appears to do so likewise; but if the former moves in a *circular* track, such is the apparent course of the latter. In like manner a spectator moving in a circle upon the rolling surface of the globe, sees the stars moving in circles in a direction contrary to his own, imagining himself all the while to be at rest.

38. Poles of the Heavens and Pole Star. The two points in the heavens towards which the axis of the earth is directed are the *north* and *south* poles of the heavens. The north pole of the heavens is directly above the north pole of the earth, and the south pole of the heavens directly above the south pole of the earth. A little way from the north pole of the heavens is a bright star called the *pole star*.

39. Changing Aspect of the Heavens arising from change in Latitude. A person standing on the surface of the earth at the *equator*, has the plane of his horizon parallel to the axis of the earth. The poles of the heavens are consequently situated in this plane, and his horizon appears to pass through them. All the circles of daily motion[1] are therefore perpen-

1. By the term *circles of daily motion*, is understood the circles described by the heavenly bodies in their apparent daily motion from east to west.

What is meant by the north and south poles of the heavens? Where is the pole star situated? Describe the celestial appearances at the equator.

dicular to the horizon. A star which rises in the east passes directly overhead and sets in the west, and each orb describing half a circle above and half below the horizon is, therefore, visible for twelve hours, and invisible for the same space of time.

40. If the observer now advances northerly his horizon constantly changes in position, being depressed below the north pole of the heavens, and elevated above the south the same number of degrees and parts of a degree that correspond to his latitude. Thus, if he has arrived at *ten degrees, north latitude*, the northern pole is ten degrees above his horizon, and the southern ten degrees below it. If, at *fifty degrees, thirty minutes, north latitude*, the north pole is fifty degrees and thirty minutes above the horizon, and the southern as much below it. And if it were possible for a person to attain the distance of ninety degrees, north latitude, and stand upon the northern pole of the earth, his horizon would be parallel to the equator, the north pole of the heavens would be ninety degrees from the horizon, that is, in the *zenith*, and the southern pole of the heavens would coincide with his *nadir*.

41. This change in the relative positions of the poles of the heavens and the horizon, produces a corresponding change both in the inclination of the circles of daily motion to the horizon, and in the period of visibility of different stars. For, all the stars apparently revolve in circles, at right angles to the

What changes occur as an observer advances towards the north? If he stood upon the pole, where would the north pole of the heavens be? Where the south? What corresponding changes are produced by the variations in position incident to the poles of the heavens and the horizon?

imaginary line joining the poles of the heavens, called the *axis of the heavens:* and as the north pole of the heavens is elevated more and more above the horizon, these circles of daily motion must cut the horizon more and more obliquely, until at the north pole of the earth a person would see the stars revolving about him in circles parallel to the horizon.

42. Moreover, when the north pole of the heavens rises above the horizon, and the south sinks below it, it is only those stars that are situated directly above the earth's equator which are visible in a clear sky for twelve hours above the horizon, and are absent as long below it, since the centre of their circle of daily motion is alone in the plane of the horizon. All the stars to the north of the equator have the centres of their circles of daily motion more and more elevated above the plane of the horizon according as they are situated farther to the north. The circumferences of the circles they describe, it is true, become smaller and smaller, but the arcs[1] described above the horizon are proportionally larger; and consequently the time that a star is visible increases up to a certain limit from the equator towards the north.

43. Circle of Perpetual Apparition. There are stars which never set; for when an orb is at a less distance from the pole than the horizon is, it is evi-

1. *Arc*, any portion of the circumference of a circle.

What is the axis of the heavens?

How would the stars appear to revolve to a spectator at the north pole? What is said respecting the times of visibility of stars at the equator and north of the equator?

Are there stars which never set? What is meant by the circle of perpetual apparition?

dent that such a star will continue to revolve about the poles without ever sinking below the horizon. A circle around the elevated pole having a radius equal to the altitude of the pole above the horizon is called the *circle of perpetual apparition*, because the stars within it never set. This circle changes in size with the change of latitude. In latitude ten degrees its radius is ten degrees; in latitude fifty degrees, fifty degrees; and at the pole it would be ninety degrees, comprehending the entire visible heavens, every star above the horizon revolving in a circle parallel to it.

44. Let us now direct our attention to the stars towards the south pole, our place of observation being the northern hemisphere. In this direction the axis of the heavens is depressed below the horizon, the south pole of the heavens being as far below the horizon as the north pole is above it. The centres of the circles of daily motion described by the stars being in this region below the horizon, the arcs they pass through above the horizon are less than semi-circumferences,[1] growing smaller and smaller the farther to the south a star is situated. Their periods of visibility will decrease in like manner, until we arrive at a point in the southern heavens where a star just glimmers for a moment upon the horizon and then sets again.

45. Circle of Perpetual Occultation. The stars that are situated at a less distance from the south pole of the heavens than the pole is depressed below

1. A semi-circumference is half a circumference.

State what is respecting the extent of the arc described by stars south of the equator, and of the extent of their times of visibility.

What is meant by the term circle of perpetual occultation? How does the circle the horizon, will never in their daily revolution come into sight. A circle around the depressed pole, having a radius equal to the distance of this pole below the horizon, is called the *circle of perpetual occultation*, because the stars within it never rise to our view.

46. Like the circle of perpetual apparition, that of occultation varies with the variation of latitude, and at the same place the magnitude is the same, since one pole is elevated the exact amount that the other is depressed. Thus, in north latitude ten degrees, the south pole of the heavens is ten degrees below the horizon, and the radius of the circle of perpetual occultation is also ten degrees. In north latitude fifty degrees, it is fifty degrees, and at north latitude ninety degrees, that is, at the north pole of the earth, it comprises the entire half of the heavens below the horizon.

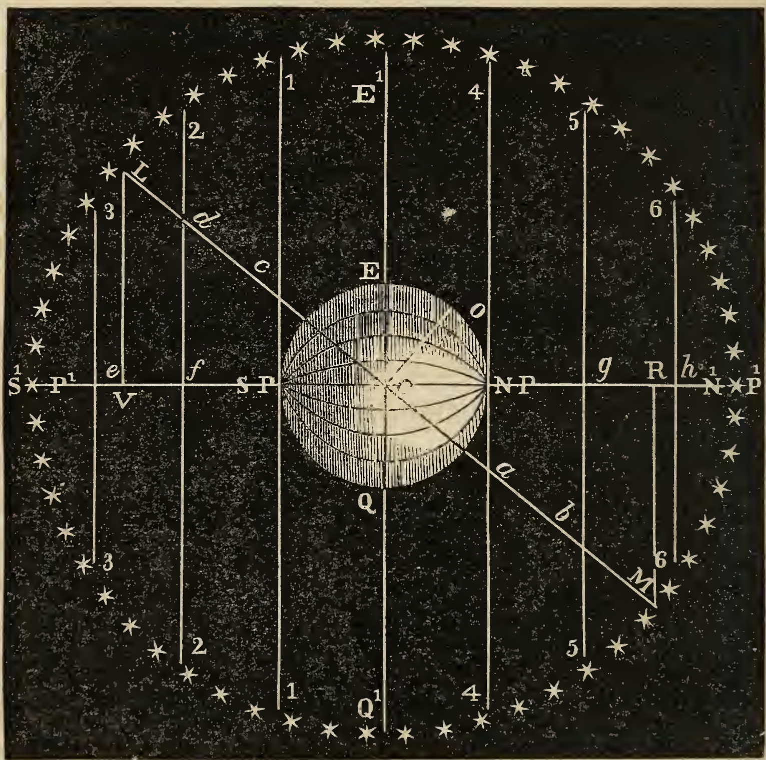
47. We have thus far described the changing aspect of the heavens, by supposing a traveller to proceed from the equator towards the north: were he to take the opposite direction and move towards the south, the phenomena we have described would be exactly the same, only reversed in position. Thus, the plane of the horizon would dip towards the south, the north pole of the heavens would be depressed, the southern elevated, and the stars would be longer above the horizon south of the equator than north of it. To an observer at the south pole of the earth,

of perpetual occultation compare in extent with that of perpetual apparition? What would be their extent to an observer at either pole of the earth? State what is said respecting the phenomena of the heavens when the observer advances south of the equator.

the south pole of the heavens would be in the zenith, and the circles of daily motion would be parallel to the horizon. The circle of perpetual apparition would be around the south pole of the heavens, and that of occultation about the north, and so on

48. These remarks may be still farther impressed upon the mind by studying the annexed figure, where

FIG 15.



VARYING ASPECT OF THE HEAVENS, ARISING FROM CHANGES IN LATITUDE.

the outer starred circle represents a section of the concave sphere of the heavens, C the earth; SP and

Explain the figure.

NP its north and south poles; the line SPNP its axis of rotation; and EQ its equatorial diameter. S^1P^1 and N^1P^1 are the north and south poles of the heavens, and the imaginary line, $S^1P^1N^1P^1$, the axis of the heavens, about which the stars apparently revolve. E^1Q^1 is the diameter of the celestial equator.[1] 1, 1; 2, 2; 3, 3, &c., are the diameters of other circles, in the circumferences of which the stars appear daily to revolve.

49. Aspect of the Heavens at the Equator. If a spectator is at the equator, at E, his sensible horizon coincides with his rational, $S^1P^1N^1P^1$, at the vast distance of the fixed stars; and the poles of the heavens are, consequently, upon his sensible horizon. Thus situated, we see that the circles of daily motion are perpendicular to his horizon, and each of the stars that are seen at all, apparently describes a semi-circumference above and a semi-circumference below the horizon, being for twelve hours visible and for twelve hours invisible.

50. At North Latitude Forty Degrees. If the observer moves to O, *north latitude forty degrees*, LM becomes his rational horizon The north pole of the heavens is elevated, and the south depressed forty degrees. The radius of the circle of perpetual apparition is MR, whose angular breadth is also equal to forty degrees; and LV, having the same extent, is the radius of the circle of perpetual occultation. The circles of daily motion are here oblique to the horizon, LM, and the stars north of the equator are consequently above the horizon a proportionally *longer*

1. See Art. 57.

time than twelve hours, as they are nearer the circle of perpetual apparition. South of the equator they are above the horizon for a proportionally *shorter* space than twelve hours, the nearer they approach the circle of perpetual occultation. These facts are evident when we compare the parts of the lines, 1, 1; 2, 2; 4, 4; and 5, 5, which are above the horizon, LM, with the parts that are below, viz., 5*b*, *b*5; 2*d*, *d*2, &c.

51. AT THE NORTH POLE. At the north pole, NP, the horizon takes the direction of the line E^1Q^1, the north pole of the heavens, N^1P^1, is in the zenith, and all the stars in the hemisphere, $E^1N^1P^1Q^1$, revolve in circles parallel to the horizon. E^1C^1 is at once the radius of the circle of perpetual apparition and occultation, since all the stars above the horizon never set, and those below it never rise above it. If the observer moves toward the south pole of the earth, it is clearly seen that these appearances are exactly reversed.

52. LATITUDE OF ANY PLACE EQUAL TO THE ELEVATION OF THE POLE OF THE HEAVENS. From what has been just stated, it is evident that the latitude of any place is equal to the altitude of the pole of the heavens above the horizon. For we have seen that at the equator, where the latitude is nothing, the elevation of the pole is nothing; at latitude forty degrees the elevation of the pole is forty degrees, and at the poles of the earth, or latitude ninety degrees, the pole of the heavens is ninety degrees from the horizon, and is in the zenith. And the same is true for every latitude, either north or south of the equator.

To what is the latitude of any place equal?

CHAPTER III.

ON THE MODE OF DETERMINING THE PLACE OF A HEAVENLY BODY.

53. The first object of the geographer in describing the earth with its kingdoms, cities, mountains, oceans, seas, islands, &c., is to determine their exact position on the surface of the globe. This he obtains in the case of a city, for instance, by finding *first*, how many degrees, minutes and seconds, it is situated *east* or *west* from a great circle, called a *meridian*,[1] passing through the poles of the earth and some assumed point on its surface, as a celebrated observatory; and *secondly*, its distance in degrees, minutes and seconds, *north* or *south* of the great circle called the *equator*, passing through the centre of the earth at right angles to its axis of rotation. Thus, for instance, the position of New York City Hall is fixed by finding first, that it is situated seventy-four degrees, and three seconds (74° 00′ 03″) west of the meridian passing through Greenwich Observatory. This is its *longitude.* Next, that it is distant north of the equator forty degrees, forty-two minutes, and forty-three seconds (40° 42′ 43″). This is its *latitude.* These two measurements are sufficient to mark with precision its situation upon the globe; for no other spot on its surface can have this latitude and longitude.

1. See Art. 55 for the meaning of the term *meridian.*

What is the subject of Chapter III.? What is the first object of the geographer? In what manner does he determine the position of a city? Give an instance.

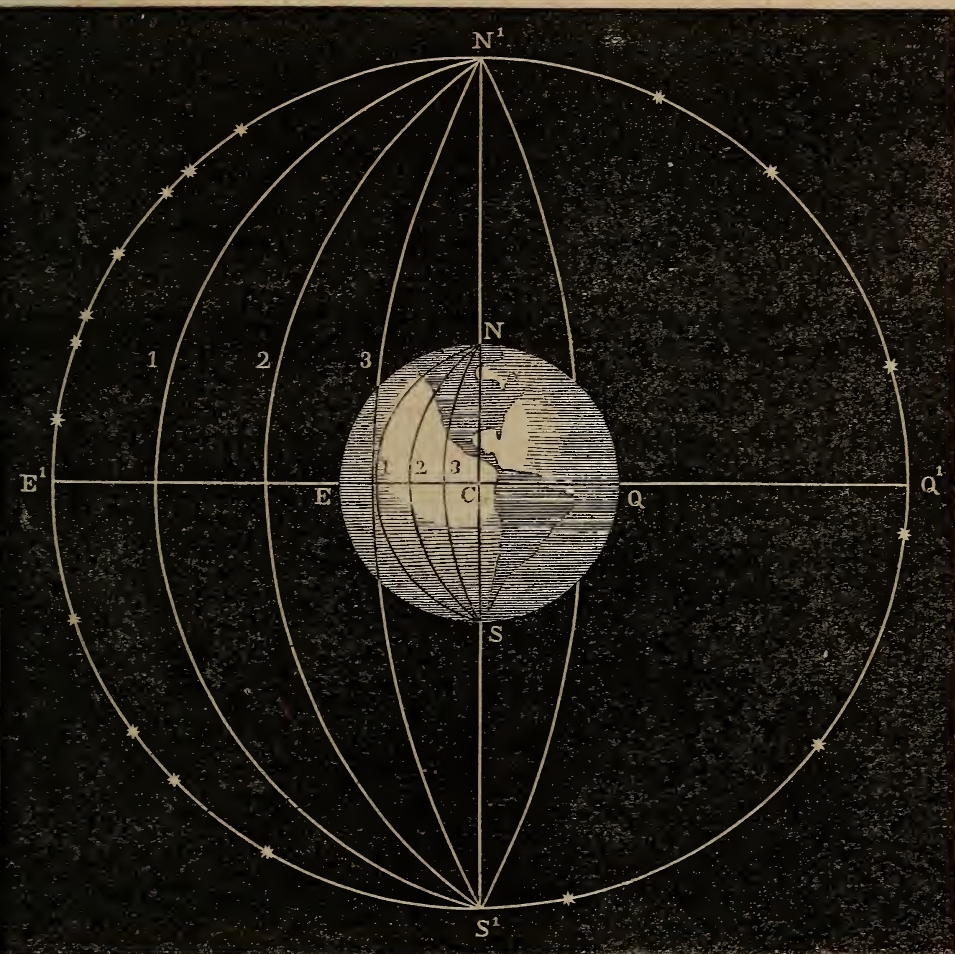
54. In a similar way the astronomer determines the position of stars in the concave sphere of the heavens, by measuring their angular distances from the planes of *two great circles, at right angles* to each other. And for this purpose he supposes the globe and sky to be intersected by certain lines and circles which we will now describe.

55. Celestial Sphere, Poles, Axes, and Meridians. The *celestial sphere* is the *concave sphere of the heavens*, in which the stars appear to be set. The *poles* of the earth are the extremities of that imaginary line upon which it revolves: the latter is called the *axis*. If any plane passes through the poles and the axis in any direction, its intersection with the surface of the earth is a circle, and is called a *terrestrial meridian*. Thus, in Fig. 16, which represents the earth and the celestial sphere, the line NS is the axis of the earth; N the north pole; S the south pole; and NES, N1S, N2S, N3S, are terrestrial meridians.

The axis of the earth, extended in imagination each way until it meets the starry sky, becomes the axis of the *heavens*, or *celestial sphere*, around which all the stars appear to revolve. The extremities of this axis are the *poles of the heavens*. Thus, in the figure, where the outer starred circle represents a section of the celestial sphere, the line N^1S^1 is the axis of the celestial sphere, and N^1 and S^1 its north and south poles.

How does the astronomer determine the position of a star? What is meant by the celestial sphere? The poles of the earth? Its axis? Terrestrial meridians? Explain from figure. What is meant by the axis of the celestial sphere? The poles of the heavens?

FIG. 16.



THE EARTH AND THE CELESTIAL SPHERE.

56. If any plane passes through the poles and axis of the heavens in any direction, its intersection with the imaginary surface of the celestial sphere is a *celestial meridian*. Thus, $N^{1}E^{1}S^{1}$, $N^{1}1S^{1}$, $N^{1}2S^{1}$, and $N^{1}3S^{1}$, are celestial meridians.

What is meant by celestial meridians? Explain from figure.

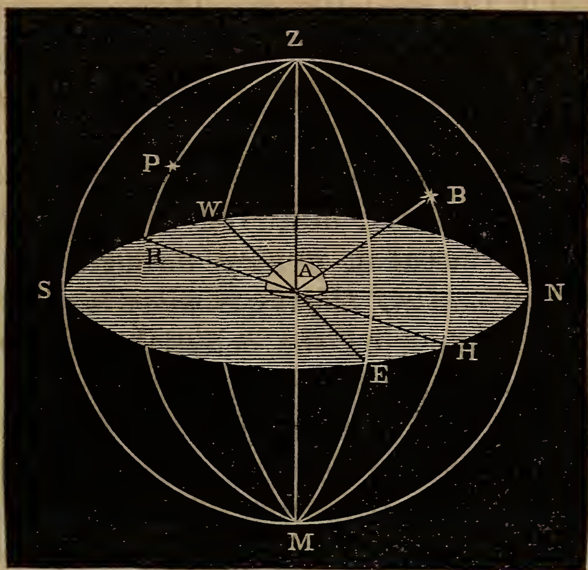
57. Equators. If we suppose a plane passing through the centre of the earth, perpendicular to the axis of rotation, its intersection with the surface of the earth forms a circle called the *equator*, or *terrestrial equator;* and if this plane is extended in imagination to the fixed stars, its intersection with the celestial sphere is also a circle, called the *celestial equator*, or *equinoctial.* Thus, in Fig. 16, EQ is the equator, and E^1Q^1 the celestial equator. They appear as straight lines in the figure, because we see them in the direction of their planes.

58. Vertical Circles. Vertical circles are those which are imagined to be formed by planes passing through the zenith, perpendicular to the horizon, and intersecting the celestial sphere. The vertical circle passing through the east and west points of the horizon is termed the *prime vertical*, while that which intersects the north and south points becomes a *meridian.* Thus, in Fig. 17, where A represents the earth, SZWMN the celestial sphere, Z the zenith, and the plane SWNE the horizon—PZHM is a *vertical circle*, WZEM the *prime vertical*, and SZNM a *meridian.*

59. The Position of a Star—how determined. The place of a star in the sky may be determined in *three* ways. *First*, by referring it to the planes of a *celestial meridian* and of the *horizon. Secondly*, by noting its distance from the planes of a given *meridian*

What is the terrestrial equator? What the celestial or equinoctial? What are vertical circles? What the prime vertical? Is a meridian a vertical circle? Explain from figure. In how many ways is the position of a star fixed? Describe them

FIG. 17.



AZIMUTH AND ALTITUDE OF A STAR.

and the *celestial equator.* *Thirdly*, by referring it to the planes of a given *meridian* and the *ecliptic.*[1]

60. AZIMUTH AND ALTITUDE OF A STAR. The *azimuth* of a star is its angular distance from a *meridian* measured on the *horizon*, and its *altitude* is its distance from the *horizon* measured on a *vertical* circle passing through the star. Thus, in Fig. 17, A represents a place on the earth; Z the zenith of the place where an observer is stationed; NEHRW the circle of the horizon; SZNM the meridian circle; B a star, and ZBHMP a vertical circle passing through the zenith and the star B: all these circles being circles of the

1. For the meaning of the term *ecliptic*, see Art. 63.

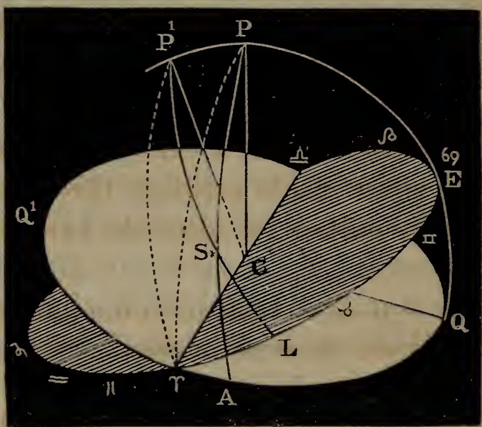
What is meant by the azimuth and altitude of a star?

celestial sphere. Then the angle NAH is the *azimuth*, and BAH the *altitude*. If the star is in the south, as at P, its azimuth would be reckoned from S, and would be SAR: ZAB is the *zenith distance* of the star.

61. Declination and Right Ascension. The angular distance of a star, measured *from* the celestial equator, on a meridian passing through the star, is called its *declination*. *Right ascension* is the distance of a star measured on the celestial equator in an easterly direction from the meridian passing through the *vernal equinox*,[1] the place where the sun meets the *celestial equator* in the spring, and is so called because when the sun appears at this point in the heavens, the nights, and consequently the days, are equal in length in every part of the world.

62. The subject is illustrated by Fig. 18, where P

FIG. 18.



DECLINATION, RIGHT ASCENSION, LATITUDE, LONGITUDE.

1. *Ver*, the Latin word for spring; *equinox*, a word formed from two Latin words, *æquus*, equal, and *nox*, night.

Show from the figure how these measurements of a star are taken. What is meant by zenith distance? What is declination and right ascension?

represents the north pole of the heavens, P ♈ [1] a celestial meridian passing through the vernal equinox; QAQ the celestial equator; S the place of a star; PSA a part of a celestial meridian passing through the star; and C the centre of the celestial sphere; or, what is the same in effect, the place of the spectator.

Now the declination of the star is the arc SA, since this arc measures the angular distance of the star from the equator QAQ¹, and if AS contains *forty degrees*, the *declination* of the star is *forty degrees*. The *right ascension* of the star is ♈A, and if this arc contains *fifteen degrees*, the star at S has *fifteen degrees* of right ascension.

63. Ecliptic. The imaginary line that the earth describes in her annual progress around the sun is termed her orbit, and its plane passes through the centre of the earth and sun, having an inclination to that of the celestial equator of about 23° 27′. Its intersection with the celestial sphere is called the *ecliptic*,[2] and constitutes what may be regarded as a great circle of the heavens.

The angular distance of a star from the ecliptic, measured on a great circle passing through the poles of the ecliptic, is called its *latitude*, and its angular

1. The character ♈ is called Aries, and is that point in the celestial equator which is termed the *vernal equinox*. P♈ is read thus, *P, Aries.*

2. So called because eclipses happen when the sun, earth and moon are in its plane.

Show from figure what is the declination and right ascension of the star at S. What is meant by the earth's orbit? What is the inclination of its plane to that of the celestial equator? What is the ecliptic? What is the latitude of a star?

distance, measured on the ecliptic, eastward from Aries, is termed its *longitude*. Thus, in Fig. 18, where ♈LE represents the ecliptic; P^1 its north pole; P^1♈ a great circle passing through Aries; and P^1SL, a great circle passing through the star at S^1SL, is the *latitude* of the star, and ♈L the *longitude* of the star, being the angular distance from Aries measured *on* the ecliptic to the great circle P^1SL passing through the star.

64. THE SIGNS. The ecliptic is divided in twelve equal parts, called *signs*, each sign occupying in the heavens an extent of thirty degrees. Within these divisions are situated certain conspicuous clusters of stars, termed *constellations*, which, in the infancy of Astronomy, received particular names, and these names were also given to the signs. The following are the names and characters of the signs, *north of the celestial equator*, beginning at the vernal equinox:

ARIES, The Ram,............ ♈	CANCER, The Crab,......... ♋
TAURUS, The Bull,.......... ♉	LEO, The Lion,.............. ♌
GEMINI, The Twins, ... ♊	VIRGO, The Virgin,.......... ♍

The next six, the names and characters of those south of the celestial equator:

LIBRA, The Scales,........... ♎	CAPRICORNUS, The Goat,.....♑
SCORPIO, The Scorpion,...... ♏	AQUARIUS, The Water-Bearer,♒
SAGITTARIUS, The Archer, ♐	PISCES, The Fish, ... ♓

65. ZODIAC. The zodiac is a belt of the celestial sphere, extending eight degrees on each side of the ecliptic. It is so called from the Greek word *zodia*,

What its longitude? Explain from figure. How is the ecliptic divided? What is the extent of each sign? What are situated within these divisions? Give the names of the signs. Which are north, and which south, of the celestial equator? What is the zodiac, and why is it so called?

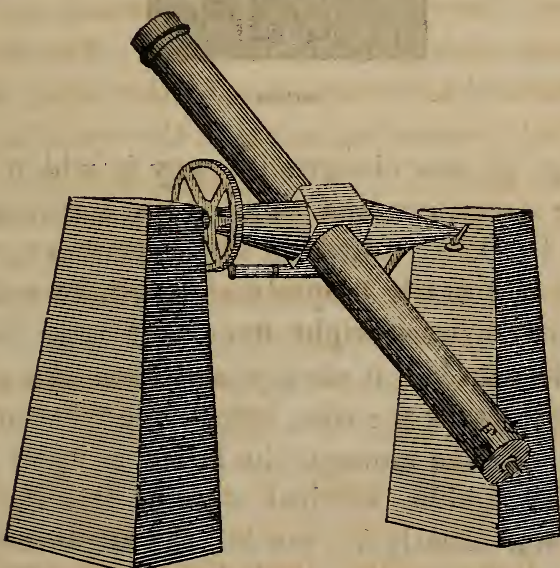
meaning *figures of animals*, because the signs of the ecliptic are formed principally of the figures of animals.

CHAPTER IV.

OF THE MEASUREMENT OF TIME.

66. Of the Time occupied by the Earth in performing one Rotation.—How determined. This is ascertained by means of an *accurate* clock, and a transit instrument (Fig. 19), which is a telescope placed in

FIG. 19.



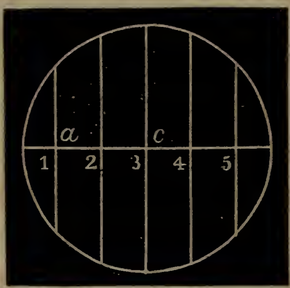
TRANSIT INSTRUMENT.

Of what does Chapter IV. treat? How can we ascertain the time occupied by the earth in performing one rotation? Describe the transit instrument.

the *plane* of the meridian; so that when a person looks through it he looks either in a north or south direction.

Within this instrument is placed a system of wires like those shown at *ac* (Fig. 20), one horizontal and five vertical: the latter being parallel to each other, and separated by equal intervals.

FIG. 20.



WIRES.

67. Let us now observe the way in which the astronomer ascertains the time of the rotation of the earth on its axis. Seated in his observatory, with his telescope and clock properly adjusted, he selects for his sky-mark some bright fixed star near the meridian. He watches it closely, and soon the earth, as it rotates towards the east, brings the telescope *up to* the star. At the moment the latter is upon the meridian, the middle vertical wire of the instrument cuts the star exactly in two, and the astronomer notes the time by his astronomical clock: we will suppose it to be eight. During the rest of the night and the succeeding day, the astronomer, with his observatory and instruments rotating with the earth, passes star

after star in succession, and as eight o'clock approaches, the observed star of the preceding evening is seen again near the meridian.

68. At eight o'clock *precisely* the central vertical wire again cuts the star exactly in two, showing that the earth has *completed one rotation. Twenty-four* hours have elapsed since the first observation: this, then, is the period of time occupied by the earth in performing *one entire rotation.* Such observations have been made repeatedly, both upon the same star and upon different stars, and at stations widely separated, and the result has been found to be *invariably* the same. Centuries may intervene between two series of observations, and yet the results are identical: we thus arrive at the conclusion that the *interval of time* elapsing between two *successive transits*[1] *of a fixed star*, and which measures *one entire revolution* of the earth, is *unchangeably the same.*

69. Standard Unit of Time. The period of the earth's rotation on its axis is the universally acknowledged unit of time, since it is the only natural marked division of time which continues unaltered from age to age. The different periods of time in common use all date from this. Weeks, months, and years, are

1. *Transit.* The transit of a star is the moment of its passage across the meridian when it is cut exactly through the centre by the central vertical wire of the transit instrument. Transit, from the Latin word *transitus*, a passage.

Describe in full how the time occupied by the earth in performing one rotation is determined. Is this period changeable?

What is the standard of time? Why is this division of time adopted as a standard? What is said of weeks, months, and years?

reckoned by days and fractions of a day, while hours, minutes, and seconds, are divisions and sub-divisions of the day.

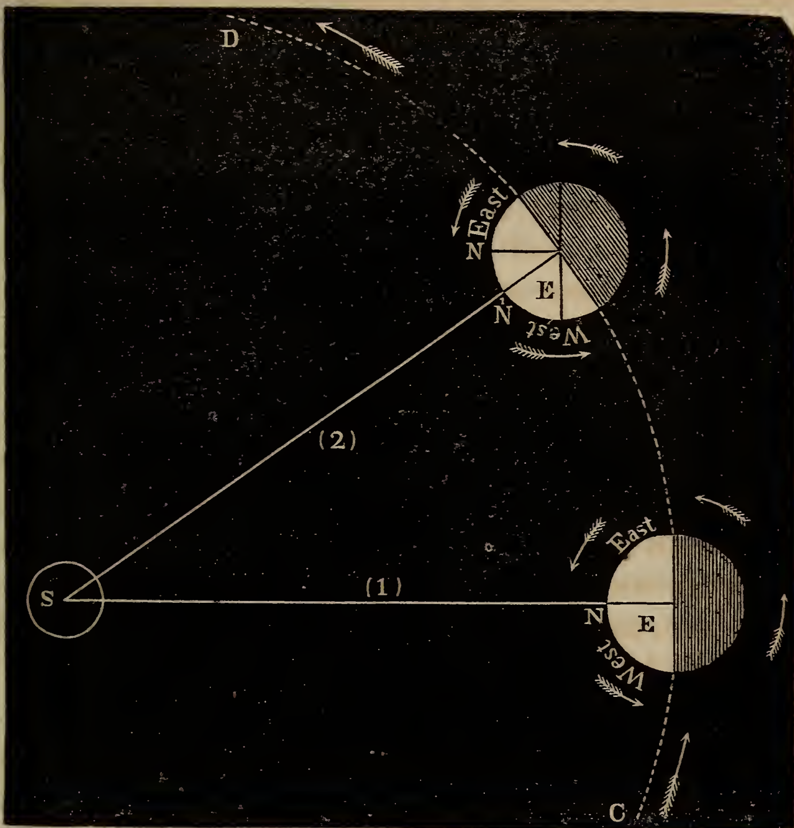
70. Of the Sidereal and Solar Day. The *sidereal*[1] *day* is the length of time that elapses between two successive transits of the *same fixed star* across the meridian—in other words, the period of the earth's rotation. The *solar*[2] *day* is the time that elapses at any place between *noon* of one day and *noon* of the next. The solar day is about *four minutes* longer than the sidereal; and the cause of this difference we will now proceed to explain.

71. The subject is illustrated by the following diagram (Fig. 21), where S represents the sun, and E, E the earth in two positions of its orbit; the *dark* semicircles are sections of the hemispheres unenlightened by the sun, and the *light* semicircles sections of the enlightened hemispheres. In *position* 1, it is *noon* at N, because there are equal portions of the illumined hemisphere on the east and west side of it. But on the next day, when the earth has made one complete rotation, and has in the meanwhile also moved along in its orbit, CD, to *position* 2, it will *not* then be *noon* at N, for the *meridian plane* now passes through N^1: the earth will have to revolve on its axis until N has arrived in the position, N^1, before it will be noon at N, and the time occupied in describing the arc NN^1, will be the *excess* of the solar above the sidereal day.

1. *Sidereal*, from *siderà*, the Latin word for stars.
2. *Solar*, from *sol*, the Latin word for the sun.

What is said of hours, minutes, and seconds? What is meant by the term *sidereal day*? What by *solar day*? How much longer is it than the sidereal day? Explain by Fig. 21.

FIG. 21.



SOLAR AND SIDEREAL DAY.

72. The difference in the length of the solar and sidereal day may be explained by the motions of the hands of a watch. Calling the time made by *one revolution* of the minute hand a *sidereal day*, a *solar day* may be compared to the extent of time that elapses from the instant the *hour* and *minute hands* are *together*, to the *next time* they are again in that

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Explain the difference between solar and sidereal time. Illustrate by the motions of the hands of a watch.

position—a period manifestly longer than the first, since the minute hand has not only to make one revolution, but must also catch up with the hour hand, which has all the while been advancing.

The difference between the solar and sidereal day is not always the same; the solar days are, therefore, of unequal length.

73. Apparent Time. Apparent time is the time computed from *noon to noon;* that is, in solar days.

74. Mean Solar Time. Mean solar time[1] is an arbitrary division of time, in which all the solar days are supposed to be of the same length, this length being found by dividing the whole amount of time in a solar year by the number of solar days in that period. Days of changing length would furnish an inconvenient method of reckoning for mankind; mean solar time is therefore employed in the common affairs of life, and constitutes *civil time.*[2]

The civil day commences at *twelve o'clock at night*, and is divided into two periods, of twelve hours each, *reckoning* from *one to twelve* from *midnight* to *noon*, and *again* from *one* to *twelve* from *noon* to *midnight.*

75. Astronomical Time. Astronomical time is apparent time, and is employed for scientific purposes. The astronomical day *commences* at *noon*, and *ends* at

1. *Mean solar time.* The word *mean* here signifies *average.*

2. *Civil time*, the *legal* time, or that appointed by a government to be used in their dominions.

Are the solar days of equal length? What is apparent time? What is mean solar time? What is civil time? Why is mean solar time adopted as civil time? When does the civil day begin, and how is it reckoned? What is astronomical time? When does the astronomical day begin? Of how many hours does it consist, and how is it reckoned?

noon on the *next* day. It consists of twenty-four hours, the hours being counted from one to twenty-four.

76. The Tropical Year. *The length of time employed by the earth in performing an entire circuit from any point in the ecliptic*, as the summer solstice,[1] *to the same point again*, constitutes a tropical[2] year, which contains three hundred and sixty-five days, five hours, forty-eight minutes, and forty-seven eight-tenths seconds (365d. 5h. 48m. 47.8sec.) The fractions of a day belonging to a year of this length would be manifestly inconvenient for the purposes of society, and for this reason the civil year is made to consist of three hundred and sixty-five entire days.

All nations who have made any progress in the art of computing time, have regarded the civil year as consisting of an even number of days. They have made, for the most part, however, at stated intervals, such corrections, that the real position of the earth in

1. The *solstices* are the two points in the ecliptic farthest from the equator. The sun is at the summer solstice about the 22d of June, and at the winter solstice about the 22d of December. These points are so called from two Latin words, *sol*, the sun, and *stare*, to stand ; because the sun appears to *stand still* at these points for a short time, before it *turns* back in its apparent course towards the equator.

2. *Tropical* year, so called, from the Greek word *trepö*, *to turn*, because the sun reverses its apparent course upon arriving at either *solstice*. In our summer, after advancing apparently as far north as the summer solstice, it then *turns* back to the south, and in winter, after retreating as far south as the winter solstice, it *turns* back to the north.

What is a tropical year? What is its length? What is the length of a civil year? Why is not the tropical year employed as the civil year? What has been the custom of all nations who have possessed a knowledge of the computation of time, in regard to the civil year?

its orbit shall on the whole correspond with the position indicated by any date in the year.

77. A moment's reflection will show the necessity of such corrections. Four civil years are shorter than four tropical years by nearly one day (4×5h. 48m. 47.8″), so that in every four years about one day would be lost in the reckoning. For if the reckoning commenced at the day of the summer solstice, on the 22d of June, four years afterwards, the earth would not have arrived at the solstice by a day's journey, and the solstice would take place on the 23d. In four years more it would happen on the 24th, and in four more on the 25th, and so on. This mode of reckoning, if continued uncorrected, would thus in course of time make either solstice, or any other position of the earth in its orbit, occur *successively* on *every day of the civil year.* We should have, therefore, at times, the summer in the winter months, and the winter in the summer months.

78. Egyptians. The ancient Egyptians regarded the civil year as consisting of 365 days. They made no corrections, and suffered their festivals, though recurring at the same date, to run through the entire natural year.

79. Mexicans. The Mexicans regarded the year as consisting of three hundred and sixty-five days, but made a correction of thirteen days for one period of fifty-two years, and twelve for the next, amounting to a correction of *twenty five days* for every *one hun-*

Supposing the year to consist of three hundred and sixty-five days only, what would happen if no corrections were made? Of how many days did the civil year consist among the ancient Egyptians? How was it computed by the Mexicans?

dred and four years. The accuracy obtained by this method is truly surprising for the excess of the actual over the civil year; viz., five hours, forty-eight minutes, and forty-seven eight-tenths seconds, multiplied by one hundred and four, gives as a product *twenty-five days*, *four hours*, *thirty-four minutes*, and *fifty-one seconds*, the error of reckoning in a *century* being only about *four and a half hours.*

80. The calendar in use among Christian nations is derived from the Romans. The civil year is here made to consist of three hundred and sixty-five days, the necessary corrections being applied at stated intervals. The first correction in this calendar was made by Julius Cæsar, and the rule was adopted of adding one day to every fourth year, by giving February twenty-nine instead of twenty-eight days. This fourth year, consisting of three hundred and sixty-six days, is called the Bissextile or leap-year.

81. But the Julian correction was too great, because the year was thereby assumed to be three hundred and sixty-five days and six hours long, when, in fact, it is about eleven minutes shorter—an error which, in the course of nine hundred years, would amount to very nearly seven days.

82. In the year 1582, it had amounted to about ten days, and a reform was made by Pope Gregory XIII. The remedy was obvious, and consisted in omitting ten nominal days, calling the day next succeeding the 4th of October the 15th, instead of the 5th. This

What is said respecting accuracy of their correction? How much did the error amount to in 1582? By whom was a reform made? How was the error corrected?

change was made at once in all Catholic countries, but was not adopted in England until the year 1752, by which time the error had amounted to eleven days. The *change of style*, as it is termed, was there effected by an Act of Parliament, decreeing that the day after the 2d of September, old style, should be called the 14th, which was the first day of the new style; and by the same authority, the year, which before had begun on the 25th of March, was made to begin on the 1st of January. This latter change was accomplished by making the preceding year (1751) to consist of nine months only, causing it to end at the beginning of the 1st of January, instead of the 25th of March. The year 1752 commenced on the 1st of January.

CHAPTER V.

OF THE EARTH'S ORBIT, AND THE SEASONS.

83. THE EARTH'S ORBIT. Astronomers have proved that the earth *revolves* about the sun. The path it describes is called its orbit. This orbit is not a circle, but an ellipse, the sun being situated in one of the foci. The average distance of the earth from the sun is 95,000,000 of miles; the extent of its orbit, 600,000,000; and through this immense space the earth sweeps

Where was the change at once adopted? When introduced into England? What was then the amount of error? How was the change of style effected, and what alterations were made in the calendar? How was the second change accomplished? What is the subject of Chapter V.? What have astronomers proved? What is the earth's distance from the sun? What the extent of its orbit?

in the course of a year at the rate of 19 miles per second. The earth is kept in its path by the attractive force of the sun, and its different positions in respect to the latter during its revolution, give rise to the *seasons* of the year.

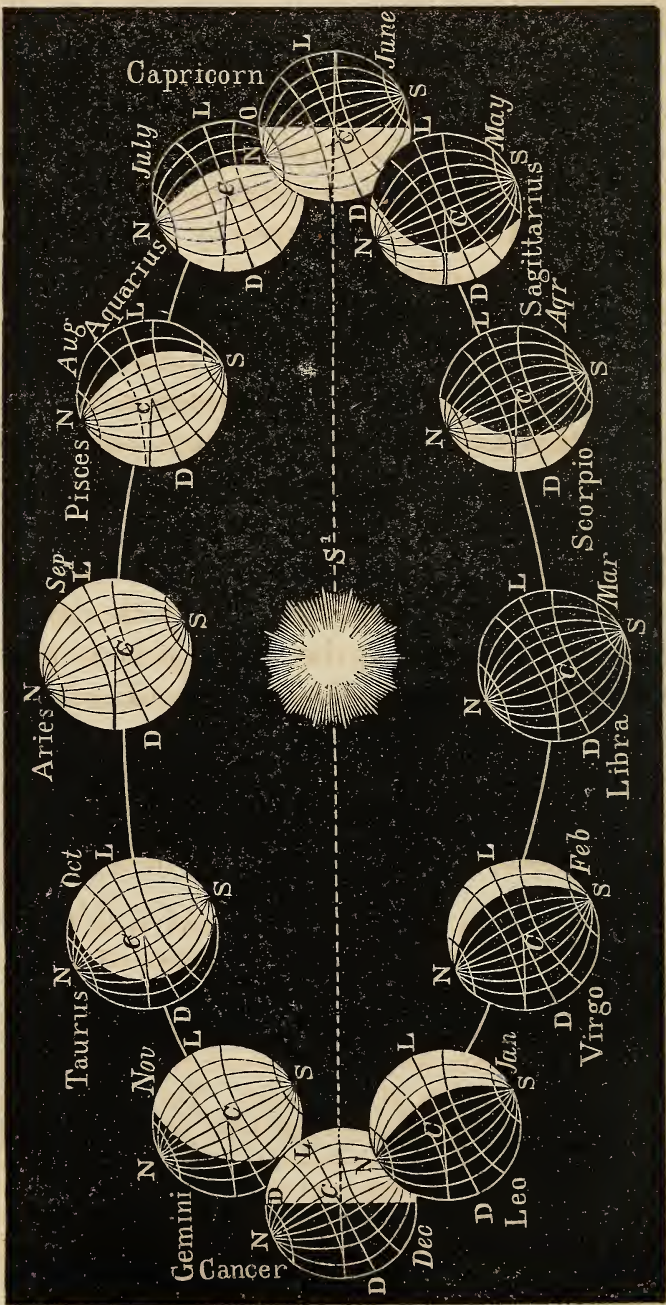
84. THE SEASONS. The changes of the seasons depend upon *three causes*. *First*, the fact that the sun illumines but one half of the earth at a time; *Secondly*, that the axis on which the earth revolves is inclined to the plane of the ecliptic; *Thirdly*, that its position at any one point in the earth's orbit is invariably parallel to its position at every other point.

85. By the aid of Fig. 22,[1] we shall be enabled to perceive how the variety of the seasons is produced by the causes just mentioned. In this cut, S^1 represents the sun, the *twelve globes* indicate the several *positions* of the earth in its orbit, in the successive *months of the year* with the *corresponding signs*, and the dotted line CS^1C gives the *direction* of the *plane* of the *ecliptic*. In the several globes C is the centre of the earth, DCL is an equatorial diameter, and shows the *direction* of the *plane* of the *equator*; the diameter at right angles to this, viz., NCS, is the *axis* of the *earth*, and its *extremities* the *north* and *south* poles—N representing the north pole. The two large arcs of circles on each side of DCL are the

1. The figure is here drawn as if the plane of the ecliptic was viewed *obliquely*; the orbit of the earth, therefore, *appears* more *eccentric* than it actually is.

Upon how many causes do the changes of the seasons depend? Name them. Explain the figure.

FIG. 22.



THE SEASONS.

tropics, and the small arcs near the poles the *arctic*[1] (northern) and *antarctic*[2] (southern), or *polar circles*. The lines drawn in each globe from C, *parallel* to CS^1C, indicate the *position* of the *plane* of the *ecliptic* with respect to that of the *equator*.

86. Spring. At the *vernal equinox* (March), when the earth is in Libra,[3] the *circle of illumination* extends to the *two poles*,[4] the sun is in the plane of the equator, and is seen from the earth in this plane. As the earth *rotates* on its *axis*, every point upon its surface is then *half the time* of *one rotation* in darkness, and the *other half* in *light*. In this position of the *earth*, the *days* and *nights* are therefore *equal* all over the globe.

87. Summer. When the *earth* is in *Capricorn* at the *northern summer solstice* (June), the axis being unchanged in direction, the *north pole* is presented towards the sun, and the *circle of illumination extends*

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1. *Arctic* (northern), from the Greek word *arktos*, meaning *bear*, because the *north* pole of the heavens is in the constellation called *the bear*.

2. *Antarctic*, from the Greek *anti*, opposite, and *arktos*, bear : i. e., *south*.

3. At the time of the vernal equinox the earth is in Libra, but the sun, as *viewed from the earth*, appears on the *opposite side* of the heavens, in the *sign Aries*.

4. In the figure, at the *vernal equinox*, the *dark hemisphere* of the earth is presented to our view, the illuminated hemisphere being *toward* the sun, as shown in the globe at Aries. The *circumference* of the circle of illumination, both at Libra and Aries, is DNLS

At the time of the vernal equinox, what is the position of the circle of illumination in respect to the poles? In what plane is the sun then situated, and in what plane seen? What is said in regard to the length of the days and nights at this time? What is the position of the circle of illumination at the northern summer solstice?

beyond the pole, N, to the *arctic* (northern) *circle*, while in the *southern hemisphere* it *falls short* of the *south pole*, S, reaching only to the antarctic (southern) circle.

The sun is now seen from the earth in the direction CS^1, having *apparently moved* toward the *north* the extent of the angle DCS^1. This angle DCS^1 *measures* the *inclination* of the *plane* of the *ecliptic* to that of the equator, which is termed its *obliquity*, and is equal to about *twenty-three and one half degrees* (more nearly 23° 27′ 38″).

88. The exact distance that the *circle of illumination* now *overlaps* the *northern* and *falls short* of the *south* pole, is *equal* to the *obliquity* of the *ecliptic;* for since the time of the *vernal* equinox, the sun in his *apparent motion* has departed from the plane of the equator at the *same rate* that the plane of the circle of illumination has departed from the poles. The *parallels* of latitude, therefore, to which the circle of illumination extends at the *summer solstice*, and which are termed the *arctic* and *antarctic* circles, are each about twenty-three and a half degrees from their respective poles. The regions inclosed within these circles are called the *frigid zones.*

89. At the time of the *northern summer solstice, continual day* reigns at all those places that are situated within the arctic circle, inasmuch as the daily rotation of the globe does *not carry them without* the *circle of illumination;* while over the *regions* that lie within the antarctic circle, an *unbroken night*

What is the obliquity of the *ecliptic*? Its extent? What is the extent of the arctic and antarctic circles, and why? What are the frigid zones? Where does continual day prevail at the time of the northern summer solstice, and why? Where unbroken night, and why?

prevails, because the earth in its rotation *does not* at this time *bring them within* the *circle of illumination.* It is evident, from an inspection of the figure, that in the *northern hemisphere*, since half the axis, CN, falls within the plane of the circle of illumination, that the *days* will *increase* in length, and the *nights decrease* from the equator to the *arctic circle*, where there exists a *continual day.* In the *southern hemisphere*, since half the axis, CS, *falls without* the *plane* of the *circle of illumination*, the *days* will *decrease* and the *nights increase* in length from the equator to the *antarctic circle*, where an *uninterrupted* night *prevails.*

90. At the vernal equinox, the days and nights, as we have seen, are *equal* in *length.* A difference in this respect commences as soon as the earth departs from this point, which gradually increases up to the time of the *summer solstice*, when the difference in the lengths of the days and nights is greatest.

91. At the summer solstice, the sun's rays fall perpendicularly upon the surface of the earth in the direction S^1C, at a point about twenty-three and a half degrees (23° 27′ 38″) north of the equator; the *parallel* of latitude passing through this point is termed the *northern tropic*, or TROPIC[1] OF CANCER, be-

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1. *Tropic*, derived from the Greek word *trepō*, to *turn about*, because when the sun, in its *apparent advance* to the *north*, has arrived at a point about twenty-three and one half degrees from the equator, it then *turns about* and moves toward the south.

What is said respecting the lengths of the days and nights in the northern hemisphere? In the southern? When do these differences in length begin? When greatest? How is the position of the northern tropic determined?

cause the sun as now seen from the earth appears in the sign Cancer.

92. AUTUMN. As the earth departs from the *northern summer solstice*, and by degrees comes round to the *autumnal equinox* (September), the circle of illumination gradually approaches the poles, *shortening* the *days*, and *lengthening* the *nights* in the *northern* hemisphere, and producing the *contrary effects* in the *southern*. When the earth has arrived at the autumnal equinox in the sign Aries, the *circle of illumination again* passes through *both poles*, and the days and nights are once more *equal* in *length*.

93. WINTER. The earth, moving onward in its course toward the *northern winter solstice*, the circle of illumination also changes its position, *falling short* of the north pole more and more, and gradually extending beyond the south pole—increasing the duration of the nights in the northern hemisphere, and diminishing that of the days; while in the southern hemisphere the opposite effects are produced. At the winter solstice, when the earth is in the sign Cancer (December), this change has reached its full extent; the circle of illumination then reaches beyond the south pole to the antarctic circle, and the regions within this circle now enjoy a continual day. But in the northern hemisphere the circle of illumination extends only to the arctic circle, and the space within the latter is now overshadowed by a *constant night*.

What is it called? What changes take place as the earth moves toward the *autumnal equinox?* What is said of the *circle of illumination*, and of the *days and nights* at the equinox? Describe the changes that occur as the earth moves toward the northern winter solstice. At the northern winter solstice, what is said in reference to the circle of illumination, and the lengths of the days and nights? Where does there now reign an unbroken day? Where an unbroken night?

94. As the earth withdraws from the northern winter solstice, and again returns to the vernal equinox, the circle of illumination by degrees again approaches the poles, and the differences between the lengths of the days and nights grow less and less until they cease to exist, when the vernal equinox is attained.

95. A glance at the figure shows us that the sun at the northern winter solstice is seen *south* of the *equator* in the direction CS^1. And it is seen at this point as far *south* of the *equator* as it was *north* at the time of the northern summer solstice, viz., 23° 27′ 38″. The circle of illumination, therefore, at the two solstices, in turn, *overlaps* and *falls short* of the *same pole* the *same extent of space.*

96. The place where the line S^1C falls upon the surface of the earth south of the equator, is the place of that parallel of latitude, which is termed the southern tropic, and which is about twenty-three and a half degrees (23° 27′ 38″) south of the equator. It is called the TROPIC OF CAPRICORN.

97. That portion of the surface of the earth included between the *northern* and *southern tropics* is called the TORRID ZONE, and those parts that lie between the two tropics and the *arctic* and *antarctic* circles, the NORTH and SOUTH TEMPERATE ZONES.

What changes take place as the earth returns to the vernal equinox? How far south of the equator is the sun seen at the northern winter solstice? How much does the circle of illumination at the two solstices *overlap* and *fall short* of the same pole? How is the position of the southern tropic determined? What is its extent? What is it called? What is meant by the torrid zone? What by the temperate zones?

98. We must bear in mind, in this explanation, that when it is *winter* in the *northern hemisphere* it is *summer* in the *southern*, and when it is *winter* in the *southern hemisphere* it is *summer* in the *northern.*

99. POLAR WINTERS. From what has just been stated, it appears that within the polar circle there are long intervals of day and night; while at the poles themselves there is but *one day* and *one night*, each of *six months duration.* But several causes exist which tend to shorten the dreary winter of the frigid zones. The principal of these are *refraction* and *twilight.*

When the sun is a little *below* the horizon, the rays that proceed from it are so bent down (refracted) towards the earth in coming through the air, that the orb is actually seen above the horizon. The refraction in the polar regions is very great.

An extraordinary instance of refraction is said to have occurred in the year 1597, at Nova Zembla, in north latitude $75\frac{1}{2}°$, the sun appearing above the horizon, when it was really *seven times* the length of its *apparent diameter below it.* The effect, therefore, of refraction upon the sun is to increase the length of the day. The combined effect of *refraction* and *twilight* in shortening the *polar night* is so great that at the *very poles*, its duration is only *seventy days* instead of *six months;* and even the obscurity that then

What must we bear in mind? What is evident from the facts that have just been stated? What is the effect of refraction upon the sun? What extraordinary instance of refraction occurred at Nova Zembla in 1597? What is said of the combined influences of refraction and twilight in shortening the polar night? What other mitigating influences exist?

prevails is relieved by the constant presence of the *moon*, when it passes north of the equator; and likewise by the frequent and fitful splendors of the *northern lights.*

PART SECOND.

SOLAR SYSTEM.

CHAPTER I.

THE SUN.

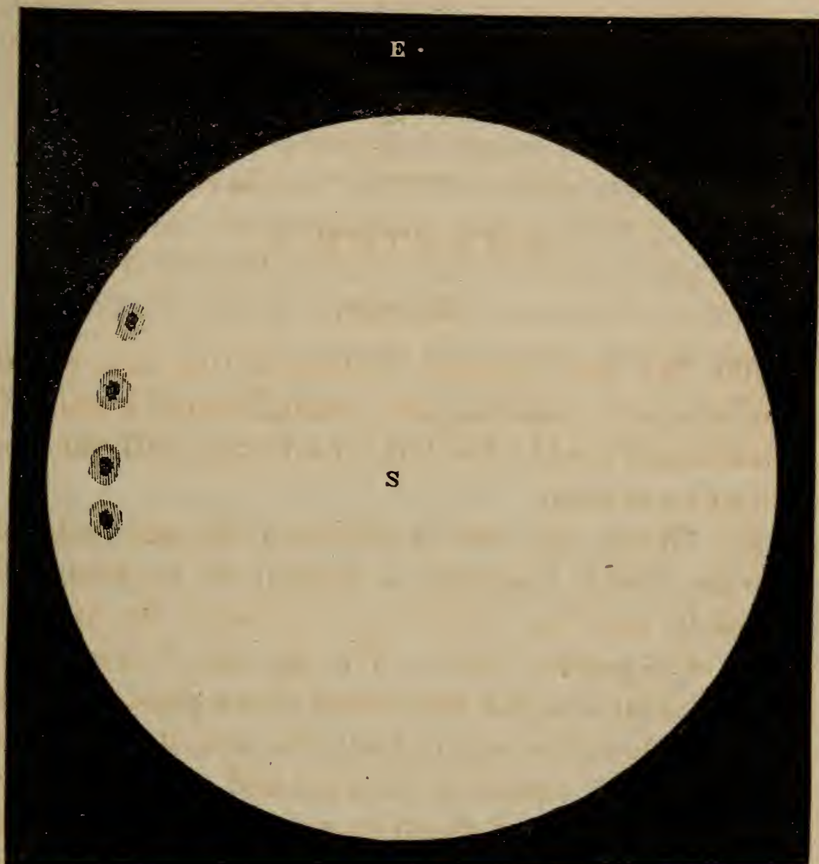
100. We now proceed to describe the SUN, a *vast luminous* and *material globe*, around which a train of *planets* and *comets* revolve, constituting with *the sun* the SOLAR SYSTEM.

101. When the sun is observed through colored glasses, which intercept a portion of its heat, and lessen its dazzling brilliancy, it presents the appearance of a *perfect circle.* We are not, however, to suppose that it is *flat* and *round* like a plate. While we revolve on the earth about the sun, the latter at the *same time rotates* on its *axis*, and yet *always appears round*—a fact which proves it to be a *globe* like our earth, for it is only a *spherical body* that will appear of a *circular form* when viewed from any direction.

102. DIAMETER. The sun's diameter is 887,036 miles—nearly *one hundred and eleven* times greater than that of the earth. In Fig. 23, the two circles S and E represent the relative magnitudes of the sun and earth, the diameter of the larger circle being 111 *times* greater than that of the *smaller*.

What is the subject of PART SECOND? What of Chapter I.? What is said of the SUN? What *form* does it present when viewed through colored glasses? Is it flat and round like a plate? What proof have we that it is a globe? What is the length of the sun's diameter? How much larger than that of the earth?

FIG. 23.



RELATIVE MAGNITUDES OF THE SUN AND EARTH.

103. SIZE OR BULK. If we had *two* cubical boxes, *A* and *B*, and the *length*, *breadth*, and *height* of A were *severally* 2 *feet*, while the *length*, *breadth*, and *height* of B were *each* 3 *feet*, the size of A would be found by *multiplying* 2 into itself *twice;* thus: 2 × 2 × 2, the *product* of which is 8. The size of B would be obtained by multiplying 3 in the same manner; thus: 3 × 3 × 3, the *product* of which is 27. The

Explain how the *size* of the sun is ascertained.

numbers 8 and 27 are respectively the cubes of 2 and 3, and the *size* of the *boxes A and B* have therefore the same relations to each other as the *cubes* of their *respective heights*, *lengths*, or *breadths.*

104. Now mathematicians have proved *that the sizes of spheres are to each other as the* CUBES *of their* DIAMETERS. Calling then the *diameter* of the earth 1, and its *size* 1, and the diameter of the sun 111, the following proportion will give us the *size* of the *sun* compared with that of the *earth:*

Cube of the Earth's diameter.		*Cube of the Sun's diameter.*		*Size of the Earth.*		*Size of the Sun.*
$1 \times 1 \times 1 = 1$	:	$111 \times 111 \times 111$	: :	1	:	1,367,631;

the last term being obtained by the common rule of three. The sun is thus found to be about *one million four hundred thousand times* (1,400,000) *larger* than the *earth.*

105. QUANTITY OF MATTER IN THE SUN. Astronomers have ascertained from reliable calculations that the *sun* is formed of much *lighter materials* than the *earth;* so much so, that if *four cubic feet* of the *sun's matter* at its average density could be transported to the *surface* of our globe, it would weigh but a trifle more than *one cubic foot* of the *earth's matter* taken at its average density. The quantity of matter in the sun is, therefore, about 350,000 *times* ($\frac{1}{4}$ of 1,400,000) *greater* than the *quantity of matter in the earth.*

106. WEIGHT OF BODIES AT THE SURFACE OF THE SUN. A body which weighs 100 pounds on the *surface of*

How much larger is it than the earth? Is the *matter* of the sun lighter or heavier than that of the earth? How much lighter? How much more matter is there in the sun than in the earth?

the earth, would, if transported to the *sun*, weigh nearly 2800 pounds. The *weight of a body* on our globe, or on any other, is a *measure* of the *force with which it is drawn toward the centre of the globe*;[1] and when the globes *vary in size*, the magnitude of this force is dependent upon *two circumstances*. *First*, the *relative quantities of matter* in the *two bodies*; *secondly*, the *comparative distances* of the *surfaces* of the globes *from their respective centres*.

107. If there were two globes, M and N, and N contained *ninety times as much matter* as M, it would, in virtue of this *greater amount of matter*, draw any body placed upon its surface down toward its centre, with *ninety* times more power than if the same body was placed on the surface of M. But if the *distance* from N's *centre* to its *surface* was *three times greater* than the distance of M's *centre* from its *surface*, the body placed on N's surface would in virtue of this circumstance be drawn toward the centre with *nine* (3 × 3, the square of 3) times *less power* than when placed upon M's surface. By being removed from M to N, the *weight of the body* would therefore be *increased* 90 *times*, and *diminished* 9 *times*,[2] which is the same as saying that the *weight of the body* would be *increased* 10 *times*.

1. This *force* is called the *force of gravity*.

2. This rule is *technically* expressed by saying that the *force of gravity varies directly* as the *quantity of matter* in the *attracting* body, and *inversely* as the *square* of the *distance* from its *centre*.

If a mass of matter weighed 100 pounds on the surface of the earth, what would be its weight on the surface of the sun? What is the weight of a body the measure of? Upon what *two circumstances* does this force depend? Give the explanation. What is the *law* respecting this force, in relation to the *quantity of matter*? What in relation to the distance from the *centre* to the surface of the attracting globe?

108. Now to apply this rule to the sun: If a mass of matter which weighs a pound at the surface of the earth were to be transported to the *surface of the sun*, its weight would be *increased* 350,000 *times*, in consequence of the greater *amount of matter in the sun*, and *diminished* 12,321 *times* (111 × 111), because it would be removed 111 times *farther* from the *centre of the body* on which it then rested than when at the earth. *Multiplying*, therefore, 1 by 350,000, and *dividing* this product by 12,321, the quotient is 28.4, which is the *weight in pounds* of the given mass at the *sun's surface.* A body, therefore, which weighs one *hundred* pounds at the surface of the earth, would weigh about *twenty-eight hundred* pounds at the surface of the sun. A person weighing at the earth 150 pounds, would weigh at the sun nearly two tons.

109. Solar Spots. When the sun is viewed through a telescope, furnished with dark-colored glasses, and its brilliancy is thereby so much diminished that the eye can gaze upon it without injury, *dusky spots* are usually seen upon its surface. Each spot consists of two parts, the *central portion* or *nucleus*,[1] which is the *darkest*, and around this is a *lighter shade* called the *penumbra*,[2] usually having the same form as the spot, though this is not always the case, as several spots are at times included within the same penumbra.

110. The spots are not *permanent*, for they are sometimes seen bursting out *suddenly* from the bright

1. *Nucleus*, from the Latin word *nucleus*, a kernel.

2. *Penumbra*, from the Latin *pene*, almost, and *umbra*, a shadow: i. e., a *light shade.*

Apply the rule found to the sun What have been detected upon the sun's disk?

disk[1] of the sun, and then as rapidly *disappearing;* one observed by Hevelius *appeared* and *vanished* within *seventeen hours.* Their *form* and *size* also *vary* from *day to day*, and even from *hour to hour.* Sometimes they are seen to *divide* and *break up* into two or more *separate portions.*

111. SIZE AND NUMBER. The *extent* and *number* of spots almost exceed belief. M. Schwabe, of Dessau, who has examined them with great attention, has discovered many without the aid of the telescope. In June, 1843, one was seen by him with the *naked eye* for the *space of a week*, which was about 77,000 miles in diameter—nearly TEN TIMES as broad as the earth. Another, mentioned by Sir John Herschel, had a diameter of 45,000 miles. This gentleman also observed at the Cape of Good Hope, toward the close of March, 1837, a *cluster* of spots that covered a space 3,780,000,000 miles in extent—an area *nineteen times greater than the entire surface of our globe.*

112. These groups often comprise a great number of individual spots. M. Schmidt, of Bonn, counted no less than *two hundred* in a large cluster that he examined on the 26th of April, 1826, and in August of the preceding year, he detected *one hundred and eighty* in a single group. It is a remarkable fact, that

1. *Disk*, the *face* of the sun, moon, or a planet, as seen from the earth, from the Latin word *discus*, a quoit.

Describe the spots. Their changes. Within what time has a spot been known to appear, pass through its changes, and vanish? What is said respecting their size and number? Who has examined them with great attention? What has he discovered? How large a spot did he behold in June, 1843? How did it compare in breadth with the earth? Give other instances of the magnitude of spots, and groups of spots. How many individual spots do the groups sometimes comprise? What is regarded as a remarkable fact?

although the spots extend over such vast spaces, they seldom last more than *six weeks.*

113. The *number of spots* varies much in different years. It occasionally happens, that during an entire year, spots may be seen upon the sun *every clear day*, while during another year it will be *free from* them for *weeks*, and even *months*, together. M. Schwabe, who has closely observed the sun for the space of *twenty-five years*, has clearly established this fact; for he found that in the years 1836–7–8 and 9, there was not a *single day* on which the sun was free from spots, while in 1843, there were no less than 145 *clear days* when *spots could not be seen.*

114. In addition to the spots, the disk of the sun is also diversified by *branching ridges* and *streaks*, *more luminous* than the general surface. These brilliant lines are usually found in the vicinity of vast spots and clusters, and from their midst the spots themselves not unfrequently break out and spread.

In Fig. 23, four spots are delineated on the solar disk, and in Fig. 24, *spots* and *clusters* are shown under their various appearances, the *nucleus* in each being represented by the *darkest* part, and the *penumbra* by the *lightest.*

115. Motion of the Spots. If the sun is watched attentively from *day to day* a spot at its *first* appearance will be perceived on the *east side* of the sun, and is then seen to move gradually *across the solar disk*, until at length it *disappears* on the *western side.* In

Does the number of spots vary in different years? Give instances. How is the sun's disk otherwise diversified? What is stated in respect to these brilliant lines? On what side of the sun does a spot first appear? How does it move, and where disappear?

FIG. 24.

SOLAR SPOTS.

this passage it occupies about a *fortnight*, which is the *period of its visibility*. After the *same lapse of time* it *reappears* on the eastern edge.

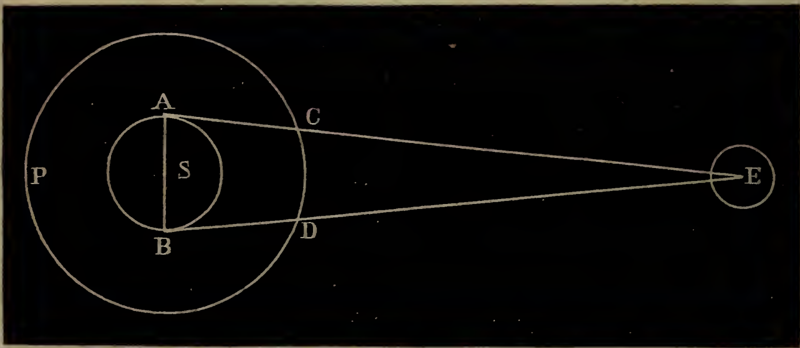
This is true with respect to *all spots* which have *been observed for this purpose*, and whose *returns* have been *noted;* and the fact that their periods of *visibility* and *invisibility* are *equal*, *proves that the spots are in contact with the sun.* For if they were at any considerable distance from the body of the sun, the *time of their visibility* would be *less* than that of their *invisibility*, as can be easily shown by the aid of Fig. 25.

116. In this figure the circle E represents the *earth*, and circle ASB the *sun*. Now if *a spot was not in contact with the sun's surface*, but moved in the large circle CDP, it is obvious that it would be *impossible* for a person at E to see it crossing the sun's surface *except while it was passing through the arc DC.* At D and C the spot would *appear* on the *edges* of the

What is the period of a spot's visibility and invisibility? What is proved by the equality of these periods? Show from the figure why the spots must be in contact with the sun.

solar disk at B and A, and it would be *invisible all the time* it was passing from C *through the rest of the circumference of the large circle*, round to D again.

FIG. 25.



SOLAR SPOTS—PERIODS OF VISIBILITY AND INVISIBILITY.

Now, as the *arc* CD is much smaller than the other part of the circumference of the large circle, to wit, CPD, the spot, if it moved uniformly, must be *visible* for a *much shorter time* than it is *invisible*, *which is not the case.*

But if the spot is upon the surface of the sun, it will take as *long a time for it to move from* B *to* A toward E, *as from* A round to B again, since the diameter ASB divides the circumference of circle S into two equal parts. The times of visibility and invisibility must consequently now be equal—a conclusion in accordance with all observations.

117. The time that elapses between the appearance of a spot at any point on the solar disk, and its reappearance at the same point, is therefore about *four* weeks (more nearly $27\frac{1}{4}$ days). A spot was observed

How long a time elapses between the appearance and reappearance of the same spot at the same point on the sun's surface? How many revolutions has a spot been known to make?

in the year 1676, A. D., which made nearly three revolutions.

118. Rotation of the Sun on its Axis. It is by means of the *solar spots* that the *rotation of the sun on its axis is ascertained*, and the *period* of its *rotation* determined. The *equality* in their times of *visibility* and *invisibility*, and the *uniform direction* they pursue in their passage across the sun's disk, lead to the conclusion that the spots have *no motion* of their own; but, being connected with the body of the sun, are all carried forward from *west to east* by the rotation of this great orb on its axis. Astronomers have differed somewhat in respect to the *period* of *rotation*, but the best and most careful measurements show that the sun *rotates once* on its *axis* in the space of 25d. 7h. 48m.

119. Physical Nature of the Sun. Various opinions have been entertained by astronomers respecting the *constitution* of this immense body. La Place considered the sun to be a *fiery globe* of *solid materials*, subject to terrible volcanic action, and that the *spots* are *deep cavities*, from whence issue at intervals vast floods of burning matter, which pour over the surface of the sun.

120. Sir William Herschel regards the sun as a *dark solid body*, surrounded at a *considerable distance* by a stratum of *cloudy matter*, *above* which, and *nearest to us*, floats an *intensely hot* and *luminous* atmosphere. Whenever these two envelopes, the *cloudy* and the *bright*, are agitated by any causes existing in

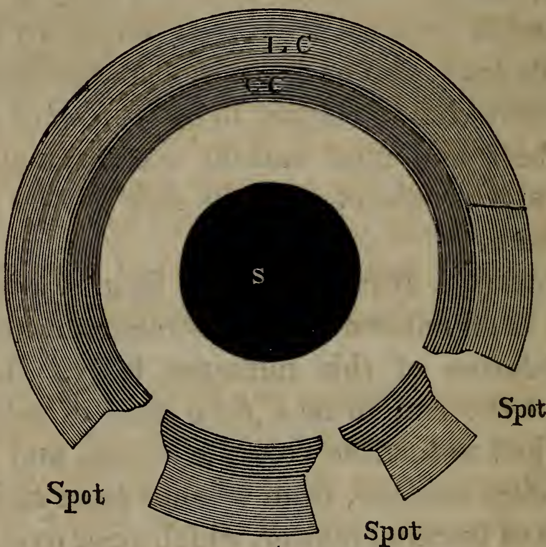
---

Are the spots supposed to have a motion of their own? What is their motion the same as? In what time does the sun complete a rotation? State La Place's opinion respecting the constitution of the sun. State Herschel's.

the sun, it frequently happens that they are *rent asunder*, and we perceive *through the opening* the *dark body* of the *sun.* Under these circumstances, a *spot appears.* The *black portion* of the sun disclosed, is the *nucleus* of the *spot*, and the *portions* of the *cloudy stratum illumined* by the *light* from the *luminous canopy* form *the penumbra.*

121. In Fig. 26, a section of the sun is delineated

FIG. 26.



THE SUN—HOW CONSTITUTED.

as it would appear, if Herschel's views are *true.* In this cut the *dark circle*, S, represents the *body of the sun*, the *deeply shaded ring*, CC, the *cloudy canopy*, and the *outer ring*, LC, of a *lighter shade*, the *luminous stratum.* The *ruptures* in the rings are the *places of the spots.* Looking through any of these openings a *portion* of the *dark* body of the sun would

Describe the figure.

be seen in the centre, forming the *nucleus*, while the *shelving edges* of the *cloudy stratum* would constitute the *penumbra*.

122. The theory of Sir William Herschel affords as satisfactory an explanation of the phenomena of the sun as any that has been advanced. Spots 45,000, and even 77,000 miles across, close up in *six weeks*. The edges must, therefore, approach each other with a *joint velocity*, varying from *one thousand* to nearly *two thousand miles a day*—a swiftness of motion which agrees better with the idea, that the spots are *ruptures* in *fluid* or *gaseous* matter, than that they are *cavities* in a *firm* and *solid mass*.

But a late experiment of a French philosopher has now proved that the *brilliant visible surface* of the sun *cannot consist* of either *solid* or *fluid* matter intensely heated, but is composed of *inflamed gaseous* matter—a fact which strongly corroborates Herschel's views.

123. Temperature at the Sun's surface. In gazing, then, upon the sun, we look not, according to Herschel's theory, upon the *body itself*, but on the *canopy* that *envelops it;* and from the latter flow all the *light* and *heat* that cheer and invigorate the various orbs that revolve around this vast luminary.

124. The *temperature* at the sun's visible surface is *very great*, for the hottest fires that rage in the fiercest furnaces, but feebly shadow forth the heat that there prevails. It can be shown, from reliable calculations, that if a given surface, as one *square mile*, receives,

Give the reasons why Herschel's theory is most satisfactory. What has been lately proved by a French philosopher? From whence do the solar light and heat emanate? What is said respecting the temperature at the sun's surface?

at the *distance* of the *earth from the sun*, a *given amount of heat*, that the *same extent* of *surface at the sun* must be *three hundred thousand times hotter.* Moreover, the *brightest flame* man can produce, as the Drummond light (which is so dazzling that it is painful to look upon), appears as a *dark spot* upon the sun when placed between the eye and the solar disk, being virtually *extinguished* by the sun's surpassing splendor.

CHAPTER II.

THE MOON.

125. This beautiful orb is a constant attendant of the earth in its circuit about the sun, revolving meanwhile in the *same direction* from *west to east around* the *earth* as its *centre.* Her influence upon our globe is by no means unimportant. Equal in *apparent* size to the sun, her mild splendor dissipates the shades of night, while her attractive power sensibly affects the *motions of the earth*, and sways the *tides of the ocean.*

126. Distance. This orb is the *nearest to us* of all celestial bodies, her *average distance* being about 239,000 miles.

127. Diameter. The moon's diameter, according to Prof. Mädler, is found to be 2160 miles long—an ex-

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How much hotter is a given surface at the sun than at the earth? What is said respecting the splendor of the solar light? What is the subject of Chapter II.? What is said respecting the motions of the moon, and her influence upon our globe? What is said in regard to her distance from the earth? How far is she from the earth? What is the extent of her diameter?

tent a little greater than one fourth of the *earth's diameter*. The *relative sizes* of the *earth* and *moon* are shown in Fig. 27, where E represents the *earth*, and M the *moon*.

FIG. 27.

RELATIVE SIZES OF THE MOON AND EARTH.

128. Moon's Phases. The moon has no light of her own, but shines by the *reflected light* of the sun, the hemisphere presented to the sun being *illumined* with his rays, while that which is turned from him is *shrouded* in *darkness*. The *relative positions* of the *sun*, *moon*, and *earth*, are not *always* the *same*, and hence arise those *periodical fluctuations* in the lunar light, which are termed the *phases*[1] *of the moon*.

129. From New Moon to the First Quarter. At *new moon*, the *centres* of the *sun*, *moon*, and *earth*, are situated in nearly the *same straight line*, the *moon* being in the *middle*, at which time she is said to be in *conjunction*. In this position, the *unenlightened* part of the moon is *turned towards* the *earth*, and the orb is lost to our view. In a short time it advances so far

1. *Phases*, from the Greek word *phasis*, meaning an appearance.

Does the moon shine by her own light? What is the cause of the periodical fluctuations in the lunar light? What name is given to these fluctuations? Describe the phases of the moon from new moon to the first quarter.

to the *east* of the *sun* as to become visible in the *west* soon *after his setting.* Its bright portion then appears of a *crescent* form, on that side of the disk which is *nearest* to the sun, while the remaining dark part of the disk is just discerned, being faintly illumined by the earth-light.[1] In this position the *convex part* of the moon's crescent is *towards* the *sun*, and the *line* which *separates* the *illumined* from the *unillumined* part, called the *terminator*, is *concave.*

130. Each succeeding night the moon is found farther eastward of the sun, and the bright crescent occupies more and more of her disk, the terminator gradually growing less *curved*, until when the moon is 90° distant from the sun, half the disk is illuminated, and the *terminator* becomes a *straight line;* the moon is then *in her* FIRST QUARTER. The *extremities* of the moon's crescent are called *cusps*,[2] and from the time of new moon to the first quarter, the moon is said to be *horned.*

131. FROM THE FIRST QUARTER TO FULL MOON. As the moon *advances* beyond her *first quarter*, the *terminator* becomes *concave toward* the *sun*, and more than half the lunar disk is illuminated, when the moon is said to be *gibbous.*[3] At length, in her *easterly* prog-

1. *Earth-light.* Some of the *light* which falls upon the earth from the sun is *reflected* to the moon, and a portion of this is *reflected back* again from the *moon's surface to the earth* This is the *earth-light.* The amount thus reflected from the lunar surface must necessarily be very small, but it is sufficient to enable us faintly to discern the outlines of the moon.

2. *Cusps*, from the Latin word *cuspis*, meaning the *point* of a spear.

3. *Gibbous*, from the Latin word *gibbus*, meaning *swelled out.*

ress, she reaches her *second quarter*, and the *sun*, *earth*, and *moon*, are *again* in nearly the *same straight line*, the *earth*, however, being in *the middle*. The moon is now in *opposition*, 180° from the sun, *rising in the east* at about *sunset;* and as her *whole* enlightened *disk* is *turned toward the earth*, she is now at the FULL.

132. FROM FULL MOON TO THE THIRD QUARTER. After *opposition*, the *enlightened* part of the moon again becomes *gibbous* as she returns toward the sun, and she rises later and later every night. When she has arrived within 90° of the sun, she is then in her THIRD QUARTER, the terminator is once more a straight line, and the bright portion of the orb again *fills up* one *half* of *the disk*.

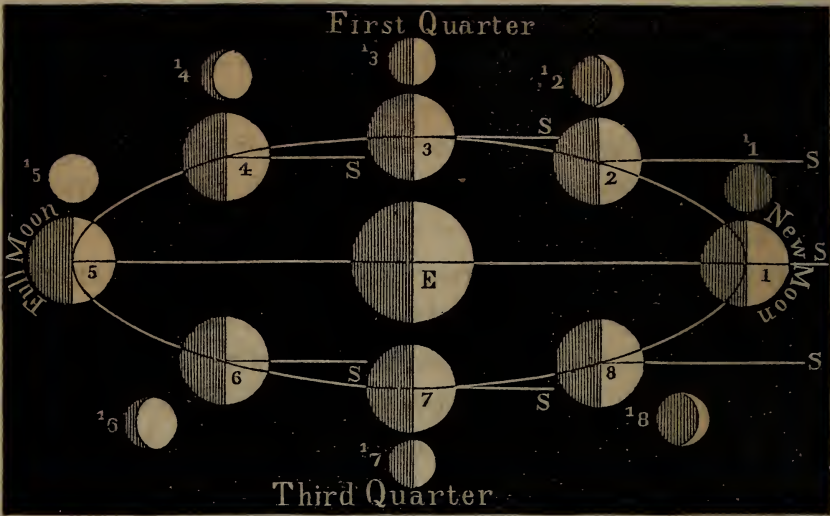
133. FROM THIRD QUARTER TO NEW MOON. After passing her third quarter the moon *resumes* her *crescent shape*, rising *early* in the *morning before the sun*. As her time of rising approaches nearer and nearer to that of the sun, the glittering crescent contracts in breadth, until at length the moon arriving again at CONJUNCTION, its light *entirely disappears*. The positions of the moon, where she is midway between any two adjacent quarters, are termed her *octants*.[1]

This subject is further illustrated by Fig. 28, where S8, S1, and all lines *parallel* to these, indicate the direction in which the sunbeams come, and E represents the earth. The *circles* 1, 2, 3, 4, 5, 6, 7, and 8,

1. *Octant*, derived from the Latin word *octo*, *eight*—an octant being distant from its *adjacent quarters* one *eighth part* of the moon's *orbit*.

From the full to the third quarter. From the third quarter to new moon. What are the octants?

FIG. 28.



MOON'S PHASES.

show the places of the moon in her orbit, at *conjunction* (1), the *first octant* (2), the *first quarter* (3), the *second octant* (4), at *opposition* (5), the *third octant* (6), the *third quarter* (7), and at the *fourth octant* (8); while the *white portions* of the circles 1^1, 2^1, 3^1, 4^1, 5^1, 6^1, 7^1, and 8^1, exhibit the *phases* of the moon in all the *preceding positions*. Thus, when the moon is at the *first octant* (2), the *phase corresponding* to this place is displayed in circle 2^1, that of the *first quarter* (3), in circle 3^1; and so of all the other positions.

134. The points in the moon's orbit, where she is one quarter of her orbit distant from the sun, are called her quadratures.[1] Fig. 29 exhibits the appear-

1. *Quadratures*, derived from the Latin word *quadrans*, meaning a *quarter*.

Explain Fig. 28. What are the quadratures? What does Fig. 29 exhibit?

FIG. 29.

MOON'S QUADRATURE.

ance presented by the moon in *quadrature* when seen *magnified* through a telescope.

135. WHAT THE PHASES PROVE. The *phases of the moon* clearly prove that this body possesses a *spherical figure*, and is *illumined by the sun;* for it is only a *spherical body*, which, viewed in the positions we have mentioned, *can exhibit the phases* that the moon has displayed through all past time. This point may be illustrated in the following manner: If in the evening we place a lamp upon a table, and, taking our stand at a distance, cause a person to carry around us a small globe, we shall perceive that the *illumined part of the globe*, in its *circuit* around us, *presents to view* all the phases *of the moon.* Being *crescent-shaped* when the globe is *nearly between us and the lamp;* in its *first quarter* when the lines drawn to it from the eye and the lamp make a right angle; and at the *full*, when it is opposite to the lamp; and so on throughout the entire circuit.

136. SIDEREAL MONTH. Upon observing the moon from night to night, we perceive that she has a *motion among the fixed stars;* for if on any particular evening she is beheld *near a star*, on the next succeeding clear evening she will be seen *far to the east of this star.* And thus the moon continues to advance from *west to east* until, in the space of 27 days 7h. 43m. 11½sec., she makes *one entire revolution*, occupying the same position among the stars as she did at the commencement of this interval. For this

What do the phases prove? Is the moon stationary or in motion? How is she proved to be in motion? In what direction does she move? How long is she in completing a revolution from west to east?

reason the period of time just mentioned is denominated a *sidereal month.*

137. Synodical or Lunar Month. *The time that elapses between two consecutive full moons* or *new moons*, is termed a *synodical*[1] *month*, and consists of 29 days 12h. 44m. 3sec. If the earth was *stationary* while the moon revolved around it, the *length* of the *synodical* month would exactly equal that of the *sidereal*, for the moon in passing *from conjunction* would then be brought round to *conjunction* again at the *completion of one revolution*. But as it is, while the *moon* is *revolving around the earth*, the *earth* is at the *same time revolving about the* sun in the *same* direction, and advances about 29° 6′, while the moon makes one revolution. The moon, therefore, in passing from *conjunction to conjunction*, describes not simply 360° *or one entire circumference*, but about 389° 6′, or *nearly one circumference and a twelfth;* and the time which she occupies in going through 389° 6′, is a *synodical month*, or 29 days, 12 hours, 44 minutes, and 3 seconds.

138. Physical Aspects of the Moon. When the moon *is full* we perceive, even with the naked eye, that *her disk* is not *uniformly bright*, but that marked *alternations* of *light* and *shade* extend over the *entire surface*. By the aid of the telescope, these peculiarities are more distinctly developed, and *chains* and

1. *Synodical.* Derived from two Greek words, *sün*, *with*, or *together with*, and *odos*, a *journey*. In union signifying *a coming together*.

What is this period termed, and why? What is meant by a synodical or lunar month? What is its length? Why longer than a sidereal month? How many degrees does the moon pass through in the period of a synodical month? When the moon is full, what appearance does her disk present to the naked eye? What when seen through a telescope?

ranges of mountains are discerned, which the early astronomers regarded *as seas*. These *tracts*, however, are most probably *broad plains* and *precipitous valleys*, for there is strong evidence that but *little moisture* exists in the moon, and close observation, moreover, shows that these regions are *too rugged* to be sheets of water.

139. The *proof* that the surface of the moon is *very uneven*, rising into *lofty* mountains, and sinking into *deep valleys*, is quite conclusive. In the first place the *terminator*, which, it will be recollected, is the *line* that separates the *illumined* part of the disk from the *unillumined*, and is in fact the *profile of the moon's surface*, is *not a regular unbroken line.* Such it would be if the *surface* of the moon was *smooth*, but it is *rough and jagged*, as seen in Fig. 29, thus revealing the existence of *prominences* and *depressions* in the *lunar surface.*

140. Moreover, *near the* terminator, *long shadows* fall *opposite to the sun within the illumined regions*—a fact which can only be accounted for by the *uprising of mountains* which *intercept* the rays of this luminary, just as on the earth lofty peaks and pinnacles cast extended *shadows* at the *rising* and *setting* of the *sun.*

141. Lastly, *beyond the terminator*, *within the unenlightened* parts, *bright spots* or *islands of light* are seen (Fig. 29), which *must* be the *tops of mountains.* For since *the light of these spots is that of the sun reflected from the moon's surface*, these luminous points

What views were entertained by the early astronomers? Are these tracts seas or mountains? What facts are stated that prove the surface of the moon to be rough, rising into mountains and sinking into valleys?

catch the solar rays only on account of their being *more elevated than the contiguous regions* that are veiled in obscurity; and the *farther* these spots are from the *terminator*, the *higher* must the mountains be.

142. LUNAR MOUNTAINS. The mountainous regions of the moon present a greater diversity of arrangement than those of the earth. Rugged and precipitous ranges are seen, as on our globe, traversing the lunar surface in all directions; but the moon possesses, besides, a peculiar mountain formation, termed *ring mountains*, which are detected in every part of her visible surface.

The surface of the moon is *more rugged* than that of the earth; for though the former is much smaller than the latter, yet its mountains nearly equal in altitude the *highest* of our own.

143. Prof. Mädler of Prussia, who has studied the physical condition of the moon with more success than any living astronomer, has constructed, in connection with Prof. Beer, another Prussian astronomer of high reputation, large *lunar maps*, in which the most remarkable spots and regions of the moon are laid down with great exactness. Their *magnitudes* have also been ascertained, and their *forms* delineated with the utmost precision.

144. The heights of no less than 1095 lunar mountains have been determined by these astronomers, and out of *twenty* measured by Mädler, *three* tower to an

What facts are adduced in Arts. 139, 140, and 141, which show that the surface is rugged? What is said respecting the mountainous regions of the moon? State what has been done by Profs. Mädler and Beer. How many lunar heights have been determined by these astronomers? What is said respecting the heights of twenty measured by Mädler?

altitude of more than 20,000 feet, while the rest exceed the height of 16,000 feet, or about *three miles.* The names of a few of the loftiest mountains are as follows:

	FEET.		FEET.
Newton,	23,800	Casatus,	20,800
Curtius,	22,200	Posidonius,	19,800

145. The highest lunar mountain, as we perceive, reaches an altitude of nearly 24,000 feet, or about *four miles and a half*, which is nearly the height of the loftiest mountains of our globe. If our mountains were as much higher than the lunar mountains as the earth is *larger* than the moon, the Himmalehs and Andes would soar to an altitude of $16\frac{1}{2}$ miles above the level of the ocean.

145. LUNAR CRATERS. The moon is not only distinguished for lofty mountains, but also for singularly formed cavities and craters, which are depressed far below the general surface. They are of various sizes, and are scattered all over the disk of the moon, being however most numerous in the southwestern part. In form they are nearly all *circular*, and are shaped like a *bowl*, and from the level bottom of most of the larger a conical hill usually rises at the centre.

146. Oftentimes the *circular walls* of these craters are entirely *below* the general surface of the moon, but they are *usually* elevated somewhat *above* the surface, forming a *ring mountain*, whose height on the *outside* is frequently not more than one third or one

Give the names and altitudes of the *four highest.* If the mountains of our globe were as much higher than the lunar mountains as the earth is larger than the moon, how high would the Andes and Himmalehs soar? What is said respecting the lunar craters? Of their size and forms? What is said in regard to the circular walls of these craters?

half of its altitude on the *inside*, measuring from the *bottom* of the *crater* to the top of the mountain.

Twelve craters, according to Schroeter, a distinguished German astronomer, are more than *two miles* deep, and to *some* of these a depth of over *four miles* is assigned by the same observer.

147. That these appearances, which are regarded as *cavities*, are such in *reality*, is evident from the fact, *that the side nearest the sun is in shadow, while the side most remote is illumined by his beams.* Just as the eastern side of a well is in shadow in the morning when the sun shines, while the western side at the top is bright with the solar rays.

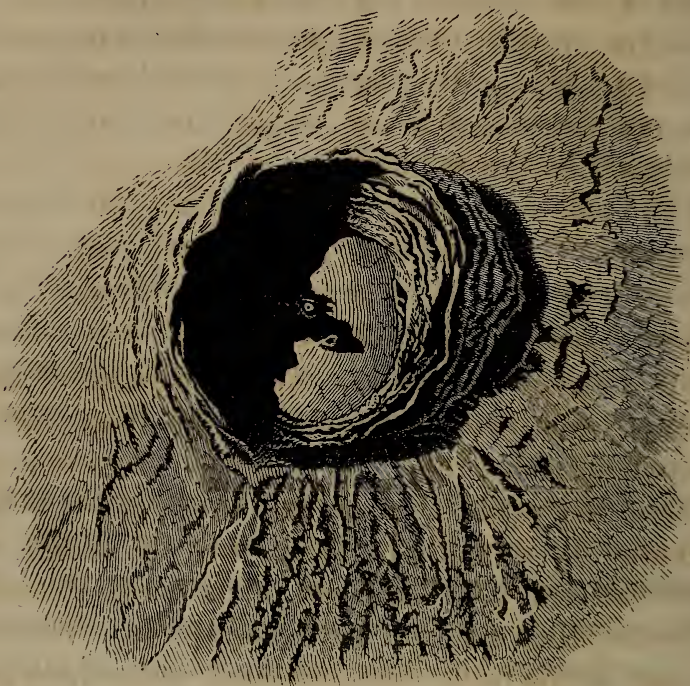
148. One of the finest instances of a ring mountain, with its enclosed crater, is the spot called Tycho. The breadth of the crater is nearly *fifty miles*, the height of the mountain on the *inside* is about 17,000 feet, and on the outside it is not less than 12,000; the *bottom* of the crater is, therefore, 5000 feet *below* the general surface of the moon.

From the centre of the enclosed area a beautiful mountain rises to the height of almost one mile.

149. By the aid of a powerful telescope, Tycho is seen as it is delineated in Fig. 30. The ranges of the *ring mountain* are here beheld on the right hand of the figure, with their summits bathed in light, while their sides opposite to the sun rest in the deepest shade. On the left hand, *nearest to the sun*, the solar rays, streaming over the encircling mountain walls of the crater, leave half of it in darkness—the heavy

How deep are these craters, according to Schroeter? State the proofs that these spots are really cavities. Describe Tycho.

FIG. 30.



A RING MOUNTAIN WITH ITS CRATER (TYCHO).

shadow of the central mountain projecting far into the illumined portion.

150. Many of the craters are of great dimensions, the largest being nearly 150 miles in diameter. The diameters of the *six* broadest, as inferred from the observations of Prof. Mädler, are as follows:

MILES.	MILES.	MILES.
149	143	127
115	113	96

And of 148 craters, whose diameters were measured by the same astronomer—

Explain the cut. What is said respecting the magnitude of these craters? Give the diameters of the *six broadest* according to Mädler's measurements. State what is said of the diameters of 148 craters measured by the same astronomer.

2	were	between	1	and	2	miles	wide,
7	"	"	2	"	3	"	"
16	"	"	3	"	4	"	"
19	"	"	4	"	5	"	"
17	"	"	5	"	6	"	"
18	"	"	6	"	7	"	"
11	"	"	7	"	8	"	"
9	"	"	8	"	9	"	"
12	"	"	9	"	10	"	"

And 36 were *above* 10 miles across.

151. LUNAR VOLCANOES. The existence of *active* volcanoes has been announced more than once by astronomers. In 1787, Sir William Herschel gave notice to the world that he had observed *three* lunar volcanoes in actual operation, *two* of which were either just ready to break out or were nearly extinct, while the *third* was in a state of eruption. The burning part of the latter was estimated to be three miles in extent, while the adjacent regions were illumined with the glare of its fires. Since this period, the attention of many astronomers has been directed to this subject, and their investigations have led to the conclusion that the remarkable appearances, which were regarded as indicating the existence of volcanoes, can be satisfactorily attributed to other causes, and the opinion is now prevalent among astronomers, that *active* lunar volcanoes *do not now exist*.

152. The aspects of the moon, however, indicate that it *has been* the theatre of intense volcanic action,

What was the belief of Sir William Herschel in respect to the existence of active lunar volcanoes? Have these remarkable appearances been regarded as active volcanoes by later astronomers? What is now the prevalent opinion among astronomers? Are there any indications in the aspects of the moon that active volcanoes once existed?

and the *ring mountains* or *craters* strikingly reveal this fact. "In some of the principal craters," says Sir John Herschel, "decisive marks of volcanic stratification, arising from successive deposits of ejected matter, and evident indications of lava currents streaming outward in all directions, may be clearly traced with powerful telescopes. In Lord Rosse's magnificent reflector, the flat bottom of the crater, called Albategnius, is seen strewed with blocks, while the exterior of another is all marked over with deep gullies radiating toward its centre."

153. Bulk—Mass—Density. The *bulk* of the moon is equal to $\frac{1}{49}$th part of the bulk of the earth, and her *mass* or *quantity of matter* is equal to $\frac{1}{80}$th part of that contained in our globe. The moon's *density* is a little more than *one half* of the density of the earth.

154. The Moon's Orbit. The orbit of the moon is an ellipse, with the earth in one of the foci, and observations have shown that it is more elliptical than that of the earth. Its inclination to the plane of the earth's orbit is 5° 8′.

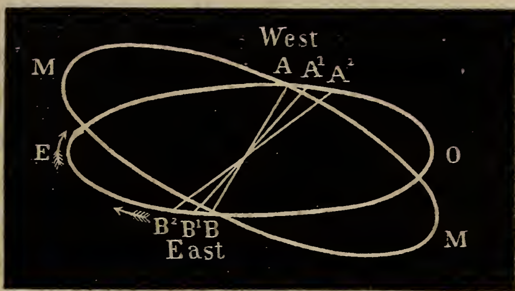
155. The Line of the Nodes. The moon, in making one revolution about the earth, comes *twice* into the plane of the earth's orbit. These *two positions*, when the centre of the moon is at the *same time* in the plane of the ecliptic, and in that of her own orbit, are called the *moon's* NODES.[1] A line joining these two points, is in *both* these planes, and is termed the

1. From the Latin word *nodus*, meaning a *knot*, a *connection*.

State the remarks of Sir John Herschel. What is the *bulk* of the moon compared with that of the earth? Her *mass?* Her *density?* What is the figure of the moon's orbit? What is the *inclination* of the *plane* of the *moon's orbit* to that of the *ecliptic?* What is meant by the moon's nodes?

line of the nodes. In Fig. 31, EO represents a part of the plane of the *earth's orbit*, MM the *moon's orbit*, A and B the *moon's nodes*, and AB the *line of the nodes.*

FIG. 31.



LINE OF THE NODES.

156. The line of the nodes retrogrades from *east* to *west* in the direction of the arrows, taking the successive positions AB, A^1B^1, and A^2B^2. It makes the *entire circuit* of the ecliptic, in the course of 18 years 218d. 21h. 22m. 46sec.

157. THE MOON ALWAYS TURNS THE SAME FACE TOWARDS THE EARTH. Every observer, whose attention has been drawn to the fact, has noticed that the appearance of one full moon is *almost* exactly like that of another. There is the *same relative arrangements* of light and shade, and the most remarkable features, such as prominent mountains and valleys, are constantly seen in nearly the *same positions* on the moon's disk. This is indeed true in respect to *all the lunar phases;* for the surface of the moon, as seen at her

What is meant by the line of the nodes? Explain the figure. Are the nodes fixed in space? Explain from figure. In what direction does the line of the nodes appear to revolve? In what period does the line of the nodes make a complete revolution? How does the appearance of the moon at any phase, during any one month, compare with her appearance at the *same phase* during any *other month?*

first quarter, is that which has been seen at every first quarter since the creation, and the same which will be seen at the same phase, as long as the sun, moon, and earth, endure.

158. This singular phenomenon can be explained only on the supposition, that the *moon rotates on her axis in about the same time that she completes a sidereal revolution around the earth;* for if she did not thus rotate, we should see the greater part of her surface in the course of a month, which is not the case.

159. This point may be thus illustrated: We will suppose a person standing in the middle of a floor, and another walking around him in a circle, holding up at a level with his eye *a globe*, of which the surface of *one hemisphere* is painted *black*, and that of the *other white.* The first person represents a spectator upon the earth; the circle in which the second walks the orbit of the moon, the globe is the *moon*, and the *white surface* the *side* that she constantly presents towards the earth. Now it is manifest, that if the second person, walking round the circle, wishes the spectator at the centre to see *nothing but the white surface of the globe*, as he performs his circuit, he must turn the globe round on its vertical axis at *exactly the same angular rate* that he himself is moving in the circle. Thus, when he has moved through one quarter of the circle, the globe must have turned *one quarter* of a circle; when he has traversed *one half* of the circle, the globe must have turned *half round*, and so on through the entire circle.

How can this phenomenon be explained? Give the illustration.

160. LENGTH OF THE LUNAR DAY. The moon, as we have seen, rotates on her axis in the *same period* that she completes a *sidereal* revolution about the earth, moving forward in the mean while with the latter around the sun through an arc of nearly 27°. Owing to these *two* motions, the average length of the day *at the moon*, reckoning by *solar time*, is equal to the length of a *synodical* month, that is, to about 29½ of our days (29 days 12h. 44m. 2.9sec.) The mean lengths of *daylight* and *night* are therefore respectively equal to nearly 15 of our entire days of 24 hours duration.

161. THE APPEARANCE OF THE EARTH AS SEEN FROM THE MOON. To the inhabitants of the moon (if any there are), our earth is seen as a *moon of immense size*, its *apparent surface* being *sixteen times* greater than that of the sun as he appears to us. For this reason a vast amount of light must be reflected from our globe to the moon, and all the varied lunar phases which we behold would be exhibited by the earth to a lunar spectator with a wonderful radiance and distinctness, but in an *inverse* order. Thus, when it is *new moon* to *us* it would be *full earth* to an observer on the moon, and when *full moon here, new earth there.*

162. Another remarkable difference also exists. The moon is seen by us occupying various positions in the heavens, as she displays her successive phases; but the earth would appear to an inhabitant of the moon to be *fixed in the heavens* during *all* her periodical fluctuations of light. The cause of this singular phe-

What is the mean length of the lunar day, measured by our days? How would our earth appear to an inhabitant of the moon? In what order would the phases of the earth be exhibited? Would the earth have any *apparent* motion as seen from the moon?

nomenon is easily explained. The moon turns on her axis from *west to east* just as the earth does, but an inhabitant of the moon would be as *unconscious* of its *rotation* as we are of the rotation of the earth. Accordingly, as with us, the sun and the other *fixed* heavenly bodies would appear to him to be moving from *east to west*, at *the same rate* that his own orb rotates on its axis. Such would be the apparent motion of the earth to a spectator upon the moon if *the earth was actually stationary;* but this is not the case, for our globe advances from *west to east* in her orbit, *just as rapidly* as the rotation of the moon *tends* to give it an *apparent retrograde* motion from east to west.[1] The earth, therefore, *apparently* moving in *one direction* exactly as fast as it *actually* moves in the *opposite* direction, consequently seems to an inhabitant of the moon to *stand still* in the heavens.

163. These phenomena would only be seen by a spectator on the side of the moon *nearest* to us, for to those inhabiting the remote hemisphere the earth would *never* come into *view*. Their long nights of nearly 15 days' duration would, therefore, be extremely dark, since the brightest heavenly bodies, whose light could dissipate the gloom, are Mars and Jupiter, which would afford no more illumination to the inhabitants of the moon than they do to us.

1. The moon would present the same phenomenon to us if she completed a revolution in her orbit in a *sidereal day*, for she would then *actually* move as fast from *west to east* as she would *apparently move* from *east to west*, on account of the rotation of the earth. Under these circumstances, she would seem *not to move at all.*

Give the explanation. Could these phenomena be seen from every point of the moon's surface? Why not? What is said respecting the nights that prevail throughout that hemisphere of the moon which is turned from us?

CHAPTER III.

ECLIPSES OF THE SUN AND MOON.

164. The *eclipses* of the sun and moon are among the most grand and sublime of the phenomena of the heavens. In all ages of the world, they have been viewed by the ignorant with wonder and awe; while to the man of science they have ever been subjects of deep interest and profound study.

165. Lunar Eclipses. *An eclipse of the moon is the partial or total obscuration of her light when she passes into the shadow of the earth.* The sun, earth, and moon, are then in nearly the same straight line with the earth *between* the other two bodies. If the moon were *self-luminous*, like the sun, a lunar eclipse could *never occur;* but, shining as she does by reflection from the sun, the interposition of the solid body of the earth cuts off the solar light, and the portions of the moon that enter the earth's shadow appear *dark* to our view. A lunar eclipse can never happen except when the moon is *full*, for it is only at this time that the earth is *between* the sun and moon, and its shadow is extended in the direction of the *latter*.

Of what does Chapter III. treat? What is said respecting the eclipses of the sun and moon? What is an eclipse of the moon? When it occurs, what are the relative positions of the sun, moon, and earth? If the moon was self-luminous, would there be any lunar eclipses? In what phase must the moon be when a lunar eclipse happens?

If the plane of the moon's orbit coincided exactly with the plane of the ecliptic, she would pass through the earth's shadow at every revolution, and a lunar eclipse would take place at *every full moon*. But as the former is inclined to the latter at an angle of about 5° (Art. 154), the *shadow* of the earth may at one time *pass above* the *full moon*, and at another *below* it. The full moon must, therefore, take place within a certain distance of one of her *nodes*,[1] that is, *near the plane of the ecliptic*, to make it *possible* for an eclipse[2] to occur.

166. When the moon, at the full, has her centre exactly at her node, it is in the *same straight line* with the centres of the sun and earth, and she is placed centrally in the shadow of the earth. But it is not necessary that the moon should be precisely in this position in order that an eclipse may happen; for since she possesses an apparent breadth of about 30′, and the shadow of the earth extends on each side of the node, her disk may be obscured when she is within a short distance of this point.

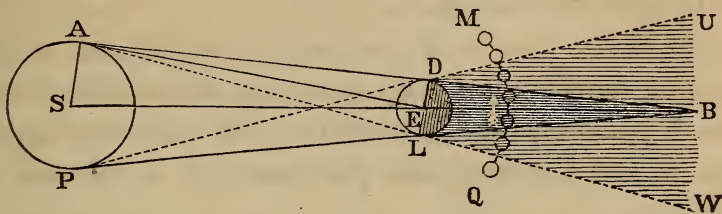
167. Of the Earth's Shadow. In Fig. 32, where S

1. It will be remembered that the moon's *nodes* are those points in her orbit where the latter *intersects* the plane of the ecliptic. They are consequently at once in the plane of the moon's orbit, and in that of the earth's.

2. *Eclipses* are so called from the fact here stated, viz., that they occur *in* or *near* the *plane of the ecliptic*.

If the plane of the ecliptic and that of the moon's orbit coincided, how often would lunar eclipses occur? Why do they not now take place every month? Near what point must the full moon be to make it possible for an eclipse to happen? Explain why it is not necessary for the moon to be exactly at one of her nodes for this phenomenon to occur?

FIG. 32.



ECLIPSE OF THE MOON.

represents the sun, and E the earth; the dark portion DBL is the *earth's shadow.* Its length from E to B is on an average 860,000 miles. On each side of the shadow there exists, to a certain limit, a space where there is a *partial shadow*, or *penumbra.*[1] Outside of this space the moon is illumined by the full orb of the sun, but as she enters the *penumbra* the dark body of the earth begins to interpose itself, and cuts off *a portion* of the sun's light. As she continues to approach the shadow, more and more light is intercepted, and at the moment the earth *totally* hides the sun from any part of the moon, that part at the same instant passes the *inner limit* of the penumbra and *enters* the shadow.

168. The space occupied by the penumbra is determined as follows: Referring to Fig. 32, and supposing the lines ALW and PDU to be drawn, touching the earth at the points D and L, the penumbra is found on each side of the shadow, bounded by the lines UD, DB, and BL, LW. QM represents the *path* of the moon, and the several small circles on the line

1. See Note 2, Art. 109.

What is the length of the earth's shadow in miles? What is the penumbra?

QM are different *positions* of the moon *at* and *near* the time of an eclipse.

169. When the moon is *entirely* obscured, the eclipse is called *total;* when only a *portion* of the disk is concealed, *partial;* and when the disk just touches the *edge* of the shadow, the phenomenon is termed an *appulse.*

170. Red Light of the Disk. During a *lunar eclipse* the darkened surface of the moon is illumined by a *reddish light*, a phenomenon resulting from the *refraction* of the solar rays by the *earth's atmosphere.* For the solar beams entering our atmosphere are refracted towards the earth, and being thus *bent into* the *shadow*, pass onwards and strike the moon. Being thence reflected to us, they are still sufficiently bright to render her surface, even in *shadow*, distinctly visible. The *color* of the light is owing to the same cause that gives rise to the ruddy tints of sunset clouds; the white light of the sun, in struggling through the atmosphere, loses its feebler rays,[1] while the *red*, which possesses the greatest power to overcome any resistance it encounters, *emerges*, and imparts its own hue to the objects upon which it falls.

This *reddish* light is of sufficient intensity to enable

1. When a sunbeam is refracted, the seven colors of which it is composed, to wit, *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*, are *turned out* of the course of the original beam. The *red* deviating the *least* and the *violet* the *most.* The red is therefore *least* affected by the resistance it meets with.

When is an eclipse *total*, when *partial*, and when does an *appulse* occur? What phenomenon occurs during a lunar eclipse? How is it caused? To what is the color owing?

observers to detect the *obscure* regions and *spots* on the lunar disk. The following facts are stated by Hind. During an eclipse of the moon that occurred on the 23d of July, 1823, M. Gambart saw all the *lunar spots* distinctly revealed. In an eclipse that happened on the 26th of December, 1833, Sir John Herschel observed, that the moon was clearly visible to the naked eye, when completely *immersed* in the earth's shadow; gleaming with a *swarthy copper hue*, which changed to *bluish green* at the edges, as the eclipse passed away. Similar phenomena were noted during the *total* lunar eclipse of March 8th, 1848.

The spots on the surface, even at the middle of the eclipse, were distinctly seen by many observers, and the general color of the moon was a *full glowing red.* So clearly did the *lunar disk* stand forth to view, that many of the observers doubted if there was any eclipse at all.

171. Earliest observations of Lunar Eclipses. Observations were made on lunar eclipses at Babylon, by the Chaldeans, in the years 719 and 720 B.C. They relate to *three* eclipses, and are the earliest observations of this kind, in the annals of science. The *first* eclipse occurred on the 19th of March, 720 B.C., and was *total* at Babylon. The *second* happened on the 8th of March, 719 B.C., and the *third*, on the 1st of September in the same year; *both* were *partial* eclipses.

172. Eclipses of the Sun. An *eclipse of the sun* takes place when the moon in her revolution about

What can be discerned on the disk of the moon by means of this light? Detail the facts mentioned by Hind? Give an account of the earliest observations of lunar eclipses.

the earth, *comes between the earth and the sun*, and casts her shadow upon the *former;* concealing from our view, by her interposition, either a *part* or the *whole* of the bright disk of the sun. A *solar eclipse* can therefore only occur at the time of *new moon* or *conjunction;* and, as in the case of lunar eclipses, it would happen *every revolution*, if the plane of the ecliptic coincided with that of the moon's orbit. But this is not the fact, and a *solar eclipse* can therefore only take place when at *new moon* the lunar orb is *at* or *near* one of her nodes. The *greatest possible distance* of the moon from the node, at which a solar eclipse can occur, is 18° 36′.

173. Form of the Eclipse. A solar eclipse may be *partial*, *total*, or *annular*. It is *partial* when only a portion of the dark body of the moon interposes between the sun and a spectator upon the earth; *total*, when the *apparent diameter* of the *moon exceeds* that of the *sun*, and the former body passes nearly *centrally* across the solar disk; *annular*, when the moon passes in like manner nearly centrally before the sun, but her *apparent diameter* is *less* than the *solar;* the entire body of the sun being then obscured with the exception of a *brilliant ring*, around the borders of the moon. When in this case the centres of the *sun*, *moon*, and *earth*, are exactly in the *same straight line*, the eclipse is termed *annular* and *central*, and the bright ring possesses a uniform breadth.

What is the cause of a solar eclipse? At what phase of the moon can it only occur? Why not at every new moon? Where must the new moon occur? What is the *greatest* possible distance from the *node* that a solar eclipse can take place? What is stated respecting the form of a solar eclipse? When is it *partial?* When *total?* When *annular?* When *annular* and *central?*

174. Shadow of the Moon. The distance of the moon from the sun is subject to variation, and this circumstance affects the *length of the moon's shadow.* The *farther* this orb is from the sun, the *longer* will be her shadow, and the *nearer* the *shorter.*

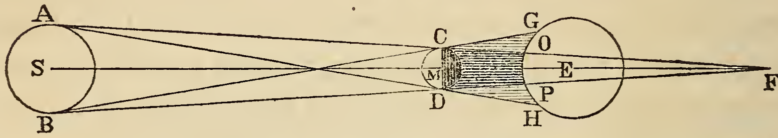
175. The *average length* of the moon's shadow is found to be about *equal* to her *mean distance* from the *earth.* It will accordingly, for the reasons above assigned, at times *fall short* of the earth, while at others it will be so much extended, that a shadow of considerable breadth passes over the surface of the globe.

176. When the shadow *does not* reach the earth, it is manifest that *no total eclipse* can occur; though the sun, moon, and earth, may be so situated in every other respect as to tend to cause this phenomenon. When it *does* reach the earth, the space that it covers on the surface of the latter, will depend upon the position of the *end* of the shadow in reference to the *surface* of the earth. If the *end* of the shadow just *touches* the earth, there will be an eclipse only at the place where it touches. But if the point where the shadow would terminate, if the earth did not interpose, is situated, as at F in Fig. 33, *far* on the *other side* of the *earth*, then the eclipse will be visible throughout a region of considerable extent. The *largest extent* of surface on the earth, covered *at once* by the *shadow of the moon*, is about 180 miles.

State the cause of the variations in the length of the moon's shadow. When is it *shortest*? When *longest*? To what is the average length of the moon's shadow nearly equal? What happens if it is *less* or *greater* than the mean length? When will no *total* eclipse occur? Upon what does the extent of terrestial surface covered by the shadow depend? Give the two illustrations. What is the greatest extent of surface obscured by the shadow?

177. The lunar shadow, like that of the earth, has also its *penumbra*, which partially obscures our globe. The greatest breadth of terrestrial surface enclosed by the penumbra is nearly 5000 miles.

FIG. 33.



SOLAR ECLIPSE.

178. In Fig. 33, this subject is illustrated. S here represents the *sun*, M the *moon*, and E the *earth*. The *form* of the shadow is defined by the line CF and DF; a portion of the shadow is, however, cut off by the interposition of the earth. The *breadth* of the shadow *on* the earth is represented by the distance from O to P, and the *breadth* of the *penumbra* on each side of the shadow, by the curved lines GO, and PH.

179. Total Eclipse of the Sun. We have remarked that eclipses of the sun and moon are among the grandest phenomena in nature; but no form of eclipse is so impressively sublime as a *total eclipse of the sun*. The gradual withdrawal of the solar light, and at length its total extinction; the oppressive and unnatural gloom that overspreads the earth, so different from the obscurity of night, and the appearance of the stars, at such an unusual time, all impress the mind with a deep solemnity. It is not surprising that

State what is said respecting the penumbra and its breadth. Illustrate from Fig. 33. What is said in respect to a total eclipse of the sun?

a spectacle of this kind has ever filled barbarous, and even civilized nations, with astonishment and dread, as though they were on the brink of some awful calamity.[1] But *eclipses*, whether total or otherwise, are the source of one of the noblest triumphs of science; for astronomers are now so well acquainted with the laws that regulate the motions of the heavenly bodies, that the very minute of an eclipse can be predicted centuries before it occurs, and the dates of events which happened thousands of years ago, can be unerringly fixed, by retrograde calculations of these phenomena.[2]

180. During a total eclipse of the sun, many singular appearances are usually observed. Soon after the eclipse has commenced, and as it gradually ad-

1. A total eclipse of the sun occurred during the war between the Medes and Lydians, related by Herodotus. In the midst of a battle, the sun was blotted out from the sight of the contending armies, and so great was their terror at such a strange event, that they threw down the weapons, and made a peace upon the spot. This eclipse is said to have been predicted by Thales.

2. When Agathocles, the tyrant of Syracuse, invaded Africa, for the purpose of attacking the Carthaginians in their own country, a total eclipse of the sun occurred at the time the expedition was setting sail. This circumstance disheartened the soldiers, but Agathocles revived their courage by representing that this event portended the defeat and ruin of their enemies. This eclipse occurred, according to retrograde calculations, on the 15th of August, 310 B.C. An eclipse of the sun also happened at the very time Xerxes set out from Sardis, to invade Greece. The eclipse proves that this historical event occurred on the 19th of April, 481 B.C. A lunar eclipse which happened on the 21st of September, 331 B.C., fixes the date of the battle of Arbela, in which Alexander triumphed over Darius, king of Persia. The eclipse occurred eleven days before the victory.

How have these phenomena been regarded by barbarous, and even civilized nations? What have they proved to astronomers?

vances, jets of *light* are sometimes seen flashing over the lunar disk; and as the total obscuration approaches, the bright portion of the sun changes color by degrees, either becoming fainter than before, or else assuming a *reddish tinge.*

When the sun is completely hidden, a beautiful *ring* or *corona*[1] of light appears around the dark body of the moon, like the crown of light or *glory* with which painters surround the heads of saints. In the eclipse of 1842, one observer describes it as a *ring of peach-colored light*, another as *white*, and a third as *beaming* with a *yellowish hue.* Its breadth likewise does not always appear to be the same; for in the eclipse just mentioned, while some observers estimated the width at one eighth of the moon's diameter, others saw radiations of the corona *eight times as long as the moon's diameter.* The breadth of the corona noticed by Mr. Bond, during the eclipse of July 28, 1851, was about *one half* of the sun's diameter.

181. But the most brilliant phenomena remain to be described. When the sun is completely concealed, and the corona is displayed, *rose-colored flames* appear to dart out from the edge of the moon, emanating from the bright ground of the corona, and so distinct that they are frequently visible without the aid of the telescope. They vary from *two* to *four* in number, and though mainly of a rose color, yet they are seen tinged with *lilac*, *greenish blue*, and *purple.* During the eclipse of July 28th, 1851, Prof. Bond, of Cam-

1. *Corona*, a Latin word signifying *a crown.*

Describe the various appearances that are beheld during a total eclipse of the sun.

bridge, noticed these beautiful *rose-colored* flames, *two* of which were connected by an *arch of light*, resembling a *rainbow*.

FIG. 34.

TOTAL ECLIPSE OF THE SUN, AS SEEN BY MR. J. R. HIND, NEAR ENGELHOLM, IN SWEDEN, JULY 28, 1851.

182. Fig. 34 represents this eclipse as seen by Mr. J. R. Hind, in Sweden. The eclipsed sun is here seen surrounded by a corona, the *whiter* portions of which near the dark circle indicate the positions of the *jets of flame* and the *arch of light*.

What appearances were observed by Mr. Bond, during the eclipse of July 28th, 1851? Describe Fig. 34.

183. Solar and Lunar Eclipses—Points of Difference. When a *lunar* eclipse occurs, it can be seen from every part of that side of the earth, which is *turned towards* the moon. For this hemisphere is necessarily in the earth's shadow, and a spectator here situated beholds the moon eclipsed when *she enters the shadow.*

184. In the case of a *solar* eclipse, the shadow of the moon passes across the earth, and an eclipse can only occur in the *path of the moon's shadow.* Every part of the terrestrial hemisphere turned toward the sun, will not, therefore, be eclipsed, but only those portions that are traversed by the lunar shadow. These differences in respect to *lunar* and *solar* eclipses, arise from the different positions of the *observer* in the two cases. During a *lunar eclipse* he is on the body that *forms* the shadow; during a *solar eclipse* he is on the body that *receives* the shadow.

185. Frequency of Eclipses. *Seven* is the *greatest number* of *eclipses* that can occur in the course of a *year*, and *two* the *least.* If *seven* take place, *five* may be *solar* and *two lunar*, or *three* may be eclipses of the *sun* and *four* of the *moon.* *Six* eclipses in a *year* is an *unusual* number, *four* the *average*, and two the *least;* in the last case the eclipses will be *solar.*

State in what respects *solar* and *lunar* eclipses differ. How do these differences arise? What is the *greatest* number of eclipses that can occur in a year? What the *least?* If seven take place, what will be the number of solar eclipses, and what the number of lunar? What is an *unusual* number in a year? What the *average?* What the *least* number? If only *two* occur, are they solar or lunar?

CHAPTER V.

THE PLANETS.

186. The *planets* are those heavenly bodies that revolve directly about the sun,[1] from *west* to *east*, and shine by its reflected light. They have received this appellation, as we have stated (Art. 2, Note 1), from the fact that they are seen moving among the fixed stars, and are constantly changing their places in the heavens.

187. The names of the different planets have already been given (Art. 6). Mercury, Venus, Mars, Jupiter, and Saturn, have been known from the earliest ages, for they are visible to the naked eye, and, all but Mercury, conspicuously so. The *rest* of the planets, 44 in number, excluding the Earth, are recent discoveries, all of these having been found since the year 1780, and 38 of them within the last 12 years.

Many of the planets are attended by *moons*, like the earth. The earth, as we know, has *one* moon—

1. The planetary bodies that revolve *directly* about the sun are called *primary* planets. *Moons* are termed *secondary* planets. The body about which another *directly* revolves is denominated its *primary;* thus: the *sun* is the *primary* of the *earth*, and the *earth* the *primary* of the moon.

What are *planets?* Why are they so called? Which have been known from a high antiquity? How many have been discovered since the year 1780? How many within the last 12 years? How many planets have moons, and what is the number of moons that each of these respectively have?

Jupiter *four*, Saturn *eight*, Uranus *six*, and Neptune *one*. Up to the present time, the known number of *planets*, including the Earth, is 50, and of *moons* 20.

There doubtless exist other planetary bodies in our system yet undiscovered, if we can infer anything from the harvest of planets that has lately rewarded the searching labors of zealous astronomers.

188. The planets are named after the personages of the classic mythology, and are distinguished by appropriate symbols. Thus, the symbol of Venus, the goddess of beauty, is a *mirror;* that of Mars, the god of war, a *spear and buckler.* The sign of Vesta, the goddess of fire, is an *altar;* that of Ceres, the divinity that presides over harvest, a *sickle;* while Neptune, the god of the ocean, has for his symbol a *trident;* and so of others. The symbols of the asteroids are, for the most part, figures, which represent the order in which they were discovered.

189. Universal Attraction. It is the attractive force of the sun that causes the planets and every body of the solar system to revolve about this mighty orb. Indeed it is an universal law, that all bodies mutually attract each other in the *direct ratio of their quantities of matter, and in the inverse ratio of the squares of their distances from each other.* For example, if the moon contained twice as much matter as it now does, it would, at its present distance, attract the earth *twice* as much; but if it was half its present distance from the earth, though it contained

What is the known number of planets at the present time? What the number of moons? Are there reasons for believing that other planets will be discovered? What is said of universal attraction?

no more matter than it now does, its attraction would be increased four times.

190. Kepler's Laws. The great astronomer Kepler, who lived about 250 years ago, discovered THREE great laws of planetary motion, which, from their importance, are termed the laws of Kepler. They are enunciated as follows:

First Law.—*The planets move in ellipses around the sun, which occupies a focus common to all these ellipses.*

Second Law.—*The radius-vector describes areas proportional to the times.*[1]

Third Law.—*The squares of the periodic*[2] *times of the planets are proportional to the cubes*[3] *of their average distances from the sun.*

191. The respective distances of the planets from the sun, beginning with the *nearest*, are presented in the following table. The distances of a few of the latest discovered asteroids have not yet been ascertained.

1. If we were to imagine the sun to be joined to the earth by a rod, the rod would be the *radius-vector;* and as the earth carried one end of the rod around, the other being fastened to the sun, the areas or spaces swept over by the rod in equal times, as days or weeks, would be always equal. This is true of all the planets.

2. *Periodic time* is the time occupied by a planet in performing *one revolution about the sun.* Thus, one year is the periodic time of the earth.

3. *A cube* is the quantity resulting from multiplying a quantity into itself twice; thus: 8 is the *cube* of 2, because 2 × 2 × 2 equals 8.

State the *laws* of Kepler. Enumerate the planets, and give the distances.

	MILES.		MILES.
MERCURY,	36,890,000	IRENE,	245,536,620
VENUS,	68,770,000	POMONA,	245,580,320
EARTH,	95,298,260	PROSERPINE,	245,841,190
MARS,	145,205,000	FIDES,	247,399,000
		EUNOMIA,	251,123,950
ASTEROIDS.		THALIA,	251,286,780
FLORA,	209,131,670	JUNO,	253,518,005
HARMONIA,	215,441,000	CIRCE,	253,916,000
ISIS,	217,531,000	CERES,	262,747,675
MELPOMENE	217,890,100	LÆTITIA,	262,969,500
VICTORIA, or CLIO,	221,794,600	PALLAS,	263,105,635
EUTERPE,	223,046,035	BELLONA,	264,168,875
URANIA,	224,041,065	CALLIOPE,	276,612,450
VESTA,	224,253,105	PSYCHE,	278,630,345
POLYMNIA,	225,985,050	THEMIS	298,727,120
METIS,	226,700,875	HYGEIA,	299,191,480
IRIS,	226,718,830	EUPHROSYNE,	303,267,265
PHOCEA,	228,063,935	——	
MASSALIA,	228,139,650	LEUCOTHEA,	——
HEBE,	230,327,785	ATALANTA,	——
LUTETIA,	231.240,070	LEDA,	——
FORTUNA,	232,187,030	DAPHNE,	——
PARTHENOPE,	232,569,215	——	
THETIS,	235,971,260	JUPITER,	495,817,000
AMPHITRITE,	241,898,215	SATURN,	909,028,000
EGERIA,	244,804,550	HERSCHEL, or URANUS,	1,828,071,000
ASTREA,	244,853,190	NEPTUNE,	2,862,457,000

192. The average velocity of electricity through the telegraphic wires is about 16,000 miles *per second.* If, therefore, for example, London was united to New-York by a telegraphic line, news could be sent from one city to the other in about *one fifth of a second.* Now, supposing the *sun* was connected with the

Take the velocity of the electric current as the unit of measurement, and give the different estimates of the planetary distances with this unit.

planets by telegraphic lines, then the time it would take to transmit a message from the

Sun to the Earth,	would be		1*h*. 39′
to Jupiter,	"		8*h*. 36′
to Saturn,	"		15*h*. 47′
to Herschel,	"	1*d*.	7*h*. 44′
to Neptune,	"	2*d*.	1*h*. 42′

193. Apparent Size. The apparent magnitude of a body *is inversely proportioned to its distance;* that is, if at a certain distance it appears of a certain size, when *ten times nearer* it will appear *ten times larger*, and if *five times farther* off, *five times smaller*, and so on.

It follows, therefore, that the *sun* will *appear* of *various* sizes at the different planets. The *relative apparent magnitudes* of this body, as it would be seen from the *eight* principal planets, are shown in Fig. 35.

194. Kepler's Law of Distances. From the *third* law of Kepler, viz., that the *squares of the periodic times of the planets are as the cubes of their mean distances from the sun*, the *unknown* mean distance of a planet can be found, when its *periodic* time is ascertained, together with the *distance* and *periodic* time of *another planet*.

Thus the *periodic* time of Mars having been ascertained by observation to be 687 days, and the *distance* of the *earth* from the sun and her *periodic time* being known, the mean distance of the former can be found

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What is said respecting the apparent size of the sun as viewed from the different planets? When can the distance of a planet be found by Kepler's *third* law? Give an instance.

by the following proportion, viz.: *the square of the earth's periodic time is to the square of Mars' periodic time, as the cube of the earth's distance is to the cube of Mars' distance.*[1]

In this way the *periodic* time of a planet can also be found, when its *distance* is known, and also the *distance* and *periodic time* of another planet.

195. The laws of Kepler are alike applicable to *moons and planets.* The *mean* distances of the former from the planets about which they revolve can, therefore, be determined, as in the case of planets, by the law just mentioned.

196. DIVISION OF THE PLANETS. The planets are usually divided into TWO CLASSES. First, the INFERIOR, whose orbits are *within that* of the earth: Mercury and Venus constitute this class. Secondly, the SUPERIOR, whose orbits *inclose* the earth's orbit: within this division are comprised all the planets from Mars to Neptune inclusive.

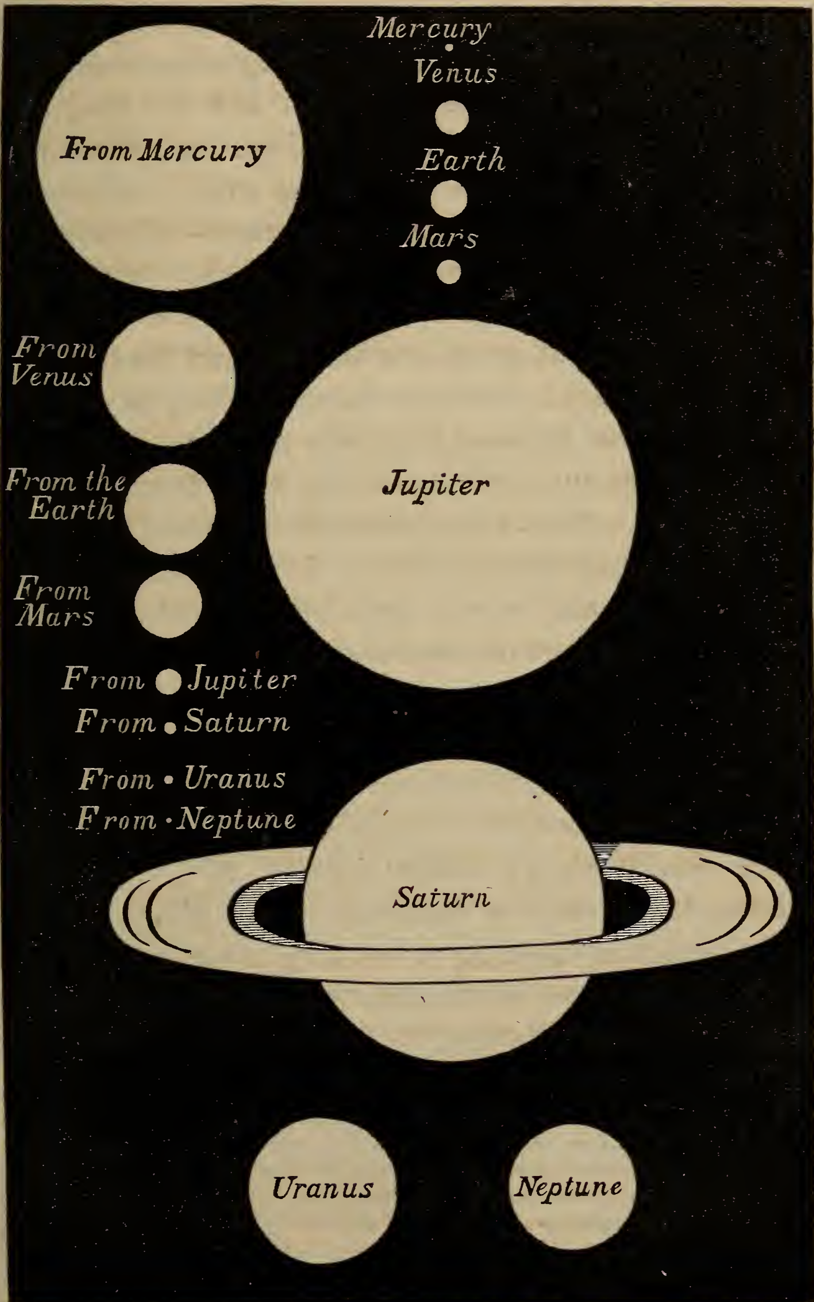
197. INFERIOR PLANETS. The two planets, Mercury and Venus, are known to have their orbits within that of the earth: *First*, because they are never seen by us, like the other planets, in a part of the heavens *opposite* to that which the sun occupies, which would

1. This proportion, expressed in figures, is as follows: (365.256 [days] × 365,256) : (687 × 687) : : (95,298,000 [miles] × 95,298,000 × 95,298,000) : (145,210,000 [miles] × 145,210,000 × 145,210,000). The last term is the cube of Mars' mean distance from the sun. The *distance* is, therefore, 145,210,000 miles.

Can the *periodic* time of a planet be found by this rule? Is this law applicable to moons? Into how many classes are the planets divided? What are they? What is meant by an *inferior*, what by a *superior* planet? How do we know that the orbits of Mercury and Venus are within that of the earth?

FIG. 35.

APPARENT SIZE OF THE SUN, AS VIEWED — RELATIVE SIZES OF THE EIGHT PRINCIPAL PLANETS.



be the case if they included the earth within the circuit of their respective orbits.

198. *Secondly:* if viewed with a telescope, they present *phases* like the moon, being *crescent-shaped*, when situated between the earth and the sun, and *full* when the sun is between them and the earth, and in other positions exhibiting every variety of phase between these two extremes—phenomena which can be accounted for only on the supposition that these planets receive light from the sun, and move around it at a *nearer* distance than the earth.

199. *Thirdly:* because these bodies, at certain times, are seen *between* the earth and sun, appearing as *dark spots* on his disk, as they cross from one side to the other. Such an appearance is termed a *transit*. When *either* of these planets is *between* the *earth* and the *sun*, it is said to be in *inferior conjunction;* when the *sun* is *between it and the earth*, it is in *superior conjunction.*

Mercury. ☿

200. This planet is the *nearest* to the sun of any that have been discovered. Its greatest angular distance from this luminary never reaches 29°. For this reason, it can only be discerned in the gloom of twilight, either at morning or evening, according as it is to the *east* or *west* of the sun. Even under the most favorable circumstances, it does not appear conspicu-

What is the *interposition* of a planet between the earth and the *disk* of the sun called? When are these planets respectively in their *inferior* and *superior* conjunctions? What is said respecting the proximity of Mercury to the sun? What is the extent of its greatest angular distance from this orb? When can this planet be seen? When is it most conspicuous? What is its appearance? What is its distance from the sun?

ous to the unaided eye, but shines like a small star beaming with a pale red light. Its *average distance* from the sun is 36,890,000 miles. Its orbit is very elliptical, and the plane of its orbit is inclined to that of the ecliptic about 7°. From measurements taken with the utmost accuracy within the last few years, the diameter of this planet is estimated to be 2950 miles, and it revolves about the sun in nearly 3 months, or more exactly 87d. 23h. 15m. 44sec.

201. Rotation on its Axis. The powerful illumination to which this planet is subjected on account of its proximity to the sun, has thrown a degree of uncertainty upon all investigations respecting its physical characteristics, and the number of reliable observations upon it is therefore few. Sir William Herschel, with all his ability and skill, obtained no conclusive proof of the existence of *spots* upon the surface of the planet, which would have enabled him to determine the *time of its rotation on its axis.* Schroeter appears, however, to have met with better success. In the early part of this century he subjected Mercury to a most careful scrutiny, and obtained, as he believed, decisive evidence of the existence of *mountains*, rising to the lofty altitude of more that ten miles above the general surface of the planet. By noting, likewise, the variation in the appearance of the *horns* of the planet, when it assumed a *crescent shape*, the same astronomer ascertained to his own satisfaction the fact of its

What is the inclination of its orbit to the plane of the ecliptic? What is its actual diameter in miles? What is the periodic time of Mercury? State why it is difficult to ascertain, with certainty, the physical characteristics of this planet. Are there many reliable observations on Mercury? State what is said respecting Sir William Herschel's efforts.

rotation; the period of which he estimated at 24h. 5m. 28sec. Since the time of Schroeter no astronomer has gained any further information on these points, which future observations may modify or confirm.

202. Phases. On examining Mercury with the telescope in different points of his orbit, we find that he presents *phases like* those of the moon in her revolution about the earth.

203. Transit of Mercury. If the plane of the orbit of Mercury was coincident with that of the ecliptic, the planet at *every inferior conjunction*, would pass directly *between us* and the *disk of the sun*, and would appear as a *black spot* upon it. But since the plane of its orbit is inclined to that of the ecliptic about 7 degrees, this phenomenon does not occur at every inferior conjunction, for the planet may be *on one side of the disk of the sun* when it is in this position.

204. In order that a *transit* may occur, the *earth* must be in the *line of the nodes* of Mercury, *at* or *very near* the time when the planet passes through *one of them*, in its revolution about the sun. For Mercury being at the node, is consequently *in the plane of the ecliptic*, and the *line of the nodes* will then pass through the *sun*, the *earth*, and *Mercury*, and the latter, as seen from the earth, will be projected as a *dark spot* upon the sun; just as the moon is during

What success had Schroeter? What is the period of Mercury's rotation, as determined by him? Have later astronomers increased our knowledge of the physical characteristics of Mercury? What phenomenon is observed in respect to this planet, when viewed with a telescope? Why does not a transit of Mercury occur at every inferior conjunction? What must be the respective positions of the planet and the earth, that a transit may occur? Why?

a solar eclipse. If the *planet*, *the earth*, and *sun*, are not exactly in the line of the nodes, still a *transit* may occur within certain limits, on account of the magnitude of the sun; the planet crossing the disk of the sun, not through its *centre*, but on one side of it.

205. The earth arrives at the line of the nodes *twice a year*, about the 10th of November and the 7th of May, and the transits of Mercury will for a long time happen in these months. The *last* transit occurred on the 8th of November, 1848, and the *second* after the next will happen on the 6th of May, 1878.

206. Mass and Density. The investigations of astronomers in respect to these particulars have led to the conclusion, that the *mass* of the *sun exceeds* that of Mercury 4,865,750 times, and that the *density* of the planet is $\frac{1}{8}$th *greater* than that of the earth.

Venus. ♀

207. We now come to Venus, the second planet in order from the sun, and the most beautiful star that adorns the heavens. Her *mean distance* from the sun is 68,770,000 miles, and she revolves about this luminary in 225½ days, or more accurately, 224 days 16h. 49m. 8sec.

208. The length of her diameter, according to the best observations, is about 7900 miles, which is very nearly the same as that of the earth. Unlike that of Mercury, the orbit of Venus is almost a *circle*, and

If these three bodies are not exactly in the *line of Mercury's node*, can this phenomenon occur? Why? In what months do the transits happen? When did the last transit occur? When will the second after the next take place? State what is said respecting the mass and density of Mercury. What is said respecting Venus? What is her *distance* from the sun? What her *periodic time?* What is the length of her diameter? What is said of her orbit?

the inclination of its plane to that of the ecliptic is about 3° 23′.

209. ROTATION. The intense splendor of Venus invests every part of her disk with such a brilliant light, that any variation in the surface of the orb, for the most part, escapes detection, since the valleys, as well as the mountains, if such inequalities exist, are bathed in floods of light; and astronomers therefore speak doubtingly of *cloudy spots* upon the surface of the planet.

210. It is usually by directing their observations to *well-defined spots*, that astronomers determine the period of the rotation of a planet upon its axis; the *absence* of such marks upon Venus, for a long time, rendered the time of her rotation a matter of uncertainty.

At length Schroeter, the celebrated German astronomer, ascertained that this orb revolved on its axis in 23h. 21m. and 8sec. This result has been almost universally received, though it is not regarded by astronomers as exact beyond the possibility of an error.

211. PHASES. In her revolution about the sun, Venus, like Mercury, presents to our view similar *phases* to those of the moon. But since this planet is *nearly* twice as far from the sun as Mercury, and its *real diameter* is almost *three times* greater, these

How much is its plane inclined to that of the ecliptic? Why do we know scarcely anything respecting the *surface* of this planet? What is said in regard to the existence of spots? How do astronomers ascertain the *fact* and *time* of a planet's rotation? State by whom the rotation of Venus was discovered, and the period of the same determined. Is this period of Venus' rotation considered by astronomers as absolutely exact? Describe the phases in full.

phenomena are more conspicuous, and can be observed for a longer consecutive period.

212. In a certain part of her orbit, we behold this beautiful planet rising a little *before* the *sun*, when it is termed the *morning star*. It has then just passed its *inferior conjunction*, and its *dark* side is turned *towards* the *earth*, like that of the moon when she is new; and it is now crescent-shaped. At its greatest angular distance from the sun, which is about $47\frac{1}{4}°$, it appears like a *half moon*, and shines with great splendor. When Venus arrives at her superior conjunction, she is seen like the full moon, her bright disk being nearly circular.

Passing this point of her orbit, she rises after the sun, and of course sets after it, and is now the *evening star*.

FIG. 36.

TELESCOPIC APPEARANCE OF VENUS WHEN NEAR HER INFERIOR CONJUNCTION.

Fig. 36 is a representation of Venus as she appears when viewed through a telescope near her inferior conjunction.

213. Splendor of Venus. Venus shines with the greatest brilliancy when her angular distance from the sun is a little less than 40°. About once in *eight years*, under a favorable concurrence of circumstances, her splendor is usually great. The brightness of the planet is then so intense that under a serene sky it can be seen even at noon day.

214. Transit of Venus. This appellation is given, as in the case of Mercury, to the passage of Venus across the sun's disk. A high importance is attached to this phenomenon by astronomers, since by means of it they are enabled to obtain with great accuracy the *parallax of the sun*, without which the distance of the earth from the sun could not be determined.

215. The transits of Venus, for a long time, will occur early in the months of June and December; since the planet passes her nodes in the beginning of these months, and the *motion* of the nodes along the ecliptic is extremely small. They are, however, phenomena of rare occurrence, happening at intervals of about *eight* and *one hundred and thirteen years*. The next transit takes place on the 6th of December, 1882. None happens during the 20th century, the next occurring on the morning of the 7th of June, 2004, A.D.

216. Mass—Density. From the latest and most accurate investigations, it appears that the sun contains 401,839 times *more matter* than Venus. She has therefore a little *less* matter than the earth, since the mass of the sun is only 354,000 times greater than

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State what is said of the splendor of Venus. What is said in regard to the transits of Venus? In what months of the year will the transits of Venus occur for a long while? Why? Are these phenomena frequent? When will the next transit take place? What is the *mass* of Venus?

that of the earth. The *density of Venus* nearly equals the *density* of the earth, the former being to the *latter* as 92 to 100.

THE EARTH. ⊕

217. The next planet is the Earth. This, with its attendant *moon*, we have already discussed, and therefore pass on to the *superior planets.*

SUPERIOR PLANETS.

218. These celestial bodies are more distant from the sun than the earth is, and their *orbits* consequently *encircle* that of the earth. They are in *superior conjunction* when the *sun* is directly *between them* and *earth*, and in *opposition* when the earth is *directly between* them and the *sun.* As they can never come between the earth and the sun, it is of course impossible that they should have any inferior conjunction; on this account they are *not subject* to *phases* like those of Mercury and Venus. Moreover, they are seen at all angular distances from the sun, from 0° to 180°. In these *three respects*, as viewed from the earth, they differ from the inferior planets. The next planet in order is Mars.

MARS. ♂

219. This planet is situated at the average distance of about 145,205,000 miles from the sun, and the inclination of its orbit to that of the ecliptic is

What her density? What is the next planet in order? What is said of it? What is said respecting the superior planets? Have they any inferior conjunction? State the *three particulars* in which they differ from the inferior planets, as viewed from the earth. What is the name of the superior planet next in order? What is the solar distance of Mars? What is his *periodic time?* What is the inclination of its plane to that of the ecliptic?

about 1° 53′. The period of time occupied by Mars in making one revolution about the sun, is, according to the best computation, 686 days 23h. 30m. 41sec.; the time of its rotation on its axis 24h. 37m. and 20sec.; and the length of its diameter 4500 miles. Its density is nearly the same as that of the earth.

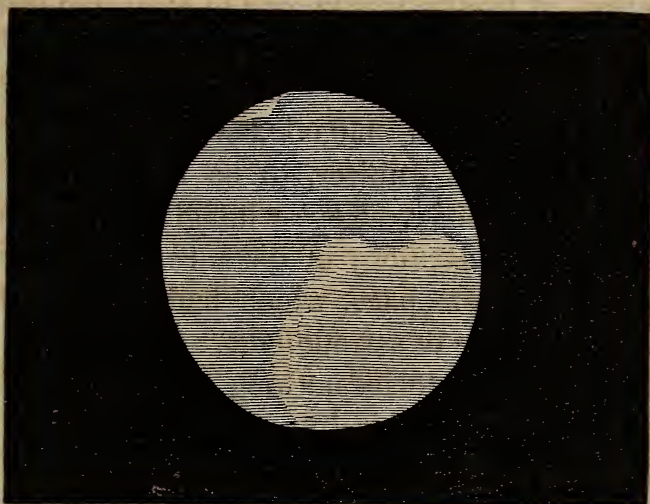
220. SPLENDOR. Mars, when nearest to us, shines with great splendor, and rising about sunset, moves along the sky a conspicuous object throughout the night; but when most remote from the earth, he appears like a star of ordinary size. The cause of these great changes is readily perceived, when we consider, that inasmuch as the orbit of Mars includes that of the earth, his distance from the earth at *superior conjunction*, equals his own distance from the sun, *increased* by that of the earth's solar distance, and at *opposition* it is only equal to the *difference* of these distances. Stating the same in figures, the distance of Mars from the earth at superior conjunction, amounts in round numbers to 145,000,000 miles *added* to 95,000,000 miles, or 240,000,000 miles; while at opposition it is equal to 145,000,000 miles *diminished* by 95,000,000 miles, or 50,000,000 miles. A variation in distance so extensive as this, must, of course, give rise to corresponding changes in the *apparent size* and *brilliancy* of the planet.

221. PHYSICAL ASPECT. When viewed through a telescope of adequate power, the outlines of *continents* and *seas* are revealed on the surface of Mars, while

What is the time of its rotation on its axis? What the length of its diameter? What is said of its density? What is said respecting the changes in the splendor of Mars? Explain the cause of these variations. Describe the physical aspects of Mars.

near *the poles white spots* are discerned, which, from their increase and decrease, with the change of its seasons, have been regarded by Sir Wm. Herschel, as *masses of ice and snow* that accumulate during the winter of Mars, and diminish in the summer. The *continents* appear of a dull *red hue*, while the seas possess a *greenish tinge.* The *ruddy hue* of the planet, by which it is easily distinguished from other heavenly bodies, is attributed by Sir John Herschel to the prevailing color of the land.

FIG. 37.



MARS, AS SEEN BY SIR JOHN HERSCHEL.

222. Fig. 37 represents Mars as viewed by the accomplished astronomer, Sir John Herschel, in his 20 feet telescope, on the 16th of August, 1830. It shows the planet in its *gibbous* state, with the outlines of its *continents* and *seas;* while *one* of the *white spots* which are situated near its poles, is distinctly discernable on its surface.

What does Fig. 37 represent?

The Asteroids.

223. The astronomer Kepler, 250 years ago, noticed a tendency to a *regular progression* in the distances of the planets from the sun, as far as Mars. *Twice* the distance of Mercury from the sun, is nearly the *distance of Venus; three times* that of Mercury is about the *distance of the earth;* and *four times* the distance of Mercury gives almost exactly the *distance of Mars.* But in order to represent the distance of Jupiter, between which orb and Mars no planet in the time of Kepler was known to exist, the distance of Mercury must be multiplied, *not by* 5, *but by* 13.

224. The law appeared here to be *broken*, and an immense interval of 350,000,000 miles, extending between Mars and Jupiter, to be unoccupied by a single planetary body. Kepler imagined that in order to preserve the harmony of distance, *another planet* existed in this vast space, which had hitherto eluded the searching gaze of astronomers.

225. For two centuries nothing was done either to verify or overthrow this hypothesis of Kepler; but when, in 1781, Uranus was discovered by Sir Wm. Herschel, an impulse was given to astronomical investigations, and an association of astronomers commenced a systematic search for this supposed planet. Ere long, instead of *one, four small planets* were discovered, to which were assigned the names of Ceres, Pallas, Juno, and Vesta.

What did Kepler remark in regard to the solar distances of the planets? Where was this law broken? What did this fact lead him to think? Was anything done by the astronomers who immediately succeeded Kepler, to confirm or overthrow his hypothesis? When was a new impulse given to astronomical research, and why? What was then done by astronomers?

226. Nearly 50 years more elapsed, when the search was renewed in the same region of space, and the discovery of 38 *additional asteroids* has rewarded the labors of the astronomer.

227. A list of the asteroids, in the *order* of their discovery, is given on the following page, together with their *distances*, *periodic* times, and other particulars respecting them.

228. From this list it appears that 42 asteroids have already been discovered between Mars and Jupiter. In the opinion of Leverrier, a distinguished French astronomer, all have not yet been found, and he thinks it probable that before the year 1860, as many as a hundred will have been discovered within this space.

229. Dr. Olbers believed that a large planet once existed between Mars and Jupiter, that it was shattered into fragments by some tremendous convulsion, and that from these fragments the asteroids have been formed.

Jupiter. ♃

230. Next in order from the sun is Jupiter, the most magnificent planet that illumines the sky. Its *periodic time* is 4332 days, or somewhat more than *twelve* of our years. The average *distance* of Jupiter is 495,817,000 miles, and his diameter, according to Prof. Struve, is 88,780 miles.

231. The *bulk* of the planet is more than *twelve hundred* times greater than that of the earth. It revolves on

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What success has attended this search for planets? How many asteroids have been discovered? What are Leverrier's views respecting their number? What is Dr. Olbers' theory? What is the next planet in order from the sun? What is his *periodic time*? His *solar distance*? What the extent of his *diameter*? What is said respecting the *bulk* of this planet?

TABLE OF ASTEROIDS.

NAME.	DISTANCE FROM THE SUN.	PERIODIC TIME.	BY WHOM DISCOVERED.	WHEN.	DIAM.
	Miles.	*Days*			*Miles*
CERES .... ⚳.	262,747,675	1680	Piazzi, of Palermo, ...	Jan. 1801	163
PALLAS .... ⚴.	263,105,635	1683	Olbers, of Bremen, ...	Mar. 1802	670
JUNO .... ⚵.	253,518,045	1592	Harding, of Lilienthal, ..	Sept. 1804	....
VESTA .... ⚶.	224,253,105	1325	Olbers, of Bremen, ...	Mar. 1807	295
ASTREA	244,853,190	1511	Hencke, of Driessen, ...	Dec. 1845	
HEBE	230,327,785	1379	Hencke, of Driessen, ...	July, 1847	
IRIS	226,718,830	1347	J. R. Hind, of London, ..	Aug. 1847	
FLORA	209.131,670	1193	J. R. Hind, of London, ..	Oct. 1847	
METIS	226,700,875	1346	Graham, of Markree, ...	Apr. 1848	
HYGEIA ....(10).	299,191,480	2041	Gasparis, of Naples, ...	Apr. 1849	
PARTHENOPE ....(11).	232,569,215	1399	Gasparis, of Naples, ...	May, 1850	
VICTORIA, or CLIO	221,794,600	1303	J. R. Hind, of London, ..	Sept. 1850	
EGERIA ....(13).	244,804,550	1512	Gasparis, of Naples, ...	Nov. 1850	
IRENE	245,536,620	1518	J. R. Hind, of London, ..	May, 1851	
EUNOMIA ....(15).	251,123,950	1570	Gasparis, of Naples, ...	July, 1851	
PSYCHE ....(16).	278,630.345	1835	Gasparis, of Naples, ...	Mar. 1852	
THETIS ....(17).	235,971,260	1430	Luther, of Bilk, ...	Apr. 1852	
MELPOMENE .....(18).	217,890.100	1269	J. R. Hind, of London, ...	June, 1852	
FORTUNA ....(19)	232,187,030	1396	J. R. Hind, of London, ...	Aug. 1852	
MASSALIA ....(20).	228,139,650	1359	Gasparis, of Naples, ...	Sept. 1852	
LUTETIA ....(21).	231,240,070	1387	Goldschmidt, ...	Nov. 1852	
CALLIOPE ....(22)	276,612,450	1815	J. R. Hind, of London, ...	Nov. 1852	
THALIA ....(23).	251.286,780	1571	J. R. Hind, of London, ...	Dec. 1852	
THEMIS ....(24).	298,727,120	2037	Gasparis, of Naples, ...	Apr. 1853	
PHOCEA ....(25).	228,063,935	1359	Chacornac, of Marseilles,	Apr. 1853	
PROSERPINE ......(26).	245,841,190	1522	Luther, of Bilk, ...	May, 1853	
EUTERPE ....(27).	223,046,035	1314	J. R. Hind, of London, ..	Nov. 1853	
BELLONA ....(28).	264,168,875	1694	Luther, of Bilk, ...	Mar. 1854	
AMPHITRITE ......(29).	241,898,215	1484	Marth, of London, ...	Mar. 1854	
URANIA ....(30).	224,041,065	1323	J. R. Hind, of London, ..	July, 1854	
EUPHROSYNE ....(31).	303,267,265	2083	Ferguson, of Wash., D.C.,	Sept. 1854	
POMONA ....(32)	245,580,320	1518	Goldschmidt, of Paris, ...	Oct. 1854	
POLYMNIA ....(33).	225,985,050	1340	Chacornac, of Paris, ...	Oct. 1854	
CIRCE ....(34)	253,916,000	1596	Chacornac, of Paris, ...	Apr. 1855	
LEUCOTHEA ......(35).	....	....	Luther, of Bilk, ...	Apr. 1855	
FIDES ....(36)	247,399,000	1535	Luther, of Bilk, ...	Oct. 1855	
ATALANTA ....(37).	....	....	Goldschmidt, of Paris, ...	Oct. 1855	
LEDA ....(38).	....	....	Chacornac, of Paris, ...	Jan. 1856	
LÆTITIA ....(39).	262,969,500	1682	Chacornac, of Paris, ...	Feb. 1856	
HARMONIA ....(40).	215,441,000	1247	Goldschmidt, of Paris, ...	Mar. 1856	
DAPHNE ....(41).	....	....	Goldschmidt, of Paris, ...	May, 1856	
ISIS ....(42).	217,531,000	1265	Pogson, of Oxford, ...	May, 1856	

its axis in a little less than 10 hours (9h. 55m. 30sec.), and it contains about *one thousandth* part of the amount of matter that is contained in the sun.

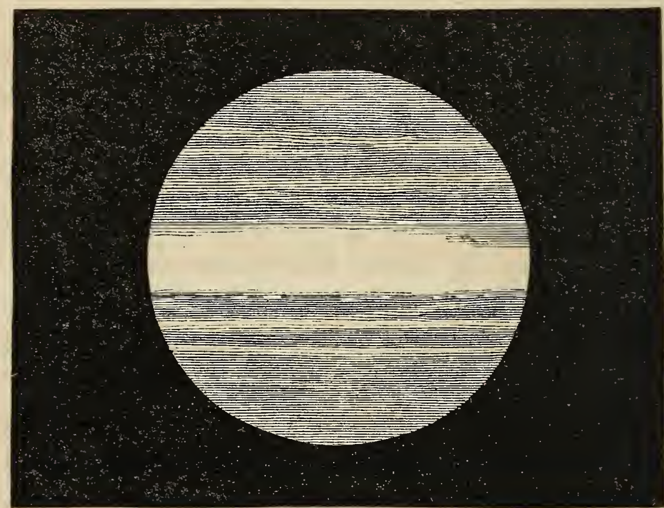
232. PHYSICAL ASPECT OF JUPITER—BELTS. When this beautiful planet is seen through a telescope, no configurations are beheld on its surface, marking the positions of continents and seas, as is the case of Mars, but *dark bands*, termed *belts*, are seen, stretching from side to side in the same direction. They are by no means uniform in their appearance; and, although for months they sometimes remained unchanged, they are yet liable to sudden and extensive alterations in their *breadth* and *situation*, though not in respect to their *general direction*. In a few rare instances, they have been seen broken up and distributed over the *entire disk of the planet*. Branches are frequently observed diverging from the main belts, and *dark spots* have likewise been noticed, of which astronomers have availed themselves to ascertain the period occupied by the planet in revolving on its axis.

233. The views generally entertained by astronomers in respect to the *cause* of the *belts*, are the following: It is supposed that Jupiter is surrounded by a luminous *atmospheric* envelope, which conceals, for the most part, the planet itself; and that this bright canopy is parted by *narrow openings* parallel to the equator of Jupiter. That an observer on the earth *looking through these openings* sees the *dark surface* of the planet, and that the *glimpses* thus caught of the *solid body* constitute the *narrow dusky bands* or *belts*.

What of its rotation? How much matter does it contain? Describe the *belts* and their *changes*. What is the prevailing opinion of astronomers as to the cause of the belts?

234. These *rents* in the atmosphere of Jupiter are supposed to be caused by *currents*, like our *trade winds*, but vastly more powerful, owing to the immense velocity with which the planet rotates; and the variations in the action of these winds upon the atmosphere of the planet would account for the changes that are noticed in the aspect of the belts. The appearance which Jupiter displays when seen through a telescope, is shown in Fig. 38.

FIG. 38.



JUPITER AND HIS BELTS.

235. Satellites of Jupiter—Their Discovery. A splendid train of four *moons*, or *satellites*, are seen by the aid of the telescope circling around this planet. They were discovered by Galileo of Padua, on the 8th of January, 1610, and were the first fruits of his invention of the telescope. From that time to the present they have ever engaged the attention of

How are the changes in the appearance of the belts supposed to arise? How many moons has Jupiter? By whom, when, and how were they discovered? Why are they regarded with interest by astronomers?

astronomers, and their *eclipses* have been eminently serviceable in certain scientific investigations.

236. THEIR MAGNITUDES—DIAMETERS—DISTANCES—AND PERIODS OF REVOLUTION. No names have been given to these *moons*, but they are denominated the *first*, *second*, *third*, and *fourth* satellites, according to their distances from Jupiter, the *first* being the *nearest*. Their respective *diameters*, *distances*, and *periods of revolution* around Jupiter, are given in the table below:

	Diameter.	*Dist. from Jupiter.*	*Periods of Revolution.*
First Satellite,	2,440 miles,	278,500 miles,	1d. 18h. 27m. 34sec.
Second "	2,190 "	443 000 "	3d. 13h. 14m. 36sec.
Third "	3,580 "	707,000 "	7d. 3h. 42m. 33sec.
Fourth, "	3,060 "	1,243,500 "	16d. 16h. 31m. 50sec.

The *first two* satellites are *larger* than our *moon*, and the *last two greater* than the planet *Mercury*—the *diameter* of the third exceeding that of Mercury by 630 miles.

237. KEPLER'S LAWS—ROTATION. The satellites in their respective *distances* from the planet Jupiter, and in their *periodic times*, obey the *third* law of Kepler—the *squares* of their *periodic times* being as the *cubes* of their *distances* from their common primary. An extended series of observations upon the periodical changes in their light, led Sir William Herschel to infer that each of the satellites revolves on its axis in exactly the *same* time as it completes one *synodical revolution* about Jupiter, thus following exactly the same law as our moon does in respect to the earth.

State their *magnitudes*, *diameters*, *distances*, and *periodic times*. How do they compare in their actual dimensions with our moon and Mercury? Does Kepler's third law apply to the satellites? State what is said in regard to their rotation. In what direction do the satellites revolve about Jupiter?

238. Transits and Eclipses of the Satellites. The satellites revolve about Jupiter from *west* to *east*, and in planes nearly coincident with each other. They are, therefore, seen ranging together in almost a *straight line*, and seem to move backwards and forwards in the heavens, now passing in *front* of the planet, and now *behind* it.

239. When they pass *before* the planet, their *transits* occur, and they cast *shadows* upon their primary, which appear as *dark spots* crossing its bright disk.

240. In passing *behind* the body of the planet, or into its shadow at a distance from it, the satellites *disappear* and their *eclipses* occur. The *three* satellites which are nearest to Jupiter are *totally* eclipsed, every revolution around their *primary*, but the *fourth*, from the greater inclination of its orbit, sometimes escapes being eclipsed, yet so seldom that its eclipses may be regarded as happening, for the most part, at every revolution, like those of the others.

Saturn. ♄

241. The next planet is *Saturn*, a vast globe, inferior in magnitude only to Jupiter, but surpassing it in the wondrous structure of its system, for Saturn is attended by a train of no less than *eight satellites*, and is girdled by several *rings* of stupendous size. Its average distance from the sun is about 900,000,000 miles, and it revolves around it in 29½ years.

242. The equatorial diameter of Saturn is 77,000 miles, and it contains about one thirty-five hundredth

Why are they seen in a straight line with each other? How do they appear to move in the heavens? When do their *transits* occur? Describe them. Under what circumstances do their *eclipses* happen? State what is said of their frequency. What planet is next discussed? What is said of its grandeur? What is its *solar distance* and *periodic time*? What is the length of its diameter?

part of the amount of matter existing in the sun. From the observations of Sir William Herschel, who watched this planet through a hundred rotations, it appears that it revolves on its axis in 10 hours, 16 minutes, and 4 seconds.

243. PHYSICAL ASPECT. Saturn appears of a *pale yellowish hue*, and when viewed through a good telescope, *belts* are frequently seen upon its surface, but far more faint and obscure than those which are revealed upon the disk of Jupiter. *Spots* are rarely noticed on this planet.

244. RING OF SATURN—ITS DISCOVERY. When Galileo, in the year 1610, directed his telescope to Saturn, the figure of the planet appeared so singular, that he thought it consisted of a *large globe*, with a *smaller one on each side*. About 50 years afterwards, Huyghens, a distinguished Dutch philosopher, observed Saturn with telescopes of greater magnifying power than those which had been employed by Galileo, and soon made the discovery that the planet was surrounded by a *vast luminous ring*, *unconnected* with the body of the planet.

245. When the telescope had been still farther improved, and instruments of higher magnifying powers and finer construction were at command, two English gentlemen of the name of Ball, in October of the year 1665, *first* noticed that the ring was *double*; a phenomenon which was observed by Cassini, at Paris, 1675, and to whom the honor of this *second* discovery is usually attributed.

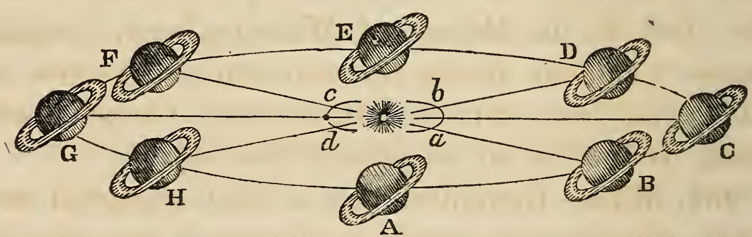
246. FORM—CONSTITUTION. The whole ring may be described as *circular*, *broad*, and *flat*, like a coin with

How much matter does it contain? What is the period of its rotation? Describe the physical aspects of this planet. Give an account of the discovery of Saturn's ring. What is said respecting its *form* and *constitution*?

a *round central* opening. Like the planet, it shines by the reflected rays of the sun, and has usually been supposed by astronomers to consist of *solid matter*, since it *casts a shade* upon the surface of the planet, when it is situated *between* the latter and the sun. Professors Pierce and Bond, of Harvard University, have, however, arrived at the conclusion that the ring of Saturn is not *solid*, but *fluid*. Professor Pierce remarks, "that the ring of Saturn consists of a number of *streams* of some *fluid* about *one fourth heavier* than *water*, flowing around the planet."

247. Rotation—Position. From the observations made upon certain spots on its surface, Sir William Herschel inferred that the ring rotated in its own plane in the space of 10h. 32m. 15sec. The plane of the ring maintains invariably the same position in space, as is seen in Fig. 39.

FIG. 39.



SATURN AND HIS RING.

248. Divisions of the Ring. We have just alluded to the discovery made by the Messrs. Ball, and also by Cassini, that the ring of Saturn is *double*. For nearly a century, astronomers have been led to think, from the appearance of *dark lines* upon the ring, that other subdivisions exist, and these surmises have proved correct.

What of its *rotation* and *position*? Relate in full the discoveries that have been made in respect to the divisions of the ring.

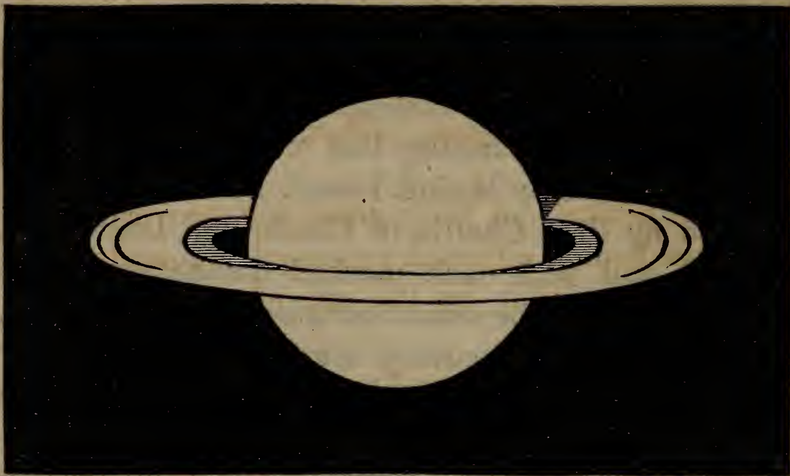
249. In 1837, Prof. Encke, of Berlin, saw, through the famous telescope of Fraunhofer, the *outer ring* of Saturn divided by a *black line*, and so clearly defined that he was enabled to take the measurements of its breadth. This separating line was observed some years afterwards by Messrs. Lassel, Dawes, and Hind, and also by Prof. Challis, of Cambridge University, England, and with such marked distinctness as to leave no doubt of the *actual division* of the *outer ring.*

250. But this discovery was soon followed by another still more surprising, which was no less than the detection of a *dusky obscure ring*, *nearer* to the planet than what is usually termed the *bright inner ring.* On the 11th of November, 1850, Mr. G. P. Bond, of Harvard University, saw such evidences of subdivision in the *inner ring* as led him to infer that a *third ring* existed *nearer* the planet, and less bright than the other two. On the 29th of the same month, the Rev. W. R. Dawes, of Wateringbury, England, made the same discovery, and noticed, likewise, the additional fact, that the *dusky ring* is itself *double*, being divided by an extremely fine line.

251. What, therefore, was at first regarded as a *single* ring, is now found to consist of *five*, viz., *two obscure rings* nearest the planet, and *three bright ones* beyond them. The *two exterior luminous* rings constitute what has hitherto been termed the *outer ring* of Saturn, and the *third* the *inner ring.* Fig. 40 represents Saturn and his rings, as they appeared to Mr. Dawes, of Wateringbury, when viewed through a telescope of the finest construction. The *division* of the *dark inner ring* is, however, not delineated.

How many rings have been found?

FIG. 40.



SATURN, AS VIEWED BY THE REV. W. R. DAWES, ON NOVEMBER 29TH, 1850.

252. Dimensions of the Rings. The dimensions of the *outer* and *inner*[1] *rings* of Saturn have been determined, by the most accurate and careful measurements, to be as follows:

From the surface of the planet to the *inner* edge of the *first* bright ring,.................... ..	18,628 miles.
Breadth of the inner ring, ...	16,755 "
Breadth of the interval between the bright inner and outer ring,..........................	1,752 "
Breadth of the outer ring,......................	10,316 "
Outer diameter of the outer ring,................	172,130 "

253. The *thickness* of the rings has been estimated by Sir John Herschel, at not more than 100 miles, while Mr. G. P. Bond, of Cambridge, places the thickness as low as 40 miles.

1. *Outer* and *inner ring*. By the *outer ring* is here meant, as stated in the preceding article, the *two exterior bright* rings. The *inner* ring is the *third bright* ring, next to the *dark* one.

Give the dimensions of the *outer* and *inner* rings of Saturn. What is the thickness of the rings, according to Sir John Herschel? What, according to Mr. G. P. Bond?

254. Satellites of Saturn. Saturn is attended by *eight* moons, *seven* of which revolve about the planet in orbits whose planes are nearly *coincident* with that of the ring. They have received the names of *Mimas*, *Enceladus*, *Tethys*, *Dione*, *Rhea*, *Titan*, *Hyperion*, and *Japetus*.

255. On account of their great distance from the earth, these bodies, although possessed of considerable size, are only visible by the aid of powerful telescopes.

256. Hyperion. This satellite was discovered as late as September, 1848, and almost at the same time by two observers. Mr. G. P. Bond, of Harvard University, detected it on the 16th of September, and Mr. Lassel, of Liverpool, on the 18th of the same month.

Uranus, or Herschel. ♅

257. Until the year 1781, all the known planets, excluding our earth, were *Mercury*, *Venus*, *Mars*, *Jupiter*, and *Saturn*. Each of these, more or less conspicuous to the unaided eye, had been recognized as *planets* for ages, but about this time, Sir William Herschel, having constructed telescopes of great power, commenced a systematic examination of the heavens, which led to the most surprising discoveries.

258. On the 13th of March, 1781, between ten and eleven o'clock, this eminent astronomer detected an object which he at first suspected to be a comet, but subsequent observations established its planetary

How many moons has Saturn? What is the position of the planes of the orbits of *seven*? Give the names of the satellites. What is said as to their visibility? Give an account of Hyperion. *When* was Uranus discovered, and by *whom*?

nature. The *new planet* was called by Herschel, *Georgium Sidus*, as a compliment to his patron, George III., and by others, *Herschel*, in honor of the discoverer; but the name proposed by Bode, of *Uranus*, is now universally adopted.

259. Aspect—Diameter—Mass. Uranus appears of a *pale color*, uniformly bright, and undiversified with *spots*, *belts*, or *configurations of surface*, such as are seen on Jupiter and Mars. Its *diameter* is about 35,000 miles. According to the recent calculations of Mr. Adams, the sun contains 21,000 times as much matter as Uranus. The *density* of Uranus is exactly the same as that of Jupiter, or about one fourth of that of the earth.

260. Rotation. The *absence* of *spots* and *outlines* upon the unvarying bright surface of Uranus, deprives astronomers of the means of determining the period of its rotation. In fact, whether it *revolves at all* upon its axis, is a point not yet fully determined, but as it belongs to a *system* of planets, *all the rest* of which revolve on their axes, it is reasonable to infer from analogy that Uranus also does.

261. Distance—Periodic Time. The *average distance* of Uranus from the sun is 1,828,071,000 miles, and it *revolves* about the sun in a little more than 84 of our years.

262. Satellites of Uranus. Uranus was found by Sir William Herschel to be attended by *six satellites*, but, notwithstanding the zealous efforts of astrono-

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What are the various names of this planet? State what is said in regard to its *aspect*, *diameter*, and *mass*. What of its *rotation*, *distance*, and *periodic time*. How many satellites has Uranus?

mers, little certain knowledge has yet been gained in respect to them.

263. The *satellites* of Uranus differ in two *particulars* from all the other planetary bodies that compose the *solar system.* For all the planets and their satellites, excepting those of Uranus, revolve in their orbits from *west* to *east*, and the *planes of their orbits* do not deviate far from the *plane of the ecliptic;* but the attendants of Uranus move around the planet from *east* to *west*, and the *planes of their orbits* are nearly *perpendicular* to the *plane of the ecliptic.*

NEPTUNE. ♆

264. HISTORY OF ITS DISCOVERY. When an astronomer knows perfectly all the *elements* of a planet, he can tell at what time it will be in a particular place in the heavens, with greater precision than the station-master of a railroad can tell when a certain train will arrive at a given station. If the planet does not arrive at its *appointed place* at the *computed time*, it must be owing to some *influence unknown* to the *astronomer*, provided he has made no error in his calculations. Now Uranus, ever since its discovery, has not *kept its appointments*, for astronomers have been constantly finding it in a different place from that in which it ought to have been according to their calculations. It was always off the track, and they at length suspected that these deviations were caused by the attraction of a *planet hitherto undiscovered.*

265. Mr. Adams, of St. John's College, Cambridge,

What do we know respecting them? Have they any peculiarities? What are they? What is the next planet in order? Give the history of the discovery of Neptune.

in 1843, and Mr. Leverrier, of Paris, in 1845, unknown to each other, undertook the task of solving this intricate problem, calculating *how large* a planet would account for these deviations, *what distance* it must be from the sun, *what orbit* it must have, and various other particulars. In September, 1846, the French astronomer had so fully completed his computations, that on the 23d of the month, he wrote to Dr. Galle, of Berlin, telling him *where* to look in the heavens for the *unknown planet*, and of *what size* it would appear. Dr. Galle, the same evening he received the letter, pointed his instrument to that region in the heavens where he had been directed to gaze, and there he immediately saw a star of the magnitude mentioned by Leverrier, and which proved to be the planet sought.

266. Name — Diameter — Mass — Density. The planet of Leverrier has generally received from astronomers the name of *Neptune*. Its *diameter*, deduced from measurements made with the best instruments of Europe, is 31,000 miles. Its *mass* is not yet accurately known, but from the computations of several very able astronomers, it is ascertained that the sun contains about 18,000 *times more matter* than Neptune.

267. Orbit—Distance—Periodic Time. The most accurate determination of Neptune's orbit is that made by Mr. Sears C. Walker, of Philadelphia. According to this astronomer, the average solar distance of Neptune is 2,862,457,000 miles, and its *periodic time* about 164½ years.

What is said respecting the *name* of this planet? What of its *diameter*, *mass*, *solar distance*, and *periodic time?*

268. Has Neptune a Ring? Mr. Lassel, of Liverpool, and Prof. Challis, of Cambridge, England, have at various times supposed that they saw traces of a ring surrounding the planet. Prof. Bond, of Cambridge, has frequently noticed a *luminous appendage*, but not so defined as to enable him to announce the *existence* of a ring.

269. The Satellite of Neptune. In about a month after the discovery of Neptune by Dr. Galle, Mr. Lassel, of Liverpool, detected a satellite at about the same distance from the planet as the moon is from the earth.

CHAPTER VI.

COMETS.

270. Comets are a class of bodies belonging to the solar system, entirely different in appearance from any we have yet considered. The orbits in which they revolve are so elliptical that during the greater part of their circuit they are *invisible*, being only detected when near the sun.

271. Constitution. The *comet*, when entire, consists of *three parts*—the head or nucleus, the coma or envelope, and the tail. The *head* is nearest to the sun, and appears as a bright spot, more *dense* than the other portions. Surrounding the head, but

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Has Neptune a ring? What is said of its satellite? What does Chapter VI. treat of? What is said respecting these bodies? Of how many parts does a comet consist? Describe each of them in full.

yet perhaps separated from it, is the *coma*, which is a luminous, fog-like covering, that probably conceals from our view the real body of the comet. This envelope is conceived to give to comets a *hairy appearance;* hence their name.[1]

272. The *tail* is an expansion of the *coma*, the light matter of which, streaming backward on either side in a direction *opposite* to the sun, diffuses itself, for the most part, into *two broad trains* of light, extending to an *immense distance*, and which constitute the *tail.* All comets do not possess tails; even some of the most conspicuous present to view tails of only moderate dimensions, while others are as perfectly free from them as a planet.

273. In Fig. 41, where the comet of 1819 is delineated, its *three* distinct parts are easily recognized.

274. NUMBER OF COMETS. This class of celestial bodies is without doubt very numerous, for, according to Sir John Herschel, the list of those on record, before the invention of the telescope, amounts to *several hundred.* M. Arago has considered that he might safely estimate the number of comets within the orbit of Uranus at 7,000,000, and there are probably within the orbit of Neptune more than 28,000,000.

275. SPLENDOR AND SIZE. Comets *vary* much in respect to their *brilliancy* and *magnitude;* for, while multitudes are only visible through the telescope,

1. *Comet*, from the Greek word *komē*, signifying *hair.*

Do all comets possess tails or trains? What is said respecting the number of comets on record before the telescope was invented? What was Arago's estimate of the number? How many are there probably within the orbit of Neptune? What is said of the splendor and size of comets?

FIG. 41.

COMET OF 1819.

many of which are destitute of tails and heads, appearing only as *cloudy stars*, others almost dazzle the gaze with their brightness, and extend their bright tails half across the heavens. Some comets have been seen of such surpassing splendor that they were visible in *clear daylight*.

276. COMET OF 1680. The famous comet of 1680 was conspicuous for the great length of its tail; for soon after its nearest approach to the sun, this wondrous appendage shot out from the body of the comet to the distance of 60,000,000 miles, and in the incredible short space of *two days*. When it had attained its *greatest length*, it extended no less than 123,000,000 miles from the head, covering a space in the heavens greater than the distance from the *horizon* to the *zenith*. So swiftly did it move that it

Describe the comet of 1680.

is said to have gone half around the sun in *ten* and a *half* hours, moving with the speed of 880,000 miles an hour.

This comet came within the distance of only 147,000 miles from the surface of the sun, and was exposed to a heat 27,500 times greater than that received by the earth in the same time—a heat 2000 times *greater than that of red-hot iron.*

277. Comet of 1843. This comet was seen on the 28th of February, 1843, *close to the sun*, its brightness being so great that the splendor of the solar beams could not overpower its brilliancy. The *diameter* of its envelope was 36,000 miles, and the *greatest length* of the train 108,000,000 miles.

At the Cape of Good Hope it appeared on the 3d of March to be *double*, *two trains* diverging from the head in a straight line, forming a small angle with each other. Near the *equator* this magnificent appendage shone with such a glow that at times it threw a bright light upon the sea. It swept more than half around the sun in *two and a half hours*, moving with a velocity of 1,300,000 miles an hour. It came within about 60,000 miles of the sun's surface, and, according to Sir John Herschel, the heat it received from the sun was 47,000 times greater than that which falls upon the earth in the same time, when the sun is shining perpendicularly upon it. So *intense* is such a heat, that it is $24\frac{1}{2}$ times greater than that which is sufficient to *melt agate* or *rock crystal.*

278. Orbits. The *orbits* of comets, for the most

Describe the comet of 1843. State what is said respecting the *orbits of comets.*

part, are *ellipses*, with the sun in their *common focus;* but, unlike those of the planets, which deviate but little from a circle in form, the elliptical orbits of comets are exceedingly *elongated.*

In consequence of this extended form of the orbit, the comet is only beheld for a short time while it is *near the sun;* after which it occupies *years*, and even *centuries*, in accomplishing the remainder of its circuit, sweeping far beyond the limits of the planetary system, where no telescope can begin to descry it.

279. THE COMETS OF HALLEY, ENCKE, BIELA, AND FAYE. Of all the comets that have been observed, the orbits of about 190 have been determined, and out of all these, the return of only *four* have been verified by observation, namely: Halley's, Encke's, Biela's, and Faye's. Halley's comet returns at intervals of about 75 or 76 years. Its last appearance was in 1835, when its predicted corresponded with its actual return within *one* day. It recedes from the sun 600,000,000 miles beyond Neptune. The period of Encke's comet is 3⅓ years, that of Biela's, 6¾ years, and that of Faye's, 7½ years.

280. NATURE OF COMETS. These extraordinary bodies consist of *matter*, but existing in an attenuated and diffused state, of which we have no adequate conception. A light cloud, in comparison with the matter composing the *tail of a comet*, is to be regarded as a *dense* and *heavy* body.

281. The *amount of matter* in comets, even of the *largest size*, is so *small* that their passage around the

Of how many comets have the orbits been determined? Of how many has the return been verified by observation? Describe Halley's comet, Encke's, Biela's, and Faye's. What is said of the *nature* of comets, and their amount of matter?

sun has never, in the least perceptible degree, affected the *stability of the solar system;* in other words, they have never, as far as could be perceived, caused the planets to deviate a hair's breadth from their accustomed paths around the sun.

CHAPTER VII.

TIDES.

282. The *periodical rising and falling of the waters of the ocean, in alternate succession, are called tides.* Standing on the sea shore, a person will perceive that for the space of nearly 6 *hours*, the waters of the sea continue to rise higher and higher, overflowing the shores, and running into the channels of the rivers. When they have attained their greatest elevation, it is then said to be *high tide*, *full sea*, or *flood tide.* Remaining at this elevation only for a few moments, they then begin to fall, and continue to sink for about 6 *hours more.* When the waters have reached their *greatest depression*, it is then *low*, or *ebb tide.* After attaining this point, the sea, in a short time, again begins to *swell*, in the same manner as before, and thus, from *year* to *year*, and from *century* to *century*, the *ebb* and *flow* of the ocean follow each other at regular intervals of time.

283. From the above explanation, it will be seen that there are *daily two high tides* and *two low tides*,

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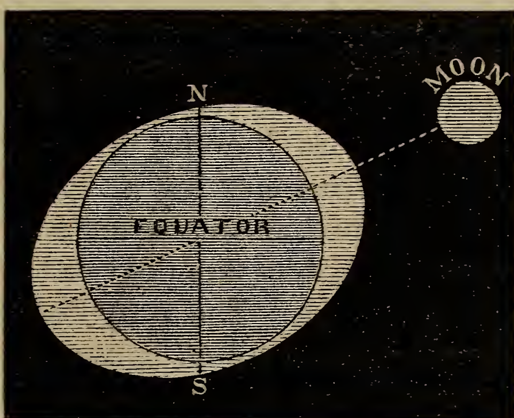
What does Chapter VII. treat of? What are the tides? Describe them, explaining the meaning of *high tide* and *low tide.* How many *high tides* and *low tides* occur *daily?*

The *interval of time* between two successive high or low tides, is about 12h. 25m. Accordingly, when there is a high tide at any place, as New York, for instance, there must also be a high tide on the *opposite side* of the globe; and the same is true in respect to a *low tide.*

284. A marked correspondence exists between the *motion of the tides* and the *motion of the moon.* If *to-day*, at 10 A.M., it is high tide in a certain harbor, it will be high tide *to-morrow* in the same harbor at 10h. 50m. 28sec. A.M. The interval, therefore, that

FIG. 42.



THE TIDES.

elapses between any *high tide* and the *next but one* after it, is 24h. 50m. 28sec. Now, this is the *exact* amount of *time* that intervenes between two successive passages of the moon over the *meridian* of any place. In fact, as the earth revolves on her axis, the *tide wave* tends to keep *under the moon*, and thus sweeps around

What is the interval of time between two successive high or low tides? When a high tide, for instance, occurs at any port, where is there then also *another* high tide? What marked correspondence is here alluded to? Describe it particularly.

the globe, from any port to the same port again, in the precise period of time that elapses between two *successive returns* of the *moon* to the *meridian* of this port. This subject is illustrated by Fig. 42.

285. CAUSE OF THE TIDES. *The* UNEQUAL *attraction exerted by the sun and moon upon different parts of the globe, produces the tides*, and we will now proceed to explain this phenomenon, commencing with the moon.

The waters of the earth directly under the moon, are more attracted by the moon than the solid part of the earth, because they are *nearer* (Art. 189), and a high tide is therefore produced about under the moon. The solid part of the earth is nearer to the moon than the waters on the side of the earth opposite to the moon; the solid part is, therefore, more attracted than these waters, and is, as it were, drawn away from them by the moon, thus creating a high tide on the side of the earth opposite to the moon. Half-way between the two high tides, are the two low tides.

286. SOLAR INFLUENCE. The *sun*, like the moon, produces tides by the *unequal* attraction it exerts upon the waters of the ocean, causing *high tides* at the points immediately beneath it, *on opposite sides* of the globe; and *low tides* half-way from these points. The sun's influence is, however, only about *one third* of that of the moon, notwithstanding its vast superiority in size and mass. But any difficulty that may arise in understanding this fact, will vanish, when we reflect that it is the *unequal action* of these bodies upon

What is the *cause of the tides?* Explain the action of the moon in producing tides. What is said respecting the sun's influence in producing tides? What is said of the amount of solar influence?

the waters of the earth that produces the tides, and not their *whole attraction.* Now, the waters of the globe just under the sun and moon, are about 8000 miles (the earth's diameter) *nearer* the sun and moon than the waters on the opposite side; but 8000 miles is $\frac{1}{30}$th part of the moon's distance from the *earth*, while it is only $\frac{1}{12000}$th part of the sun's distance from the *earth.*

287. Spring and Neap Tides. We have just seen that the sun and moon cause tides in the ocean, *independently of each other.* These bodies, however, are perpetually *changing their relative positions* in the heavens, and on this account their separate actions are at alternate periods of time *united* and *opposed* to each other. The sun and moon act together *twice a month*, viz., at the *opposition* and *conjunction*, and the tides are then unusually high, since the *lunar* and *solar* tide waves are then *heaped* one upon the other. These are the spring tides.

288. *Twice every month*, at the *quadratures*, the sun and moon *oppose* each other; for at those points on the earth's surface where the *sun's* action then tends to *elevate* the waters, the *moon's* influence *depresses* them, and where the *moon raises* the *surface* of the ocean, the influence of the sun is exerted to cause it to *sink.* These are the neap tides.

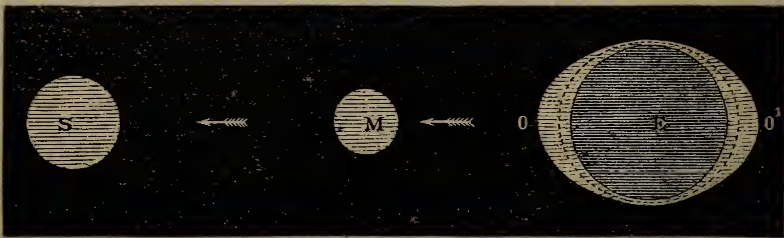
289. The height of the *lunar tide wave* being about 5 feet, and the *solar* 2, the *average heights* of the *spring* and *neap tides* will be in the ratio of 7 to 3. At the time of the *neap tides*, the *low tides* are *higher* than *ordinary*, since at the places where they occur,

---

Explain why it is small. When do the spring tides occur? When the neap tides?

the *solar tide wave* is at its *greatest altitude*, and its height must be *added* to the height of the low water, caused by the moon's action. But the *high tides* are then unusually *low*, since the *lunar high tide wave* is *diminished* by the *solar low tide.*

FIG. 43.



SPRING TIDE—NEW MOON.

290. In Figs. 43 and 44, the subject of the *spring tides* is illustrated. In each of these figures, S represents the *sun*, M the *moon*, and E the *solid portion of the earth.* The *dotted line* inclosing the earth, is the *solar tide wave*, and upon this, in the line of the *three bodies*, is heaped the *lunar tide wave*, the boundary of which is the *outer* curved line.

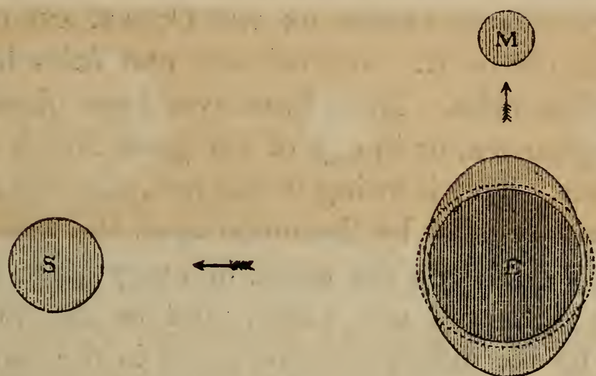
FIG. 44.

SPRING TIDE—FULL MOON.

Describe these phenomena in full, and explain from Figures 43, 44, and 45.

291. In Fig. 45 is exhibited the phenomenon of the *neap tides.* The moon is in *quadrature*, 90° from the sun, and the two bodies evidently *counteract* each other's influence in producing their respective tides. The solar tide wave, as in the preceding figure, is rep-

FIG. 45.



NEAP TIDE—QUADRATURE.

resented by the *dotted oval line*, and the *lunar tide wave* by the *unbroken curved line.*

292. Actual Heights of the Tide. The *theoretical height* of the tide does not correspond to the *real height.* This difference is owing to *local causes*, such as the union of two tides, or the rushing of the tide wave into a *narrow channel.* In the latter case, the advance of the tide is often very rapid, and the water rises to a great elevation. Thus within the British Channel, the sea is so compressed that the tide rises 50 feet at St. Malo's, on the coast of France. In the Bay of Fundy, the tide swells to the height of 60 or

Why does not the *theoretical* height of the tide in any place correspond with the *actual* height? State the cases cited.

70 feet. Here, according to Prof. Whewell, the tide wave of the South Atlantic meets the tide wave of the Northern Ocean, and their union raises the surface of the sea to the height just mentioned. On the vast Pacific, where the great tide wave moves without obstruction, the rise of the water is only about *two feet* on the shores of some of the South Sea Islands.

293. No Tides except on the Ocean, and on Seas connected with it. *Inland seas* and *lakes* have no perceptible tides. None have ever been observed in the Caspian sea, or in any of the great North American lakes. This is owing to the fact, that the attractive forces exerted by the moon upon the waters of a lake, are so *nearly* the same, in every part, that no *sensible difference* can exist; and as the tides are caused by the differences that occur in the *amount* of attraction, it follows that where there is no *difference*, there is *no tide.* These remarks apply with greater force to the attraction of the sun. It is only in the ocean that the expanse of water is sufficiently great to cause such an inequality of action, both in the *lunar and solar* attraction, as to produce tides.

294. In the Mediterranean and Black seas, which are almost entirely encircled by land, the tides are scarcely *perceptible.*

Have tides been noticed in *lakes* and inland seas? Why do they not occur in such waters? What is said of the tides in the Mediterranean and Black seas?

PART THIRD.

THE STARRY HEAVENS.

CHAPTER I.

OF THE FIXED STARS IN GENERAL AND THE CONSTELLATIONS.

295. We pass now in imagination beyond the *solar system*, and direct our attention to those *heavenly* bodies that lie beyond it.

296. The Fixed Stars. When we gaze at night upon the unclouded sky, we behold, in addition to the objects already described, a multitude of sparkling *orbs*, varying in *brightness* and *magnitude*. These are termed the *fixed stars*, not because they are known to be actually *stationary* in space, for many of the stars are undoubtedly in *motion*, and possibly all may be; but from the fact that their *changes* in position, wherever noticed, are *so slow*, that, compared with the swiftly-moving members of the solar system, they may be regarded as *fixed*.

297. Magnitudes. Astronomers have classed the fixed stars according to their *degrees of brightness*. Those possessing the *greatest* splendor are termed stars of the *first magnitude*, while others which differ from the first by a *perceptible diminution* of brightness, rank as stars of the *second magnitude;* and so on

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What does *Part Third* treat of? What is the subject of *Chapter I.*? To what do we now direct our attention? What is said of the *fixed stars*? How have they been classed by astronomers?

to the *seventh magnitude*, which is the *limit of visibility* to the *naked eye*. But the *telescope* now comes to our aid, and we discern stars ranging down in minuteness from the *seventh* to the *sixteenth magnitude;* and the series ends, even here, not from the want of stars to discover, but because our *noblest* instruments have not sufficient power to detect them.

298. NUMBER OF STARS. The stars are literally *innumerable.* There are but 23 or 24 of the *first* magnitude, from 50 to 60 of the *second*, about 200 of the third; and as we descend in the scale the number comprised in the different classes rapidly increases. The number already noted down, from the *first* to the *seventh* magnitude inclusive, amounts to from 12,000 to 15,000, while the entire number registered amounts to 150,000 or 200,000.

299. But when the telescope sounds the depths of space, the heavens appear to be blazing with bright orbs, and the more powerful the instrument the more numerous are the stars revealed. Sir Wm. Herschel estimated, that, in a certain region of the sky remarkably rich with stars, no less than 116,000 passed through the field of his telescope in the space of fifteen minutes, and throughout the entire expanse of the heavens, it is reckoned that at least *one hundred millions of stars* are within the range of telescopic vision.

How many magnitudes are visible to the naked eye? How far are these magnitudes extended by the telescope? What is said respecting the number of the stars? How many are there of the *first* magnitude? Of the *second?* Of the *third?* What is said of their number as we descend in the scale? How many are noted down from the *first* to the *seventh* magnitude? What is the amount of the entire list registered? What is said of the number of stars observed when the *telescope* is employed? What estimate was made by Sir William Herschel?

The Constellations.

300. In *geography*, we observe that the entire surface of the globe is divided and subdivided into numerous *regions* and *districts*, under different names. So likewise in the records of Astronomy we find that, from the earliest ages,[1] the *visible heavens* have been divided into *spaces* termed *constellations*, which are supposed to be occupied by the *figures of animals* and other objects; and whose *names* they respectively bear.

In some few instances the grouping of the stars that form a constellation, bears some resemblance to the figure which designates it, but for the most part we look in vain for any such correspondence.

301. Their Use. The constellations serve to indicate in a *general* manner *whereabout* a star is situated in the heavens, without fixing its *exact position*. Thus if a star is said to be in the *head of the Bull*, we know something respecting its situation, but there are *many stars* in the head of the Bull, and we cannot tell what star is meant unless either its *right ascension* and *declination* are given, or its *celestial latitude* and *longitude*. These measurements deter-

1. In the book of Job, which, according to chronologists, was written at least 3300 years ago, the constellations of Orion and the Pleiades are particularly mentioned. The oldest Greek poets also speak of several of the constellations and principal stars. Thus Homer mentions Orion, the Bear, the Pleiades, and Hyades.

How have the visible heavens been divided from the earliest times? In what manner have these spaces been supposed to be occupied? What is said of the resemblance of the grouping of the stars in a constellation to the figure which represents it? What do the constellations serve to indicate?

mine its *precise situation* in the heavens, and designate the star.

302. To illustrate from geography. If a traveller were to speak of an adventure that occurred in Egypt, we should know *whereabout* on the surface of the globe it happened, but not the *precise place*. This, however, we should ascertain at once if the *latitude* and *longitude* of the place were mentioned.

303. PRINCIPAL CONSTELLATIONS. A list of the *chief* constellations is given below.

CONSTELLATIONS NORTH OF THE ZODIAC.

CASSIOPEA,
ANDROMEDA,
THE TRIANGLES,
PERSEUS,
THE CAMELOPARD,
AURIGA, the Charioteer,
THE LYNX,
THE LESSER LION,
URSA MAJOR, the Great Bear,
THE DRAGON,
BERENICE'S HAIR,
THE GREYHOUNDS,
BOOTES,
MOUNT MENALUS,
URSA MINOR, the Lesser Bear,
THE NORTHERN CROWN,
HERCULES,
THE SERPENT,
OPHIUCHUS,
LYRA, the Harp.
AQUILA, the Eagle,
ANTINOUS,
SOBIESKI'S SHIELD,
SAGITTA, the Arrow,
THE FOX AND GOOSE,
CYGNUS, the Swan,
DELPHINUS, the Dolphin,
THE LESSER HORSE,
PEGASUS, the Winged Horse,
THE LIZARD,
CEPHEUS.

How is the *precise situation* of a star ascertained? Illustrate from geography. Recite the names of the principal constellations *north* of the Zodiac.

CONSTELLATIONS OF THE ZODIAC.

ARIES, the Ram,
TAURUS, the Bull,
GEMINI, the Twins,
CANCER, the Crab,
LEO, the Lion,
VIRGO, the Virgin,
LIBRA, the Scales,
SCORPIO, the Scorpion,
SAGITTARIUS, the Archer,
CAPRICORNUS, the Goat,
AQUARIUS, the Water-bearer,
PISCES, the Fish.

CONSTELLATIONS SOUTH OF THE ZODIAC.

CETUS, the Whale,
ERIDANUS,
ORION,
THE HARE,
THE UNICORN,
THE GREAT DOG,
THE LESSER DOG,
ARGO NAVIS, the Ship,
THE HYDRA,
THE CUP,
CORVUS, the Crow,
THE SEXTANT,
CENTAURUS, the Centaur,
LUPUS, the Wolf,
THE SOUTHERN FISH

304. DISTANCE OF THE FIXED STARS. In the years 1832 and 1833, Professor Henderson, of Edinburgh, made an extended series of observations of the most refined nature, at the Cape of Good Hope, upon a bright star in the constellation of the Centaur, for the purpose of ascertaining its distance. He was successful, and found it to be about *twenty millions of millions of miles* (20,000,000,000,000). Other observations made by Mr. McLear in 1839 and 1840, gave almost precisely the same result.

305. The *velocity of light* is 192,000 miles per

Recite the names of the principal constellations *of* the Zodiac, and of those *south* of the Zodiac. What do we know of the distance of the fixed stars ?

second: it would therefore take a ray of light about *three years and a quarter* to travel from the nearest *fixed star* to the earth.

306. In the year 1838, Professor Bessel, of Konigsberg, ascertained beyond a doubt that the distance from the earth to a certain star in the constellation of the Swan, was 592,000 times the earth's distance from the sun. It would take a ray of light more than *nine years* to pass from this star to our globe.

307. NATURE AND INTRINSIC SPLENDOR OF THE FIXED STARS. The *fixed stars* are supposed to be *suns* shining by their *own light.* The dog-star Sirius, a magnificent orb, shines with the brightness of *sixty-three of our suns.*

CHAPTER II.

DIFFERENT KINDS OF STARS.—STELLAR MOTIONS.—BINARY SYSTEMS.

308. PERIODICAL STARS. Among the fixed stars, several have been noticed which are subject to *periodical fluctuations* in *brightness*, and in one or two instances, the star alternately *vanishes* and *reappears.* These are termed *periodical* or *variable* stars.

309. MIRA. The most remarkable orb of this class, and which has been observed for the longest time, is the star *Mira*, in the *constellation* of the *Whale.*

State what is said respecting the nature and intrinsic splendor of the stars? What are *periodical* or *variable* stars?

Its changing splendor was first noticed by Fabricius, in 1596. It appears about *twelve times* in *eleven* years, shining then for a space of *two weeks* with its greatest brilliancy, sometimes like a star of the *second magnitude.* It then *decreases* for about *three months*, till it becomes *invisible* to the *naked eye*, and so continues for the space of *five months more;* after which it *increases* in magnitude and brightness for the remainder of its period.

310. ALGOL. Another conspicuous periodical star is *Algol*, in the *constellation of Perseus.*

It generally shines as a star of the *second magnitude*, and continues so for 2d. 13h. 30m., when its splendor, all *at once diminishes;* and in about 3½ hours it appears only as a star of the *fourth magnitude.* Thus it remains for nearly *fifteen minutes*, when it begins to *increase*, and in 3½ hours *regains* its *original brightness;* passing through all these variations in 2d. 20h. 49m. It is the opinion of astronomers, that these fluctuations may be caused by the *revolution* of some *dark body* around this singular star, which intercepts a large portion of the stellar light, when it is *between* the *star* and the *earth.* Between 30 and 40 *variable* stars have been detected by different observers, whose periods of changing brightness vary from a *few days* to *many years.*

311. TEMPORARY STARS. In different parts of the heavens, stars have now and then been seen shining forth with great splendor, and after remaining for a while apparently fixed, have gradually faded away,

Describe the variations of *Mira* and *Algol.* What is supposed to be the cause of the *variations* of Algol? How many *periodical* stars are now known? What is said as to the lengths of their respective *periods?* What are *temporary* stars?

and to all appearance become *extinct.* These are called *temporary stars*, and differ from *variable* stars in this particular, that after once vanishing from our sight, they have *never been certainly known to reappear from time to time.* Perhaps when the science of astronomy is still farther advanced, it may be found that *temporary* stars, so called, are but in fact *variable* stars, of whose long periods of change we are yet ignorant.

312. *A temporary star* is said to have been observed by Hipparchus, of Alexandria, in the year 125 B.C., which suddenly flashed forth in the heavens, with such splendor as to be visible in the daytime.

In the year 389, A.D., a star of this class appeared in the *constellation* of the *Eagle.* For the space of *three* weeks it shone with the brilliancy of Venus, and then died entirely away. Temporary stars, of great splendor, were likewise seen in the years 945, 1264, and 1572, between the constellations of *Cepheus* and *Cassiopea.* From the circumstance that these stars appeared in the same region of the heavens, and also from the fact, that the intervals of time between their epochs are almost *equal*, it has been supposed that they are *one and the same star*, which has a period of 312 years, or possibly of 156.

313. The appearance of the star of 1572, was *very sudden.* The renowned Danish astronomer, Tycho Brahe, upon returning from his laboratory to his house, on the evening of the 11th of November, 1572,

What may they, perhaps, at length be found to be? Have *temporary* stars been noticed only in modern times? Describe the *temporary* stars observed in the years 389, 945, 1264, and 1572, A.D.

found a number of persons gazing upon a star, which he was confident did not exist *half an hour before.* It was then as brilliant as *Sirius*, and continued to increase in splendor till it *exceeded Jupiter* in *brightness*, and was even *visible* at *noonday.* In December of the same year, it began to *fade*, and by March, 1574, had completely disappeared.

314. Double Stars. Many stars which appear *single* to the unaided eye, are found, when viewed through the telescope, to be, in fact, *two distinct stars*, separated by a very small interval. Moreover, numerous *telescopic* stars, which are seen *single*, when examined with ordinary instruments, are resolved into *two*, when observed through telescopes of high magnifying powers. Stars of this kind are termed *double stars.*

315. Castor—Alpha Centauri. The bright star *Castor* is one of the finest examples of a *double star.* It consists of two stars, of between the *third* and *fourth* magnitude, within 5″ of each other. *Alpha Centauri*, the nearest fixed star (Art. 304), is also a remarkable *double star*, each of the component stars being, at least, of the *second magnitude*, and separated from each other by an interval of about 15″.

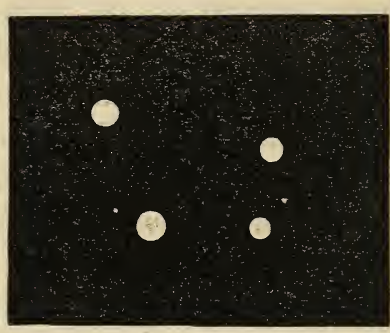
316. Colored Double Stars. Many double stars display a *beautiful variety of colors*, the component stars being of different hues. Thus, in the case of the double star Iota, in the constellation of the Crab, the *brightest* of the component stars is *yellow*, while the *other* is *blue.* The double star Gamma, in the constellation of Andromeda, presents a different variation,

What are *double stars?* Give examples. What peculiarities in respect to the colors of the component stars is observed? Give instances of *colored double stars.*

the most brilliant component being *red*, and its companion *green*.

317. Triple and Quadruple, or Multiple Stars. When stars which, under common instruments, appear *double*, are viewed through telescopes of greater power, a still further separation is not unfrequently effected. In some instances, *one* of the *twin stars* is resolved into *two*, and the combination is then termed a *triple star*. In other cases, *each* of the *two component* stars is separated into *two*, and sometimes more; and since all the four appear but as a single star to the naked eye, it is called a *quadruple*, or *multiple star*.

FIG. 46.



THE MULTIPLE STAR THETA. IN THE CONSTELLATION OF ORION.

318. The number of *double stars* now discovered, is between *five* and *six thousand*.

319. Binary Stars. The *double stars* are divided into *two* classes. *First*, those which are *optically double*,[1] the two individuals appearing under ordinary

1. Thus, in looking over a city, we not unfrequently see *two* steeples, one behind the other. so nearly in the same line of direction that they appear as one object. At the first glance the figure formed by their

What are *triple* and *multiple stars?* How many are there? Into how many classes are double stars divided?

circumstances as one object, simply because they happen to be so near to one another that we view them in almost exactly the same line of direction. *No bond of union* exists between them; for one may be *millions of millions of miles behind* the other, and altogether beyond the reach of its influence. *Secondly*, double stars which, by their mutual attraction, form *distinct sidereal systems*, the component stars *revolving about each other* in *regular orbits.* These, in order to distinguish them from double stars in general, are termed *binary stars.*[1]

320. In 1803, Sir William Herschel first announced the fact of the existence of binary stars; a discovery which was the fruit of 25 years' assiduous and close observation. At the present time, more than 100 *binary stars* have been discovered, and the list is continually increasing.

321. ORBITS—PERIODIC TIMES. The *orbits* of 15 binary stars have been ascertained, and their *periodic times* with more or less certainty determined. Like the planets of our system, they revolve in *elliptical paths.* Their known *periodic times* range from 31 to 736 years.

union may seem *single;* a closer inspection shows that it is *optically double.*

1. *Binary*, from the Latin *binus*, meaning *two and two, by couples.*

Describe these classes. *When* and by *whom* was the existence of *binary* stars first announced? Of how many years' research was this discovery the fruit? How many binary stars are at present known? Of how many have the *orbits* and *periodic times* been ascertained with more or less accuracy? In what kind of orbits do they revolve? What is said of the extent of their periodic times?

CHAPTER III.

STARRY CLUSTERS — NEBULÆ — NEBULOUS STARS — ZODIACAL LIGHT—MAGELLAN CLOUDS—STRUCTURE OF THE HEAVENS.

322. Starry Clusters. When we turn our gaze upon the heavens in a serene night, we perceive that in some parts the stars are more *crowded together* than in others, forming, by their close proximity, *groups* or *clusters.* Such a cluster is the *Pleiades*, in which six or seven stars are seen by the naked eye, but where the telescope reveals *fifty* or *sixty* comprised within a very small space.

323. The *central portion* of a cluster is usually most thickly sown with stars, and the stellar light there shines forth with the greatest brilliancy. A beautiful cluster of this kind is found in the constellation of Hercules. It is represented in Fig. 47.

324. The stars that compose a cluster are often exceedingly numerous. It has been estimated that not less than *five thousand* stars exist in some of the groups, *wedged together* into a space in the heavens, the area of which does not exceed one tenth part of that covered by the moon.

325. Milky Way, or Galaxy.[1] The most mag-

1. From the Greek word *gala*, signifying *milk.*

Describe some of the stellar clusters. What is the usual appearance presented by the central portion of a cluster? What is said respecting the number of stars they contain?

FIG. 47.

A CLUSTER OF STARS IN HERCULES.

nificent stellar cluster, by far, is the *milky way*, which like a broad zone of light encompasses the heavens. Its brightness is derived from the diffused radiance of *myriads* of *myriads* of stars that compose it, whose splendors are blended together into a *milky whiteness* on account of their immense distance from us.

326. In this cluster, Sir William Herschel estimated that, during *one hour's* observation with his telescope, no less than 50,000 stars passed before his sight within a zone 2° in breadth. Sir John Herschel has computed that the number of stars in the *milky way*, sufficiently visible to be counted, when viewed with his 20 feet telescope, amount in both hemispheres to

Which is the most splendid stellar cluster that the heavens present? What is its aspect, and whence is its light derived? What observations and computations have been made which show that it contains a vast number of stars?

five and a half millions. The *actual* number in this cluster he considers to be much greater, since in some parts they are so crowded together as to defy enumeration. Our sun is supposed to be one of the stars belonging to this group.

NEBULÆ.

327. Scattered throughout the sky are seen, either by the *naked eye* or by the aid of the telescope, *dim, misty objects*, of various shapes and sizes, *stationary to all appearance*, like the stars themselves. These objects are named *nebulæ.*[1] One of the finest is situated in the *girdle* of *Andromeda.* It is visible to the *naked eye*, and was noticed and described by

FIG. 48.

NEBULA OF ANDROMEDA.

1. For the meaning of this word, see page 9, note 3.

What is supposed of our sun? What are nebulæ? Which is one of the finest?

Simon Marius in 1612; and there is reason for believing that it was seen even as early as 995. This nebula is of *vast size*, extending over an area 15′ in diameter. It is delineated in Fig. 48.

328. Another splendid nebula is in the *sword-handle of Orion*. It consists of straggling, *cloudlike spots*, occupying a space in the heavens considerably larger than the *disk of the moon*. This nebula was discovered by Huyghens in 1656. In Fig. 49, its

FIG. 49.

NEBULA OF ORION.

What is said of the nebula in Orion ?

central portions are shown as they have been delineated by Sir John Herschel.

329. Their Constitution. *Stellar clusters* and *nebulæ* have usually been regarded as *distinct classes* of celestial objects ; the *former* consisting of groups of stars, either visible to the naked eye or through the telescope, and the *latter* of vast collections of unformed matter diffused through the infinitude of space. But it is by no means certain that such a distinction exists in nature, for the late discoveries of eminent astronomers point to the conclusion, that the *nebulæ are clusters of stars more or less distinct.*

330. Number and Distance of Stellar Clusters and Nebulæ. About *two thousand* stellar clusters and *nebulæ* were observed by Sir William Herschel. In 1833, the list amounted to *two thousand five hundred*, and this number was increased to about *four thousand* by the splendid discoveries made by Sir John Herschel, during his residence at the Cape of Good Hope. The distance of the *nebulæ* from the earth is vast beyond conception. The *ring nebula* in the constellation of the Lyre is so remote, that astronomers assert a ray of light cannot reach us from this object in less than *twenty* or *thirty thousand years.*

The nebula of Orion is still more distant, for it is computed that a ray of light, moving as it does with a velocity of 192,000 miles a second, would occupy not less than *sixty thousand years* in travelling from this nebula to the earth.

What views have been entertained respecting stellar clusters and nebulæ? Relate in full what is said respecting the number and distance of *stellar clusters* and *nebulæ*. State what is said of our distance from the nebula of Orion.

331. Their Physical Structure. Mathematicians have clearly shown it to be utterly impossible that the stars composing individual clusters and nebulæ could have been so grouped together by *mere chance.*[1] Their union must consequently be the result of some *physical law* impressed upon them by their Creator, in virtue of which they are combined in harmonious systems.

332. Nebulous Stars. In various parts of the heavens, bright and sharply-defined stars are beheld enveloped in a *cloud-like disk* or *atmosphere.* These are called *nebulous* stars. Such a star is shown in Fig. 50.

FIG. 50.

A NEBULOUS STAR.

333. Zodiacal Light. The *zodiacal light* is a luminous object *shaped like a pyramid,* that accompanies the sun in his apparent course through the heavens.

1. Mitchell has shown that if 1500 stars, like the six brightest in the Pleiades, were scattered *at random* through the heavens, there would be only *one chance* out of *five hundred thousand* that *any* six of them would come as close together as they do in the Pleiades.

What is remarked in regard to the physical structure of stellar clusters and nebulæ? What is a nebulous star? What is the *zodiacal light*?

334. ASPECTS. According to Professor Olmsted, who has made this phenomenon an especial study, the *zodiacal light*, in our climate, becomes visible in the eastern sky about the *beginning of October.* It is then seen before the dawn, its *base* resting upon that part of the horizon where the sun at this time rises, the luminous pyramid extending obliquely upward, until its point reaches above the starry cluster of the Beehive, in the constellation of Cancer. Throughout the *month of December* it is beheld on *both sides* of the sun, being seen in the *morning before sunrise*, and in the *evening* after *sunset*, extending in the *first case* sometimes as far as 50° *westward* from *the sun*, and in the *second* 70° *eastward.* In February and March, the zodiacal light appears only in the *west*, *after sunset;* it is then most conspicuous, and its luminous point is seen as far up as the Pleiades.

335. SIZE. This object possesses no well-defined outline, but its light gradually fades away from the central to the outer portion, until it becomes too faint to be discerned. Its *breadth* at the base varies from 8° to 30° according to Herschel, but Professor Olmsted has noticed it when it was 40° in *width.*

From the observations of the latter gentleman it appears, that the *zodiacal light* sometimes extends *in length* considerably beyond the orbit of the *earth;* for on the 18th of December, 1837, it was beheld stretching away *eastward* from the *sun* to the distance of 120°.

336. NATURE. Sir John Herschel conjectures that

What are its aspects in our climate? What is stated respecting the size of the zodiacal light?

the zodiacal light is an elongated *oval-shaped envelope*, enclosing the sun, consisting of extremely light matter, and possibly composed to a great extent of the same materials which form the *tails* of comets. Under this view, the sun, *surrounded* by the *zodiacal light*, presents a phenomenon similar to that of the *nebulous* stars.

337. Structure of the Heavens. Different systems have from age to age been presented to the world, professing to explain the *structure of the heavens.* The *three* which especially deserve notice are the *Ptolemaic*, the *Tychonic*, and the *Copernican.*

338. Ptolemaic. According to this system the earth is *immovably* fixed in the *centre of the universe*, while all the heavenly bodies revolve about it from *east* to *west.* It was established by Ptolemy, an Egyptian astronomer, in the second century of the Christian era, and prevailed for more than 1500 years.

339. Tychonic. This system originated with Tycho Brahe, who flourished in the sixteenth century, Like Ptolemy, he believed that the earth was *stationary* in the *centre* of the universe, and that the stars, and the sun and moon, revolved around it; but he conceived that the *planets* revolved *directly about the sun.*

340. Copernican. So called from Nicholas Copernicus, an illustrious astronomer of the fifteenth century. According to the Copernican system, the earth *rotates on her* axis from *west* to *east*, and *revolves* with

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What are the views of Sir John Herschel in regard to its nature? What are those of Professor Olmsted? Give an account of the principal different systems which have professed to explain the *structure* of the *heavens.*

the rest of the planets around this sun, in the same direction. This system is the *true* one, for it is not only *mathematically* demonstrated to be *correct*, but it *perfectly* explains *all celestial phenomena*, which every other system fails to do.

341. The *structure of the heavens* was briefly explained in the beginning of this work (Arts. 3, 4), in accordance with the Copernican system, and as we have advanced in our investigations, it has been gradually unfolding in part to our view.

Commencing with the earth, we have found that it both *rotates* on its *axis* and *revolves* about the *sun*, while around it circles a shining moon. It has been further shown that the earth is not *isolated*, but is one of a *brotherhood* of planets, endowed with the *same motions*, and in several cases similarly attended. All these, with *myriads* of comets, constitute the *solar system*.

342. Exploring further, we behold in the *binary stars*, *suns revolving about each other*, with their respective trains of *planets* and *comets*, exhibiting the phenomenon of SOLAR SYSTEMS IN MOTION.

343. Piercing deeper into abysses of space, *stellar clusters* and *nebulæ* stand forth revealed, objects of surpassing grandeur and magnificence. For here *suns crowd* upon *suns*, forming a vast and numerous GROUP OF SOLAR SYSTEMS—united, to all appearance, by a *common* bond. Possibly these associated systems *revolve about* some mighty sun centrally situated within the radiant group; for if our *solar system*,

Which is the true system, and why? Explain the structure of the heavens in accordance with the Copernican system.

together with *the stars* that glitter in our firmament, is really revolving around some *central sun*, as some astronomers have supposed, analogy would lead us to infer, that similar motions also exist amid these starry clusters and nebulæ.

344. When the scroll of the skies is still farther unrolled for our perusal, we may perhaps find that these *island universes* themselves move in *orbits* around some common centre.

For with all our surprising discoveries, we are yet upon the very *threshold* of creation; and could we continue to explore beyond the remotest nebulæ, through the successive realms of space, new scenes of grandeur would perpetually unfold; and new fields of Omniscient display would be constantly revealing that God was still before us in his creative energy, and that we saw but the "HIDINGS OF HIS POWER."

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