M. M. Lawton

1869.

ELEMENTS

OF

ASTRONOMY:

DESIGNED AS A

TEXT-BOOK

FOR

Academies, Seminaries, and Families.

BY

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PHILADELPHIA:

PRINTED BY SHERMAN & CO.,

S. W. COR. OF SEVENTH AND CHERRY STREETS.

1868.

STEREOTYPED BY MACKELLAR, SMITHS & JORDAN,
PHILADELPHIA.

CAXTON PRESS OF
SHERMAN & CO., PHILADELPHIA.

PREFACE.

THIS work is designed to fill a vacuum in academies, seminaries, and families. With the advancement of science there should be a corresponding advancement in the facilities for acquiring a knowledge of it. To economize time and expense in this department is of as much importance to the student as frugality and industry are to the success of the manufacturer or the mechanic. Impressed with the importance of these facts, and having a desire to aid in the general diffusion of useful knowledge by giving them some practical form, this work has been prepared. Its language is level to the comprehension of the youthful mind, and by an easy and familiar method it illustrates and explains all of the principal topics that are contained in the science of astronomy. It treats first of the sun and those heavenly bodies with which we are by observation most familiar, and advances consecutively in the investigation of other worlds and systems which the telescope has revealed to our view. Thus to enhance the interest and value of this work to the student and casual reader, nearly all of the topics that it contains are fully illustrated by engravings prepared expressly for that purpose. And to promote this object still further, and impart knowledge in the most impressive manner by a sensible demonstration of the arrangement, relations, and various motions of the component parts of the planetary system, the Planetelles, Heliotellus, and Lunatellus have been invented by the author and put into public use. Each of these instruments is invaluable in acquiring a knowledge of astronomy. With these facilities for illustration, which address themselves to the mind through the eye, and the plainness and simplicity which characterize this entire work, the author would respectfully present it to a generous public, trusting that it may be the means of disseminating a general knowledge of that ennobling science on which it treats

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PART II.

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URANOGRAPHY.

PLANETELLES.

THE PLANETELLES, which is represented by Fig. 1 on the opposite page, was invented by the author of this work, and has been in the course of construction for more than twenty years. Its first conception originated in the conviction that if the solar system, constituted as it is of many parts, and all of these parts having various motions, could be represented by an artificial system like itself, exhibiting the same phenomena in the same order, aid of incalculable value would be furnished in the acquisition of knowledge. With the view of rendering this idea practical, the construction of a machine for that purpose was commenced, and pursued, till the one which is here represented was completed. This instrument represents the motion of the sun on his axis, the relative annual motions of the eight primary planets, also their relative diurnal motions, and the various motions of the moon and of all the satellites around their primaries in different periods. It shows the relations existing between the sun and all the primary planets, and their satellites and each other, and is designed to illustrate, also, the phenomena resulting therefrom. It presents to the eye eighty different motions of these bodies, and illustrates the succession of day and night on each of the primary planets, the inclination of their axes to the planes of their orbits, the change of their seasons, the amount of change in the sun's declination in relation to each, and his rising and setting on each, the different lengths of their days and nights, the difference in the length of their seasons, their conjunctions, and the phases of Mercury and Venus, the retrogression of the moon's nodes, and the length of lunar days and nights, the solar and lunar eclipses, and the changes, phases, fulling, and eclipses, of all the satellites.

All these phenomena, besides a vast amount of other useful knowledge, may be explained by the use of this instrument and the artificial zodiac that is connected with it, so that even the youthful and uneducated mind cannot fail to understand the astronomy of the solar system, if disposed to give the subject any attention. No mechanical device that has ever been brought before the public presents such an ocular demonstration of the planetary system in motion, and expresses its phenomena with such precision and accuracy, as the Planetelles; and as it is portable, occupies but little space, and is not liable to get out of order, is in every way adapted to the private study and the student's class-room,—places which it fills, as an illustrator of science, with greater fidelity, in many respects, than the living instructor

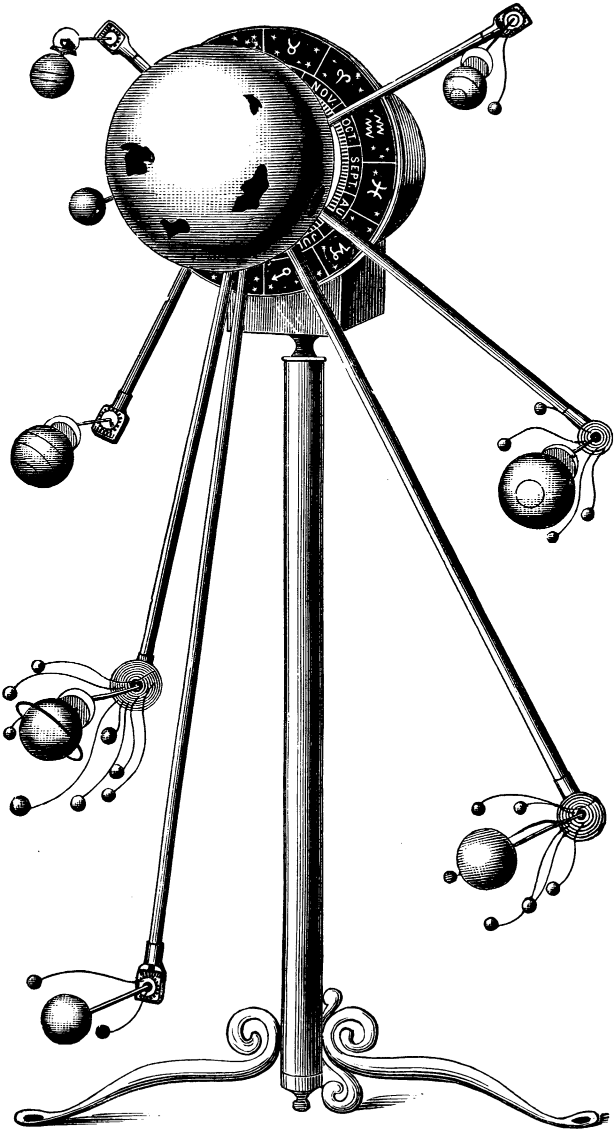

Fig. 1.—Planetelles.

HELIOTELLUS.

THE HELIOTELLUS, which is represented by Fig. 2 on the opposite page, is constructed on the same principle on which the Planetelles is, and is designed in part for the same purpose. It contains five globular bodies, which, by their arrangement, relations, and motions, exhibit the arrangement, relations, and motions of the sun, Mercury, Venus, Earth, and the moon, as so many parts of the solar system. This instrument represents the motion of the sun on his axis, the relative yearly motions of Mercury, Venus, and the earth, also their relative daily motions, and the motions of the moon around the earth, around the sun, and on her axis. It shows the inclination of the axes of Venus and the earth to the planes of their orbits, and is designed to illustrate the respective widths of their different zones, the succession and duration of their different seasons, the different lengths of their days and nights, the amount of change of the sun's declination in relation to each, and his rising and setting on each, the superior and inferior conjunctions and phases of Mercury and Venus, also the solar and lunar eclipses, the length of lunar days and nights, the retrogression of the moon's nodes, and the changes, phases, and fulling of the moon.

By the use of the Heliotellus and the artificial zodiac connected therewith, these phenomena, the tides also, and other elements of useful knowledge, can be explained with such clearness and simplicity that even a child, with little attention, cannot fail to comprehend them. This instrument, for the purpose of illustrating a portion of the planetary system and the phenomena resulting therefrom, is invaluable; and, as it can be carried in the hand, and occupies but little space, economizes the time and expense of the pupil, and diminishes the labor of the teacher, is especially adapted to the use of families, and every grade of schools in which the elements or more advanced branches of Astronomy or Geography are taught.

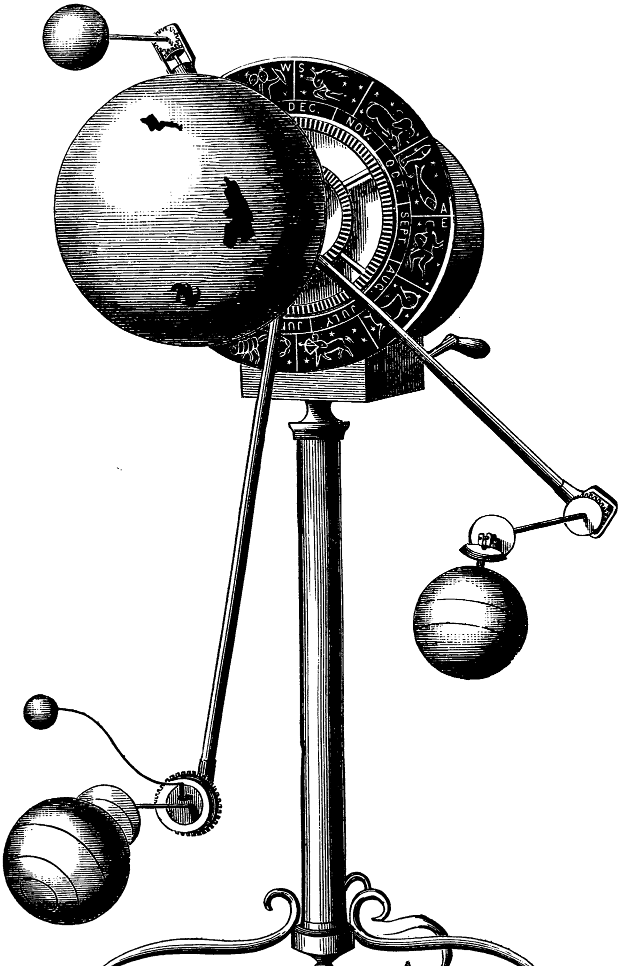

Fig. 2.—Heliotellus.

LUNATELLUS.

THE LUNATELLUS, which is represented by the cut on the opposite page, illustrates the astronomical phenomena of the sun, earth, and moon in their natural order, with the geography of the earth in its proper relation to them. The sun is made to turn on his axis, the earth revolves at her proper inclination on her axis and around the sun, producing not only the change of seasons and the vicissitudes of day and night, but also their natural increase and decrease in length. The moon revolves around the sun, on her axis, and around the earth, producing the alternation of her days and nights, her changes, phases, and fulling, and also, by her retrograding at every revolution, the interesting phenomena of solar and lunar eclipses. And as the natural divisions of the surface of the earth and the political divisions of every country are marked on the body that is employed to represent the earth, the geographical and astronomical relations of every locality, at any particular period during the year, are clearly exhibited to the eye.

The daily use of the Lunatellus by both teacher and pupil has clearly demonstrated that, in addition to its advantages in the study of astronomical phenomena, it is almost indispensable in acquiring an accurate knowledge of *Descriptive* and *Physical Geography*, as the bodies that represent the earth and the moon occupy their relative places and positions in relation to the sun and each other, and can have given to them at pleasure their relative motions in their relative periods.

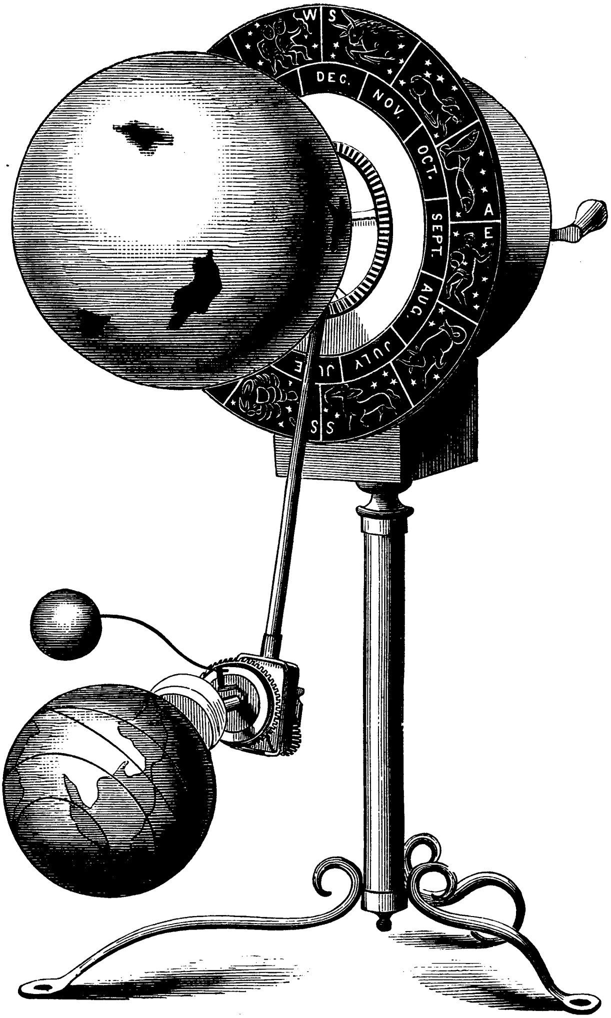

Fig. 3.—Large Lunatellus.

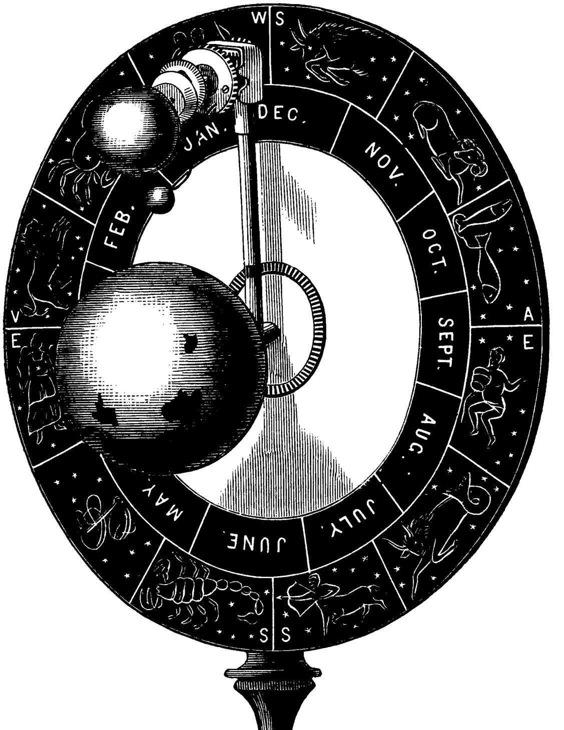

Fig. 4.—Small Lunatellus.

ELEMENTS OF ASTRONOMY.

SECTION I.

History of Astronomy.

1. ASTRONOMY is the most ancient of all the sciences. The first astronomers were shepherds, and some of their observations date back more than twenty-four hundred years before Christ. Job, who was a native of Chaldea during its early history, speaks of Orion and the Pleiades,—certain groups of stars which still retain their former names. Homer and Hesiod also had a knowledge of at least some of the divisions of the starry heavens, which had been made; and Aratus enumerated nearly all of the ancient constellations.[1]

2. It is highly probable that the Chaldeans and Egyptians were the first to draw boundary lines of the richest stellar districts and designate them by certain names. The Greeks and Romans did the same; and to these nations are we indebted for at least some of the divisions of the heavens which we find noted in our astronomical maps.

3. To what extent the Chaldeans and Egyptians carried their divisions, or where the Greeks and Romans took the subject up, is uncertain; yet it is evident from their records that not only they, but the Chinese also, had a knowledge of many of the prominent constella-

[1] Constellations—are groups of stars.

QUESTIONS.—1. What is the most ancient science? Who were the first astronomers? 2. Who first divided the starry heavens into constellations? Who next? 3. What other nation had a knowledge of them?

tions in both hemispheres,[2] as well as those that constitute the zodiac.[3]

4. Thales, one of the seven wise men of Greece, who lived six hundred years before the Christian era, was the first regular teacher of astronomy. Pythagoras, also of Greece, shortly afterwards taught this science in a celebrated school at Crotona, and was the first to discover the true theory of planetary motion; but did not succeed in having his views adopted, owing to the ancient prejudices and incredulity of those who regarded themselves as being pre-eminent in science and discovery.

5. Hipparchus—about three hundred years before the Christian era—distinguished himself as a teacher of astronomy in the most celebrated school in Egypt; and Ptolemy, of the same nation, about the middle of the second century, acquired still greater celebrity. He devised and gave prominence to the theory of celestial motion, in which the earth was regarded as stationary and centre of the universe, and around which the sun, moon, planets and starry heavens revolved from east to west once in about twenty-four hours.

6. His opinions were entertained and adopted by the various schools as being most consonant with what presented itself at different times in the heavens to the senses, and, in consequence of its resemblance to the truth, continued to be taught in the academies and schools, till Copernicus, of Prussia, revived, in fifteen hundred and thirty, the Pythagorean or true theory of planetary motion, viz.:—that the sun is the central orb of the system, and that all the planets revolve around

[2] Hemisphere—is half a sphere.
[3] Zodiac—is twelve constellations which form a belt of stars, 16° wide, clear round the heavens.

QUESTIONS.—4. Who were the first teachers of astronomy? Who discovered the true theory of planetary motion? 5. What distinguished astronomers succeeded Thales and Pythagoras? Whose astronomical theory was taught in the schools from the second till the sixteenth century? 6. Whose theory was revived by Copernicus, in fifteen hundred and thirty?

him. He discussed the true theory of the celestial motions, distinguishing between what was real and what was only apparent, and thereby rescued this science from the doubt and uncertainty which had always surrounded it.

7. Tycho Brahe, of Denmark, also lent invaluable aid to discovery, in the use of those instruments which were then employed in astronomical observation; and Kepler, a German astronomer, discovered the three great laws of planetary motion. So also did Galileo, with the aid of the telescope, make new discoveries which were highly interesting; and Sir Isaac Newton saw and made known the application of that great principle in the law of gravitation, whereby all worlds and heavenly systems are governed and controlled.

8. And to more fully develop and more firmly establish the facts already obtained, many studious observers are still engaged, in the Old World and the New, in exploring and investigating the motions and movements of those celestial bodies which are silently satisfying the will of their Creator in the economy of nature.

SECTION II.

The Planetary or Solar System.

1. THIS system of worlds and heavenly bodies is the one to which our earth belongs, and is now known to contain eight primary planets,[1] ninety-eight asteroids[2] or smaller planets, twenty-one satellites,[3] moons, or second-

[1] Planet—a wanderer.
[2] Asteroid—a small planet.
[3] Satellites, moons, or secondary planets, are those that revolve around the primary planets.

QUESTIONS.—7. What celebrated astronomer succeeded Copernicus? Who applied the principle of gravitation to the heavenly bodies? 8. Are astronomers now engaged in the study of this science?

SEC. II.—1. How many primary planets are there? How many asteroids? How many satellites, moons, or secondary planets? Are there many comets?

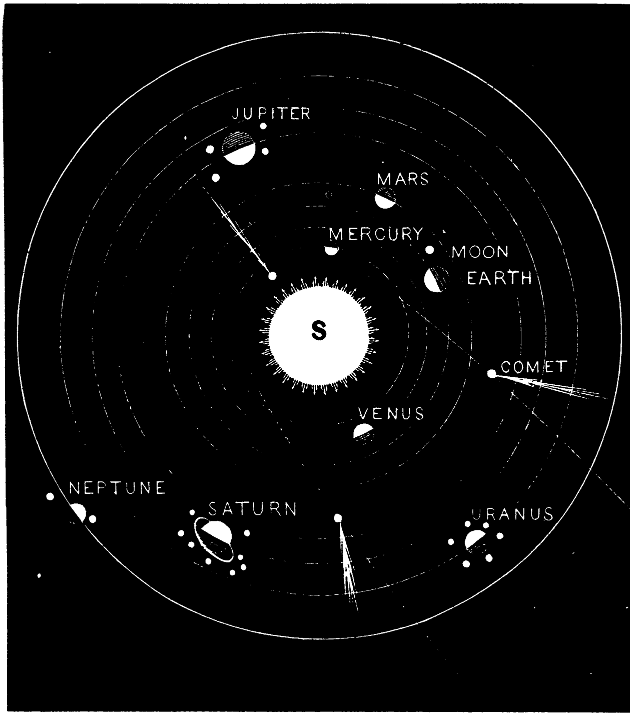

Fig. 3.—Solar System.

ary planets, a great number of comets, and the sun also, which is the controlling centre of them all.

2. The primary[4] planets are of different magnitudes, and revolve around the sun in different periods and at different distances from him. They are all known by

[4] Primary planet—a large planet.

QUESTIONS.—2. Are the primary planets alike in magnitude? Are they at different distances from the sun? Do they all revolve around him in the same length of time? Are they known by certain names? What were they named after? What are the names of the two nearest the sun?

certain names, which are derived from the names of heathen gods or objects of idolatrous worship. Mercury, which is the planet nearest the sun, was named after the god of dishonesty and injustice; and Venus, the second planet from the sun, was named after the goddess of love and beauty.

3. Mars, the fourth planet from the sun, received his name from the god that was supposed to rule over war and battle; and Jupiter, the fifth planet in point of distance from the sun, received his name from the name of the imaginary being that was supposed to be god over all. Saturn, the sixth planet from the sun, obtained his name from the imaginary being who was supposed to preside over time and chronology; and Uranus, the seventh planet from the sun, obtained his name from the god of astronomy. Neptune, the outermost planet from the sun, was named after the imaginary deity that was supposed to preside over the seas.

4. The asteroids are small planets that revolve around the sun as their centre of motion. They travel around him in orbits[5] which lie between those of Mars and Jupiter. Nearly all of them are invisible to the naked eye; and had it not been for the aid of the telescope they would have remained undiscovered.

5. The length of their annual periods is nearly the same, each being about the length of four and one-half of our years. Their average distance from the sun is about two hundred and sixty-one millions of miles. Like the primary planets, they are all known by certain names, which were given to them generally by their discoverers, and will be noticed hereafter.

6. The secondary planets are small bodies that revolve

[5] Orbit—the path of a planet round the sun.

QUESTIONS.—3. What are the names of all further away from the sun than the earth? 4. What do the asteroids revolve around? Between the orbits of what two planets do they revolve? Are they visible without the aid of the telescope? 5. What is the average length of their years? What is their average distance from the sun?

around some of the primary planets as they travel around the sun. Our moon is one of them, and the only one that revolves around the earth. Jupiter, the fifth planet from the sun, has four of them, which revolve around him in different periods. The one nearest to him moves fastest, and has the shortest period. The second moves slower than the first, and has a longer period. In like manner is it with the third and fourth.

7. Saturn, the sixth planet from the sun, has eight moons or satellites that revolve around him. They are at different distances from him, travel with different velocities, and have different periods. They follow the order of all heavenly bodies in their movements that have a centre of motion, diminishing in their velocities and increasing in their periods as their distances increase from their primaries.

8. Herschel, or Uranus, the seventh planet from the sun, has six moons, which are at different distances from him and revolve around him with various velocities and in different periods. Neptune, the outermost planet, has two moons, which are similar to those of the other planets which we have noticed, in their distances, movements, and length of their periods.

9. The comets are rare bodies which revolve around the sun, and are seldom seen except when they are near to him. Several hundred of them have been discovered with the aid of the telescope, and the motions and elements of the orbits of many of them have been pretty accurately computed. Though some of them are very large, they have very little matter in them, as has been fully demonstrated by the slight attraction which they have for other bodies that are sometimes comparatively near to them.

10. All of these heavenly bodies to which we have

QUESTIONS.—6. What do the secondary planets revolve around? Is the moon a secondary planet? How many has Jupiter? 7. How many has Saturn? 8. How many has Herschel, or Uranus? How many has Neptune? 9. Are comets rare or dense bodies? Are they large or small? Around what body do they revolve?

in this section referred are objects of special interest, and we will notice them in their order of distance from the sun, making him the subject of our first remarks.

SECTION III.

The Sun.

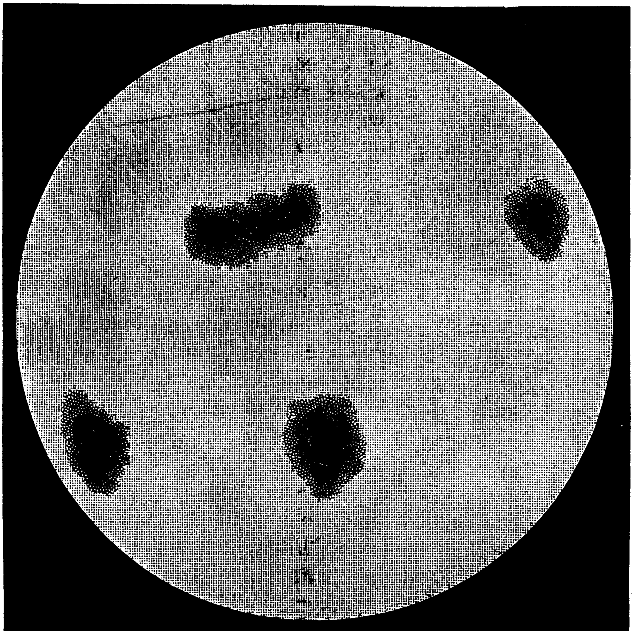

Fig. 4.—Telescopic View of the Sun.

1. THE sun, which is the central orb of our system, being the most prominent of all the heavenly bodies,

QUESTIONS.—1. What distance is it to the sun? What is his diameter? How much larger is the sun than all the bodies that revolve around him? How much heavier?

claims now our immediate attention.* He is ninety-five millions of miles distant from us, and nearly nine hundred thousand in diameter, and his axis is inclined about 7° to the plane of the ecliptic. His volume is six hundred times greater than that of all the bodies that revolve around him, and in mass or weight he is about seven hundred greater.

2. He is fourteen hundred thousand times larger than the earth, and his density is nearly one-fourth that of the earth, and a little greater than that of water. He revolves on his axis[1] in about twenty-five and one-half days, and is the great source of light and heat, which enlightens and gives warmth to all of the planets and bodies that revolve around him.

SECTION IV.

Sun's Atmosphere.

1. THE sun is nearly globular in form, and appears to be invested with three envelopes or atmospheres, differing in their nature and densities. The one next to his body seems to be in a measure transparent, sustaining cloudy matter in its upper regions, similar to the clouds which are suspended in our own atmosphere. This opinion is entertained from the different shades of light and darkness which are associated with the spots which frequently appear on his disk.[2]

2. The second envelope, or atmosphere, is supposed to

[1] Axis—an imaginary line passing through the centre of a body from one pole to the other.

[2] Disk—the face of the sun.

QUESTIONS.—2. How much larger is he than the earth? Is he as dense as the earth? Is he as dense as water? Does he revolve on his axis? In what time?

SEC. IV.—1. How many atmospheres are supposed to surround the sun? What is the nature of the inner one?

* For purposes of convenience, round numbers are generally employed in this work to express the magnitudes, distances, and velocities of the heavenly bodies.

be the great reservoir of solar light and heat, and the place where they are generated. From experiments which have been made recently, it has been discovered that the light which is reflected or emitted from a solid or liquid substance heated to a certain temperature differs from what is emitted from a gaseous or ethereal substance.

3. The sunlight is of the latter kind; which would indicate that his solid body is not its source. This light and heat may be produced by the agency of electrical currents without combustion, as it is not always essential to their production.

4. The existence of a third or outer envelope, consisting of very attenuated matter, is insisted on by some astronomers, from the peculiarities attending the sun when he is totally eclipsed. Thin cloudy matter was observed at and beyond his margin, and columns of rose-colored light ascended sometimes from it to the height of forty or fifty thousand miles, and would then move off in a horizontal direction.

5. These phenomena are indicative of the existence of a gaseous substance, capable of sustaining visible matter, and more remote from the solid solar globe than his photosphere.[1]

SECTION V.

Solar Spots.

1. THE spots which frequently appear on the sun are supposed to be openings in his luminous atmosphere—

[1] Photosphere—the spherical gaseous matter around the sun's body, in which his light is produced.

QUESTIONS.—2. Where is the sunlight supposed to be generated? Does the light that is emitted from a gaseous or ethereal substance differ from what is emitted from a solid or liquid substance? 3. What kind of light is sunlight? What agency may produce his light and heat? 4. What is the nature of the sun's outer atmosphere? 5. What evidence is there of its existence and nature?

produced probably by whirlwinds beneath, or other disturbing causes originating in their own vicinity. They are seldom seen within three degrees of the sun's equator, and never at his poles.

2. The atmosphere of the earth, at certain elevations, is in a far greater state of agitation in zones that are on either side of the equator than elsewhere; and may it not be so in similar regions on the sun? His whole surface appears, when viewed by the telescope, to be in a state of constant agitation, the agitation being always greatest where the spots break out, and their funnel-shaped forms, with other attending circumstances, show that they are not scoriæ nor any solid substance.

3. Some of them at times are forty or fifty thousand miles in diameter; and sometimes so many of them have been on the sun's disk as to diminish his light and heat at least one per cent. These spots are not only variable, but periodical, increasing in number for five and one-half years, and decreasing for the same period, corresponding exactly in point of time with a certain variation observed in the intensity of terrestrial magnetism. See Fig. 4.

SECTION VI.

Motions of the Sun.

1. THE sun has three motions,—one around the centre of gravity of the planetary system, the second on his own axis, and the third around the centre of this stellar

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QUESTIONS.—1. What are the spots on the sun supposed to be? What may cause them? Are they observed near his equator, or his poles? 2. Where is the earth's atmosphere, at certain elevations, agitated most? How does the sun's surface appear when viewed with the telescope? What evidence is there that these spots are not composed of solid substance? 3. What is the diameter of some of these spots? Are they ever so numerous as to diminish the sun's light and heat? Do these spots change in size? Are they periodical? What is the length of their periods? With what do they correspond that belongs to the earth?

SEC. VI.—1. How many motions has the sun?

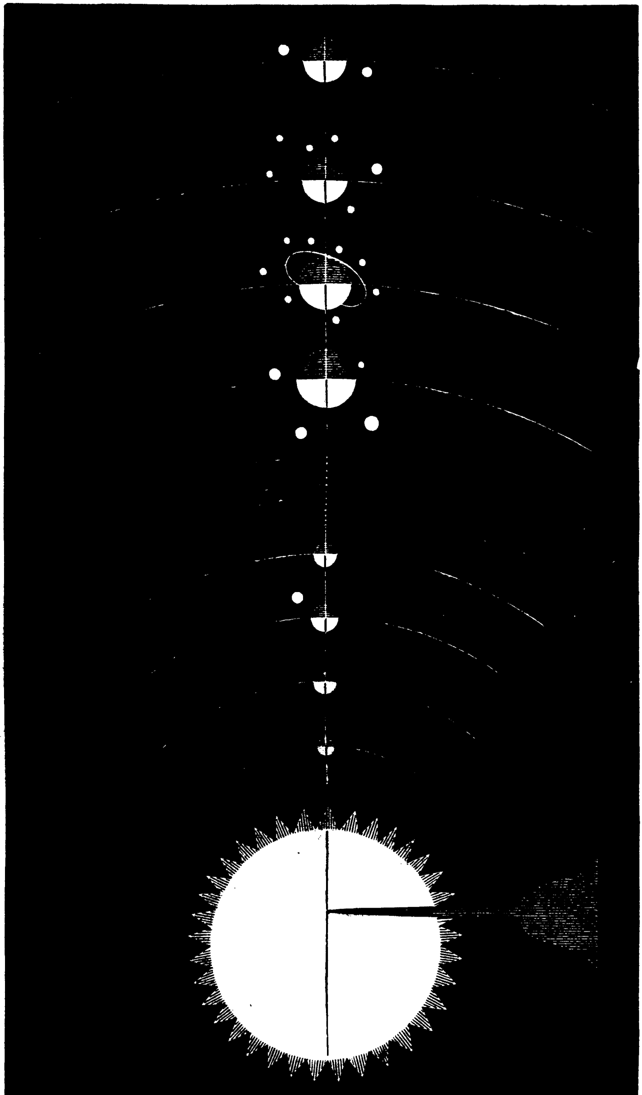

Fig. 5.

universe, supposed to be at or near the star Alcyone in the Pleiades.

2. By Fig. 5 we will illustrate the first of these motions. If all of the planets with their satellites were attached to a rod at their relative distances from the sun, and the sun himself attached to the other end, and the rod placed on a fulcrum at the point where the sun would balance or hold in equilibrium all the other bodies, that point would be the centre of gravity of the whole system.

3. By revolving this rod, all of these bodies would revolve around this centre; and, the sun being hundreds of times heavier than the aggregate of all the rest, he would be always nearest to it, even so near that it would generally be between his surface and his centre. This centre of gravity constantly changes a little in position, in consequence of the changes which the planets make in their orbits in performing their annual revolutions.

4. Besides the motion of the sun around the centre of gravity of our system, he has a motion from west to east on his axis. This fact is known by observing the spots on his disk. They always pass over his surface in one general direction, exhibiting at the same time all those changes of form which would result from the revolution of a globular body on its axis. The time they occupy in passing from one side of his disk to the other indicates that it requires nearly twenty-five and a half days for him to make one rotation.

5. Another motion of the sun is around the centre of gravity of this stellar universe, to which our whole system belongs. The most familiar evidence that we have of this motion is founded on a fixed principle

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QUESTIONS.—2. If the sun and planets were fastened to a rod at relative distances from each other, where would be their centre of gravity? 3. Around what would they revolve if put in motion? What causes this centre of gravity to change its place a little? 4. Does the sun revolve on his axis? In what direction is this rotation? How is this known? 5. Does the sun himself revolve around a centre like the planets? What is the evidence that he has a planetary motion founded on?

known to us all,—viz.: that objects at a distance appear to diverge and increase in size the nearer we approach them, and to converge and diminish the further that we recede from them. By a series of observations, this has been discovered to be true in relation to the sun.

6. Along the imaginary track over which he has travelled, the space between the heavenly bodies appears to have diminished; while in the opposite direction the space between the stars in the constellation Hercules appears to have increased. From these coincidents and other attending circumstances, it is inferred that he is not only travelling like a planet in its orbit, attended by a retinue of worlds which are controlled by him, but that he will be more than eighteen millions of years in making one of his annual revolutions.

SECTION VII.

Mercury.

1. MERCURY is the name of the planet nearest the sun, is about thirty-one hundred miles in diameter, and is one-sixteenth the size of the earth and nearly three times as dense. He makes a revolution around the sun in about eighty-eight days, is thirty-seven millions of miles distant from him, and moves in his orbit with the amazing velocity of one hundred and nine thou-

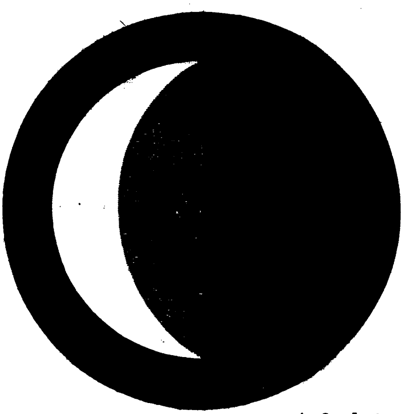

Fig. 6.—Telescopic View of Mercury in Quadrature.

QUESTION.—6. What is the evidence itself?

sand miles per hour. His days and nights are nearly the same length as ours; and it is unknown if he has a change of seasons.

2. He is an opaque[1] body, as all the bodies are that revolve around the sun, and he is seldom visible, and when so only in the twilight, owing to the proximity of his orbit to the sun. The light and heat which he receives from the sun are six and one-half times more than what we receive, if their intensities on his surface are regulated by that law which obtains concerning them. The law regulating light is illustrated by Fig. 7.

3. If this first opening is one linear foot from a

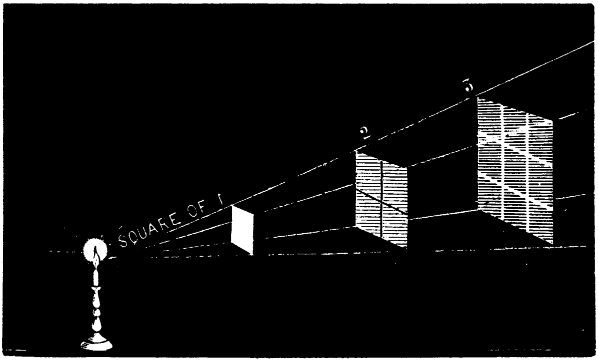

Fig. 7.

luminous body, and its area[2] one square foot, the light

[1] Opaque body—one that has no light of its own.

[2] Area—means surface generally; sometimes it means a hole or opening.

QUESTIONS.—1. What planet is nearest the sun? What is his size when compared with the earth? What is his diameter? What is the length of his year? What is his distance from the sun? What is said of his days and nights? 2. Does he shine with his own light? and when can he be seen? How much more light and heat does he receive than we, according to the law which obtains concerning them? 3. How much more feeble is light two feet from the source of light than one foot from it?—three feet than one foot from it?

which passes through it will cover an area of four square feet two feet from the source of light, and cover nine square feet three feet from the body that emits the light. The intensity of the light is nine times less three feet from the source of light than one foot from it; which makes it evident that its increase and decrease of intensity are regulated by a definite law.

4. Heat and sound, the force of attraction, and the influence of magnetism, follow this same law. They diminish in an inverse ratio as the distance increases: consequently, the definite amount of heat and light which each planet receives can be ascertained if its distance from the sun is known, unless there should be some modifying agencies connected with the planets themselves, which we will have occasion to notice hereafter.

5. The physical constitution of Mercury is probably much the same as the physical constitution of the earth. His appearance evinces that he has an atmosphere which may answer not only a similar purpose to our own, but also shield him from that insufferable light and heat with which he is constantly surrounded.

6. He passes through various phases,[1] like those of the moon as she makes her revolutions around the earth, exhibiting at various periods less and more of an enlightened surface. These phases are common to both Mercury and the next outermost planet, Venus, and serve to establish the fact that their orbits are nearer to the sun than the earth's, and that they shine by borrowed light. The various portions of enlightened surface of these bodies when in different points of their orbits may be seen by referring to Fig. 8.

[1] Phases—Different amounts of enlightened surface visible.

QUESTIONS.—4. What other agents conform to this law? Is it necessary to know the distance to a planet that we may know the amount of light and heat that it receives? 5. Does Mercury appear to have an atmosphere? What purposes may it answer? 6. Has he phases like the moon? Has Venus the same phases? What do they prove?

7. Suppose the body in the centre to be the sun, and the first from him Mercury, the second Venus, the third the earth, and the fourth Mars. If Mercury and Venus are on the opposite side of the sun from us, we will see one-half of their surfaces enlightened. Move them in either direction, and we will see less of their surfaces

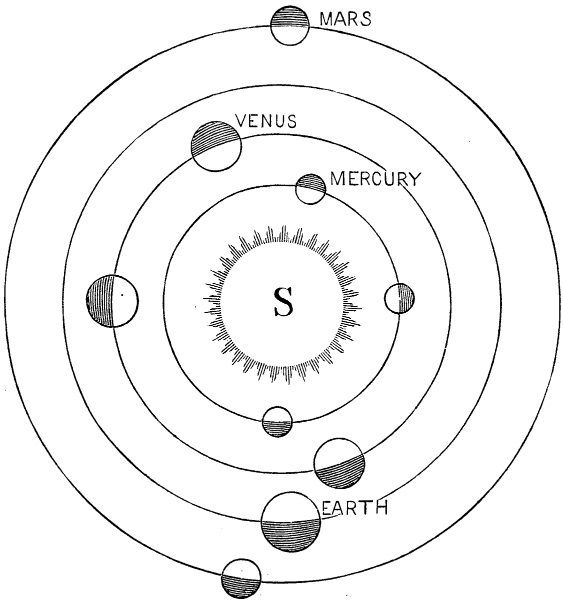

Fig. 8.

enlightened, until they become invisible, when they arrive at that point where they are between us and the sun.

8. These planets present such changes in relation to their light; and were it possible that Venus could have that half of her surface next to us enlightened when at

QUESTIONS.—7. When do Mercury and Venus present to us the greatest amount of enlightened surface? When are they invisible?

her nearest point to us, she would appear twenty-five times larger than she does. But, as she recedes from us, her hither[1] hemisphere becomes more and more enlightened; and, these changes occurring simultaneously, she appears to vary very little at any time in her size.

9. These phenomena[2] are never manifested by those planets which are more distant from the sun than the earth. They, being constantly outside of the orbit of the earth, always exhibit nearly the whole of their enlightened sides, which are next to us, as manifested by Mars, in Fig. 8.

SECTION VIII.

Venus.

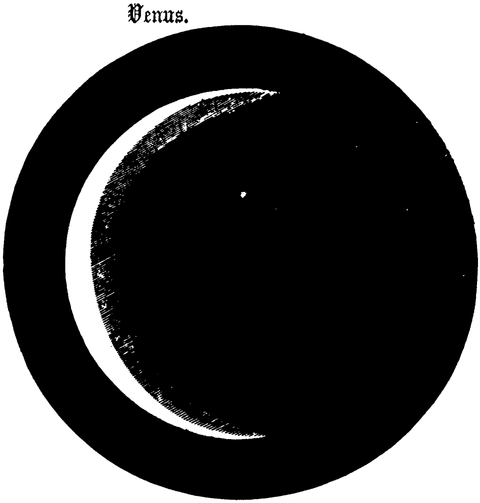

Fig. 9.—Telescopic View of Venus after Inferior Conjunction

1. VENUS is the second planet in point of distance from the sun, which is apparent from the fact that she is always seen, when visible, at a greater distance from him than Mercury.—Her mean distance from the sun is

[1] Hither hemisphere—the one next to us.
[2] Phenomena—natural characteristics or changes in appearance.

QUESTIONS.—8. Why does Venus appear to vary very little in her size? 9. Do the planets outside of the earth exhibit phases like Mercury and Venus? Why do they not?

sixty-eight millions of miles, and her magnitude is one-seventh less than that of the earth. She moves in her orbit with a velocity of eighty thousand miles per hour, and rotates on her axis in a little less than twenty-four hours.

2. She appears to have an atmosphere in which is suspended at times cloudy matter, and by the marks visible by the telescope the period of her daily rotation is determined. As the morning star she rises for a period of two hundred and ninety-two days before the sun, and as the evening star sets after him for the same length of time.

3. Unlike all of the other planets, she has eight seasons,—two springs, two summers, two autumns, and two winters, at her equator; and four at her tropics,[1]—spring, summer, autumn, and winter. This unusual number of seasons occurs in consequence of the great obliquity of her axis to the plane of her orbit, which renders her polar circles only fifteen degrees from her equator, and her tropics only fifteen degrees from her poles.

SECTION IX.

Transits and Conjunctions of Mercury and Venus.

1. VENUS, like Mercury, makes transits[2] over the sun's disk, passing like a little black spot from one side of him to the other, indicating thereby that these bodies

[1] Tropics—on the terrestrial sphere, the circles that divide the torrid from the temperate zones.

[2] Transit—passage across or over.

QUESTIONS.—1. What is the distance of Venus from the sun? How much less is she than the earth? At what rate does she travel in her orbit? Does she rotate on her axis? 2. What appears to be in her atmosphere? How long is she the morning star? How long the evening star? 3. How many seasons has she at her equator? How many at her tropics? What causes this unusual number of seasons?

are not only inferior to the earth in position, but that they shine by borrowed light. The transits of these bodies cannot occur very frequently, owing to the fact that the planes of their orbits do not coincide with the plane of the ecliptic.[1]

2. Their planes cross the plane of the ecliptic at different angles, and, consequently, transits can only occur when the sun and planets are near these crossing points or nodes. Two of these nodes belong to each orbit; and as these planets pass from the north side of the ecliptic to the south, they pass through their descending nodes, and as they return from south to north, they pass through their ascending nodes; and the imaginary line that extends from one node to the other is called the line of nodes.

3. When Mercury transits the sun, it will be in May or November; and when Venus transits him, it will be in June or December.

4. Mercury and Venus when on the side of the sun next to us are in their inferior conjunctions, and when on the opposite side of the sun from us are in their superior conjunctions.

5. Their motions are said to be direct and retrograde: direct when they are passing through their superior conjunctions, and retrograde when passing through their inferior conjunctions.

6. These planets are termed inferior, in consequence of their orbits being nearer to the sun than the orbit of the earth.

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[1] Ecliptic—the great circle which the sun appears to describe annually among the stars.

QUESTIONS.—1. What is the transit of a planet? How many of the planets transit the sun? What do their transits prove? Can they occur frequently? Why? 2. When do transits occur? When are these planets said to pass through their ascending and descending nodes? 3. In what months do Mercury and Venus transit the sun? 4. Where are Mercury and Venus when in inferior conjunction? Where when in superior conjunction? 5. When are their motions direct? When retrogade? 6. Why are these planets called inferior?

SECTION X.

The Earth—its Annual Motion.

1. THE earth resembles an orange in form, being flattened at its poles, making the distance between the poles twenty-six miles shorter than the distance from the equator on one side to the equator on the other. It is surrounded with an atmosphere about forty-five miles in depth, and has four seasons in its temperate zones; and two, summer and winter, about its poles.

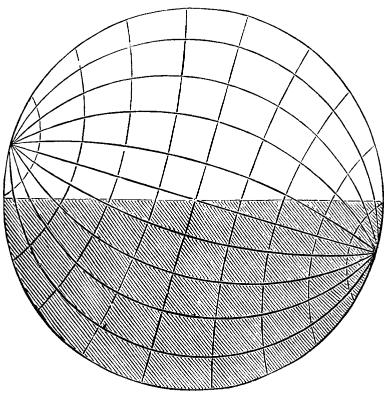

Fig. 10.

2. Its diameter is nearly eight thousand miles, and, consequently, its circumference is about twenty-five thousand. Its mean distance from the sun is ninety-five millions of miles, and it revolves around him in one year, and also rotates on its axis in twenty-four hours. Notwithstanding these declarations in relation to its motions are true, they were not only in obscurity in ancient times, but were received with much distrust by many at a much later date.

3. Every system of astronomy, as well as almost every astronomer, anterior to the revival of letters in

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QUESTIONS.—1. How much shorter is the polar than the equatorial diameter of the earth? What is the distance to the surface of the atmosphere? How many seasons in the temperate zones? How many at the poles? 2. What is the diameter of the earth? What is its circumference? What is its distance from the sun? How long does it require to revolve around the sun? How long on its axis?

Europe in the sixteenth century and the discoveries of Copernicus, considered the earth as the centre of the universe. They regarded it as the great masterpiece of creation, around which the sun and moon, planets and starry heavens, revolved. The Egyptian astronomer did this, as well as the Grecian, the Roman, the Persian, and the Arabian. All imagined themselves the distinguished inhabitants of the great central orb of the universe.

4. But this intellectual darkness was not to hang forever over the minds of men and enshroud the world. The principle of the law of gravitation was applied by Sir Isaac Newton to the heavenly bodies, whereby the relative weights of the sun and planets could be determined; elements which enable us to prove that the earth has an annual motion. As we had occasion to notice, two bodies gravitate or are attracted towards each other with forces respectively equal to the amount of matter each contains and the distance that they are apart. This fact is illustrated by Fig. 5.

5. If a heavy body is fastened on one end of a rod, and a light body on the other end, and this rod, at the point at which the two bodies balance each other, be supported by a fulcrum, or prop, that point on which it rests will be the centre of gravity of these two bodies. Now, if these two bodies are caused to revolve when connected, they will revolve around their common centre of gravity, and the lighter body will describe the larger circle, and the heavier body will describe the smaller one.

6. By applying this principle to the sun and earth, it may be made plain that the earth has an annual motion around him. His weight is ascertained to be three hundred and fifty-five thousand times greater than that

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QUESTIONS.—3. How did almost every system of astronomy view the earth before the discoveries of Copernicus? 4. Who applied the principle of gravitation to the heavenly bodies? 5. If a large body and a small one were fastened on either end of a rod, the point at which they would balance would be called what? If made to revolve, what would they revolve around? Which body would describe the smaller circle? Which the larger?

of the earth, and, consequently, his attractive force would be as three hundred and fifty-five thousand is to one. This being the case, the centre of gravity of these two bodies must be very near the centre of the sun; and, as it is apparent that one or the other does revolve in an extended orbit, it is evident that it is not the sun, but the earth, that has the annual motion.

SECTION XI.

Daily Motion of the Earth.

1. It rotates once on its axis in twenty-four hours, or the sun and starry heavens pass clear round it in the same length of time. The apparent passage of the sun from east to west, and the vicissitudes of day and night, declare that one or the other of these statements is true.

2. If it is the sun that passes round in twenty-four hours, he must fly with inconceivable velocity; for, by knowing his distance from the earth, and doubling it, and multiplying by three, we will have the measure of his orbit. By dividing the number of miles in this orbit by twenty-four, as there are twenty-four hours in a day, we will have his rate of motion, which would be over twenty-four millions of miles per hour. But this is not all. The constellations appear to pass clear round the heavens in twenty-four hours.

3. The nearest heavenly body outside of our planetary system cannot be less than twenty millions of millions of miles distant from the sun; and how much farther away must some of them be, when it takes their light

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Questions.—6. How much heavier is the sun than the earth? Where, then, is the centre of gravity of the sun and the earth? Which must revolve around the other?

Sec. XI.—1. What evidence is there that the earth revolves on its axis in twenty-four hours, or that the starry heavens revolve around the earth in the same period? If the sun revolves around the earth, what must be his velocity per hour? Must the constellations also revolve around the earth, if the sun does?

thousands of years to reach us, travelling at the rate of twelve millions of miles per minute! The star named 61 Cygni, which might for comparative distance be considered as it were a sentinel on the outposts of the solar system, to make a revolution in the allotted time would have to travel with the inconceivable velocity of one billion four hundred millions of miles per second.

4. Now, if the same process of calculation is applied to some of those bodies that are farthest removed from us, what must be their velocity! Light itself would fail—infinitely fail—to perform the task in making the circuit, let alone those innumerable self-luminous worlds, many of which are at such enormous distance from us that the human mind can have no conception of it.

5. Another difficulty also besets the theory of the whole universe revolving around the earth, and not the earth revolving on its axis, in twenty-four hours. Every star visible to us, even with the use of the telescope, would have to make its circuit clear round the heavens in precisely the same length of time, whether comparatively near or sunk in the abysmal depths of space.

6. To imagine this would be to imagine what is not only improbable, but utterly impossible according to the present constitution of nature, where the inconceivable velocities of so many thousands—yea, millions—of worlds would be involved in one universal revolution. Hence we arrive at this conclusion, which is in accordance with the Copernican theory of planetary motion,—that our earth is a planet, with a yearly and daily motion, and holds, at least to us, a conspicuous place, as the moon her satellite does in the economy of the solar system.

QUESTIONS.—3. What is the distance to the nearest fixed star? What would be the velocity per second of 61 Cygni if it revolves around the earth? 4, 5. Would the most distant stars have to make a complete circuit around the heavens in twenty-four hours if the earth did not revolve on its axis? Would it be possible for them to do it as now constituted? Could light do it, travelling at its usual rate? What is its velocity per minute or second? 6. What conclusion do we arrive at in relation to the motions of the earth?

SECTION XII.

The Moon.

1. THE Moon, though apparently the largest, is actually the smallest, heavenly body visible to the naked eye, being only a little over two thousand miles in diameter. And she is not quite half as dense as the earth. She is fifty times less than the earth, and the length of her year is about twenty-nine of our days. Many peculiarities belong to her which are not connected with the sun or planets, and phenomena are manifested by her which are nowhere else discoverable in the universe.

2. She has three motions,—one around the earth, one on her axis, and one as an attendant of the earth around the sun. She rotates once on her axis, which is inclined about 1° to the plane of her orbit, while she makes a revolution round the earth, keeping, of course, the same side always turned towards us. This being the case, each of her days and nights is nearly one-half of a month in length.

3. Though it is in a measure true that only the half of the moon next to us is visible, yet it is not strictly so. Her north pole being at one time a little inclined towards the earth, we can see beyond it; and at another time her south pole being inclined in the same way, we have a more extended view in that direction.

4. In like manner is it in regard to her eastern and western sides or limbs. In consequence of the ellipticity of her orbit, and consequent inequality of her angular velocity, she reveals and conceals alternately new territory, as it were, at the ends of her apparent equatorial diameter.

5. These variations are called her librations in lati-

QUESTIONS.—1. Why does the moon appear so large? What is her mean distance from the earth? Is she as dense as the earth? What is the length of her year? 2. How many motions has she, and what are they? Does she always keep the same hemisphere turned towards us? What is the length of her days and nights? 3. Are her north and south poles turned towards us alternately? 4. Are her eastern and western limbs turned towards us alternately? 5. What are these variations of pos'tion called?

tude and longitude, and are not necessarily connected with her phases, which take place both before and after her change and full.

SECTION XIII.

Phases of the Moon.

1. If the moon is between us and the sun in the west, she is at her change, and is invisible. When she moves eastward ninety degrees, we can see one-fourth of her surface enlightened; and if she moves eastward ninety degrees farther, we can see the half of her whole surface enlightened. By continuing this revolution around the earth, she manifests less of her enlightened surface, till she becomes invisible again in the west.

2. Owing to her constantly shifting her position in relation to the earth, her face next to us is more and more enlightened by the sun from her change to her full; and owing to the same cause, the light of the sun is gradually withdrawn from it, from her

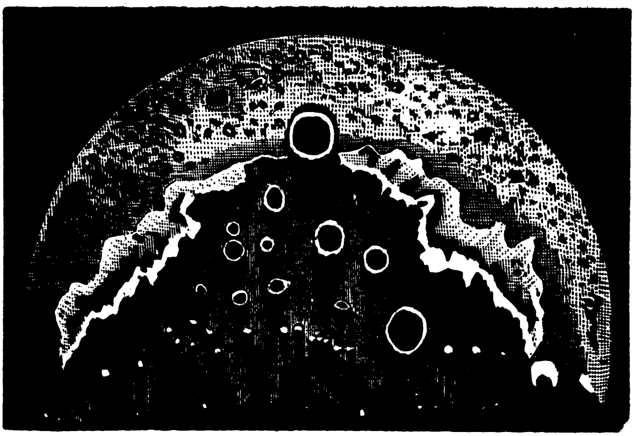

Fig. 11.

QUESTIONS.—1. Where is the moon in relation to the sun and earth when at her change?

full to change, thereby manifesting at various times the crescent, the disk, and the gibbous form.

3. She makes about twelve and one-third of these lunations, or revolutions around the earth, in one year, and, to accomplish this, must of course move in her orbit at times with greater velocity than the earth, as she has a much greater distance to travel. This fact may be readily understood if we consider that she revolves around the earth, as the earth revolves around the sun.

SECTION XIV.

Solar and Lunar Eclipses.

1. ECLIPSES of both sun and moon have been investigated with great care by philosophers of nearly every nation, sometimes for the purpose of operating on the fears of the ignorant, and at other times for the purpose of adding another leaf to the pages of science. The maximum and minimum number of solar and lunar eclipses in one year cannot be more than seven, nor less than two; and when there are seven, five may be of the sun and two of the moon, or three may be of the sun and four of the moon; but when there are only two in the year, both will be of the sun.

2. To explain these phenomena, we may observe that the orbit of the earth is an ellipse, having two points called foci, and the sun is always in one of them, as may

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QUESTIONS.—How much enlightened surface does she exhibit when about ninety degrees east of her change? Where is she in relation to the earth and the sun when she is full? 2. Does her enlightened surface increase from her change to her full? Does it diminish from her full to her change? In these variations, what forms does she exhibit? 3. How many revolutions does she make around the earth in one year? Does she travel at times faster than the earth? For what reason is this true?

SEC. XIV.—1. For what purpose have eclipses been studied? What is the maximum number of eclipses that can occur in one year? How many may be of the sun? How many of the moon? 2. Is the orbit of the earth an ellipse? What is an ellipse? Is the moon's orbit elliptical?

be seen by observing Fig. 12. The same thing is also true of the moon. In consequence of the ellipticity of

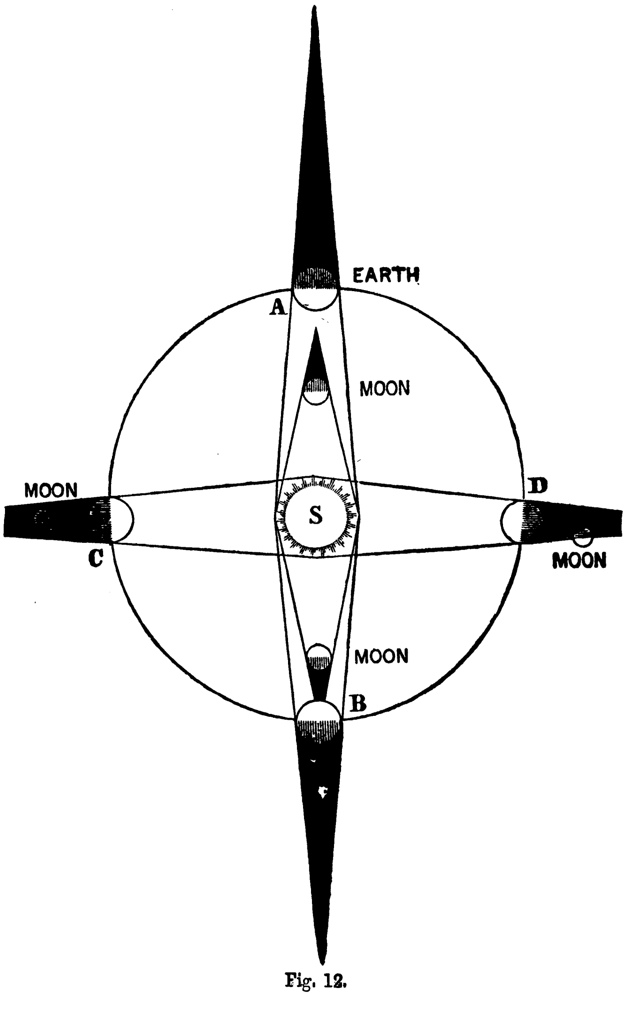

Fig. 12.

her orbit, and the eccentric[1] position which the earth occupies in it, she is at one time nearer to the earth than at another.

3. When the earth is moving in any point of its orbit, as at A, Fig. 12, and the moon directly between the earth and the sun, and at her greatest distance from the earth, there will be an annular[2] eclipse of the sun; that is, the shade of the moon will fall a little short of the earth, and the moon herself will obscure the central portion of the sun at the middle of the eclipse. Again, if the earth is moving in any part of its orbit, as at B, Fig. 12, and the moon directly between the sun and the earth, and at its least distance from the earth, there will be a total eclipse of the sun.

4. Partial eclipses of the sun are produced by the moon when she does not pass directly between the earth and the sun. If the sun, moon, and earth were not in a straight line, but the moon only a little to one side and in between the other two bodies, only a part of the sun's disk would be obscured, as she would not pass centrally over him.

5. This change of the moon, to either side of the sun north or south, is in consequence of the plane of her orbit not being coincident with the plane of the earth's orbit, but at an angle with it of a little over five degrees. If the planes of the moon's and the earth's orbits were coincident, at every new moon the sun would be eclipsed, and at every full moon she would be eclipsed.

[1] Eccentric—out of the centre.
[2] Annular—in the form of a ring.

QUESTIONS.—3. Where must the moon be in relation to the sun and the earth when there is an annular eclipse of the sun? What portion of the sun is obscured in an annular eclipse? In an annular eclipse, is the moon at her greatest distance from the earth? In a total eclipse of the sun, is the moon between the earth and the sun? In a total eclipse, is she at her least distance from the earth? 4. What is a partial eclipse of the sun? When do they occur? 5. At what angle is the plane of the moon's orbit with that of the earth? If the planes of these orbits were coincident, when would the sun and moon be eclipsed?

SECTION XV.

Lunar Eclipses.

1. To explain the lunar eclipse, we have only to consider the moon and the earth to have exchanged their places in relation to their distances from the sun, as exhibited at letter C, Fig. 12. If the moon at her full is on the outside of the earth's orbit from the sun, and the earth directly between her and the sun, the shade of the earth will cover her whole disk, or eclipse her totally. But if the earth is not directly between the moon and the sun, only a part of the shade of the earth will obscure a part of the moon's disk, which produces a partial eclipse, as may be seen at letter D, Fig. 12.

2. In solar eclipses the western edge or limb of the sun is obscured first, and in lunar eclipses the eastern edge or limb falls first within the shade of the earth. This is the invariable order of these phenomena, owing to the fact that the sun is relatively stationary, and the moon revolves eastward at times with greater velocity than the earth.

SECTION XVI.

Lunar Influences.

1. MANY happy influences are ascribed to the moon, and many grave accusations are laid to her charge. Passing by the superstitious credulity of the ignorant on this subject, we can conceive of only three influences

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QUESTIONS.—1. In lunar eclipses, what two bodies must exchange their places in relation to the sun? Where must the earth be in relation to the moon, that she may be totally eclipsed? Where must the earth be, that she may be partially eclipsed? 2. Which limb or edge of the sun is obscured first in solar eclipses? Which in lunar eclipses? What reason can you assign for these facts?

SEC. XVI.—1. What number of lunar agents affect terrestrial objects? What are they?

which the moon can have, or is known to exert, on terrestrial objects. These influences are produced by her light, her heat, and her attractive force.

2. That she reflects sunlight is evident; and that light, according to the degree of its intensity, has an influence on chemical elements, the growth of vegetables, and animal life, is clearly established. With sunlight, which is three hundred thousand times greater than that of the moon, some substances grow pale, while others grow black when exposed to its influences.

3. These changes are effected more in consequence, no doubt, of the exceeding sensitiveness of certain objects to the presence of light, than to any inherent power which may reside in it to produce them. If it requires such intense light as sunlight to produce such comparatively slight changes on terrestrial objects as that of color principally, how little indeed must be the influence of moonlight on the same objects, when it is three hundred thousand times less, and only reflected on them!

4. In like manner is it with the heat which she reflects. It is nothing when compared with the heat of the sun; for it requires one of the most powerful lenses, and it to be placed under the most favorable circumstances, to detect that she reflects any heat at all: therefore it could not produce many natural wonders on the surface of the earth.

5. But, since we have not discovered any miraculous power in either of these agents when reflected by the moon, it may be supposed to exist in her attractive force. To explain this influence, it matters not whether we say

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QUESTIONS.—2. Has sunlight any effect on animal life and the growth of vegetables? How much greater is sunlight than that of the moon? What influence has it on vegetation? 3. Is this change of color more from an inherent power in the light or sensitiveness of the objects to the presence of light? What is the influence of moonlight in comparison with that of the sun? 4. Does the earth receive any heat from the moon? How is it determined? Can it produce much change in terrestrial objects? 5, 6. Does the moon attract the earth? What effect has the mutual attraction of two bodies on each other?

that inert bodies are endowed with an inherent power which causes them to tend towards each other, or that this tendency results from power exerted on them uniformly by the great Lawgiver. Whichever view we adopt, the results are the same.

6. The only visible or known effect which the force of gravity or attraction has on either animate or inanimate matter, is to change its place. Bodies in consequence of this natural property endeavor to get together, and their efforts are mutual, and mutual in proportion to the amount of matter that each contains, and the distance they are apart. And were it not for the initial force which each heavenly body received in time or when launched into space, all worlds would gather into one chaotic mass.

7. This law is universal as creation, and prevails wherever matter exists. Were it not so, wild confusion would characterize the whole empire of the Infinite Architect. But, notwithstanding this force is everywhere exerted, yet it is not the parent or cause of every thing. Though we could not live without it, still there is a limit to its functions, both in the heavens and on the earth.

8. True it is that the attractive influence of the moon disturbs the waters of the ocean, because there is little or no cohesive attraction between them: yet I have not seen her force vegetation through a rock. So also is it true that she to a far greater degree disturbs the upper regions of our atmosphere: still I have not seen her squeeze water out of the clouds by lying on her back and turning up her horns.

9. These phenomena are not discovered by the slow, plodding student of nature, who labors assiduously all his life and then gains comparatively little, but only by

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QUESTIONS—7. Is this law universal wherever matter exists? Are there limits to its functions? 8. Does the attraction of the moon disturb the waters of the ocean? Are the upper regions of the atmosphere affected by it? Can it disturb solid substances on the earth?

those who can see spirits or read the events of the future by the twinkling of a star or some other circumstance equally significant.

SECTION XVII.

Lunar Atmosphere.

1. THE centres of figure and gravity of the moon do not coincide, or, in other words, her centre of gravity is at a greater distance from her surface next to us than from the surface of her opposite hemisphere. This discovery has been confirmed by science; and it may account for the absence of a visible atmosphere around her. Her hither hemisphere is elevated about thirty-three miles above the general level of her surface if she was a perfect sphere, and it has a less specific gravity than other parts of her body.

2. The elevation of her hither surface appears to have been the work of time; and if she at her formation had an atmosphere all around her, and seas on her surface, they would seek by their own gravity her lowest parts, as the hemisphere next us was being elevated. They would naturally flow to her opposite side, leaving the side next to us destitute of those fluids which originally belonged to it. But, whether this increase of volume and change in the specific gravity of a part of the moon, and consequences flowing therefrom, took place in time, it matters not as far as the fact is concerned that neither air nor water has been discovered on her surface.

3. According to a fixed principle in optics, light travels in straight lines, unless diverted by reflection

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QUESTIONS.—1. Do the centres of figure and gravity of the moon coincide? Which centre is at the greater distance from us? How much higher is her hither hemisphere than the general level of her surface? Is its specific gravity less than other parts of her body? 2. If air and water were on the moon, would they seek her lowest parts by their gravity? Has water or air been discovered on the moon?

or refraction; and the denser the transparent medium through which it passes, the greater is its refractive power. This fact may be illustrated by Fig. 13. Let the darkest color in the figure represent glass, which is a denser medium than water; the next above, water, which is a denser medium than air; and the lightest color, air, which is a rarer medium than water; then, if a ray of light is brought in contact with the top one at a certain point, they will manifest, as the ray passes through them, their different powers of refraction.

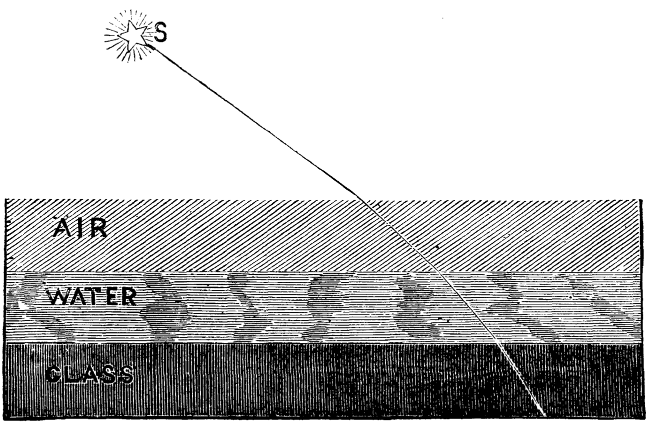

Fig. 13.

4. If a ray of light from the star S enters the atmosphere obliquely, it will turn it slightly downwards till it meets the water, which will change its direction downwards a little more till it meets the glass, which will change it still more in the direction of a perpendicular. This is in accordance with what we have noticed above: the denser the transparent medium, the greater is its refractive power.

QUESTIONS.—3, 4. Does light travel in straight lines, if not ob structed? Is light ever reflected or refracted? What kind of transparent bodies ref ıct it most?

5. Let us now apply this principle to test the presence or absence of a lunar atmosphere. If the moon had an atmosphere, even a thousand times rarer than our own, it would refract or change the direction of the rays of light if they should pass through it; but no such influence is perceptible on the rays of light coming from fixed stars as they pass by the edge of the moon to our eyes. They move in straight lines, as is represented in Fig. 14, thereby indicating that they do not pass through any transparent material medium outside of the earth's atmosphere.

6. Objects one hundred and twenty yards in diameter may be seen on the moon's surface by the aid of the telescope, and, as her poles are nearly at right angles with the plane of her orbit, it must be constantly cold in her arctic regions, so much so that water would freeze and snows accumulate, which would be visible if she had an atmosphere and they were there. But they have never been discovered, neither clouds nor changes of any kind which would indicate the presence of human intelligence, neither animal nor vegetable life.

SECTION XVIII.

Lunar Surface.

1. By referring to Fig. 14, you may obtain a pretty correct knowledge of the general outlines and most prominent features of the lunar surface. In the south and southeastern and southwestern parts it is exceedingly mountainous. In the north and northeastern and north-

QUESTIONS.—5. Would atmosphere, a thousand times rarer than our own, refract light? Is the light of fixed stars as it passes by the edge of the moon refracted? What does this prove? 6. How small a body may be seen on the moon with a large telescope? If snow would fall on the surface of the moon, could it be seen? Are there any indications there of animal or vegetable life?

SEC. XVIII.—1. Is the lunar surface level? Where is it most mountainous?

western parts it is not so hilly: still, it is very far from being a level plain.

2. Where very high mountains are not observed, the country appears level, except when examined by a telescope of very high power, and then it exhibits hundreds

Fig. 14.—Telescopic View of the Moon.

of conical hillocks all over its surface. These low places are at various elevations with the general level of the lunar surface, and are of various colors, which may result from the nature of the different kinds of rock or soil from which the solar light is reflected.

QUESTIONS.—2. What is observed on the more level places on the moon? Are the low places on the moon at the same level? Are they of the same color?

3. Sir William Herschel supposed them to be seas, but modern discovery has dissipated these conjectures and revealed their true nature and character. Some of these low lands appear to be entirely surrounded by high elevations, and others appear more like an archipelago, where large isolated mountains rise up promiscuously in their interior. These mountains are most frequently conical in form, and the great majority of them at their summits resemble the crater of a volcano.

4. Nearly the whole of the southern hemisphere which is visible is covered with them, and they vary in their height, from the little hillock which is scarcely perceptible, to the rugged mountain of ten thousand feet of elevation. Often they appear to be crowded one on another, as if they had been formed at different periods by one bursting up through the base of another.

5. Their craters or openings are sometimes of enormous magnitude, many of them being twenty miles in diameter, and, without the elevations of the mountains in which they are, they sink sometimes to the depth of seventeen thousand feet below the general level of the surrounding country. They are generally cup-shaped, and often on their inner surfaces small openings or craters open out into the main crater, and frequently a small mountain rises up from the lowest part a few thousand feet, with a crater or opening in its summit.

6. From some of these craters radiate a great number of white rays or lines, which diverge and extend outwards several hundred miles in every direction. They reflect light of the same color with the interior of the

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QUESTIONS.—3. What surround some of these low places? Do large mountains ever rise up in them? What is the shape of these mountains? What do they resemble at their summits? 4. What is the elevation of some of these mountains? Do some appear to have burst up through the base of others? 5. Are their craters or openings sometimes very large? How far do some of them sink below the general level of the lunar surface? What is their general shape? 6. What radiates from these craters? What color is the light that these lines reflect?

craters, and they hold their way over valley and hill till they terminate in the distance. By their color and directions we may infer that the material which formed them issued from these openings anterior to other upheavals which have elevated parts of them from the positions which they originally occupied.

7. In like manner also do we find a few lines about a thousand yards in width and a hundred miles in length, passing over some of the most level portions of her surface. They resemble great highways prepared for public convenience: still, no weary traveller has ever been discovered by their sides, neither have the glowing wheels of Dives ever been known to have marked their dust. Like the highest lunar peaks and deepest caverns, they appear never to have been visited by any sentient being or any thing else, except floods of insufferable light by day and impenetrable darkness by night.

8. No animated being is known to be there, to witness these mighty desolations or disturb the monotony of this universal solitude. No flowing stream is there, to irrigate these barren wastes or stimulate the plant to germinate; neither is the bird of the morning there, to hymn its harmonious song. No forest is there, to create the welcome shade; no rivulet, to give variety; no flower, to emit its fragrance; no oasis, to awaken the imagination; no verdant landscape, to enchant the eye; no human voice, to break the unutterable silence; but she appears to have lost her pristine beauty, and now to present a surface distorted probably by her own volcanic agencies and internal convulsions.

QUESTIONS.—7. What may be seen on the more level places of the moon? What do they resemble? What visits the moon? 8. Is any animal or vegetable life on the moon? What agency elevated her hither hemisphere?

SECTION XIX.

Mars.

1. MARS is about one hundred and forty-five millions of miles distant from the sun, revolves on his axis in about twenty-four and one-half hours, is seven times less than the earth, and travels in his orbit at the rate of fifty-five thousand miles per hour, making one revolution round the sun in twenty-three months. His diameter is a little more than four thousand miles, and his density is nearly the same as that of the earth.

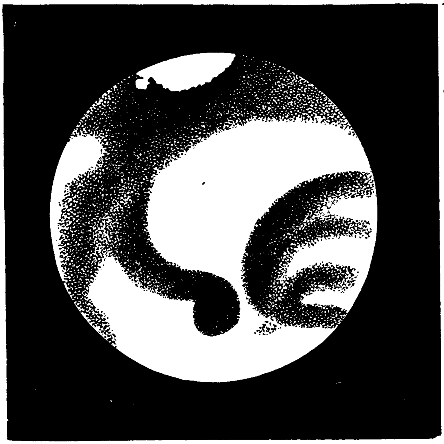

Fig. 15.—Telescopic View of Mars.

2. He appears much larger and more brilliant to us at one time than at another. This is owing to the constant changes which he makes in his position as he travels in his orbit. When nearest to us, he is only fifty millions of miles distant, and when in the opposite part of his orbit from us, he is more than two hundred and forty millions of miles distant from the earth.

3. His daily motion on his axis is determined by certain marks which are visible by the use of the tele-

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QUESTIONS.—1. What distance is Mars from the sun? In what time does he revolve on his axis? How much less than the earth? At what rate does he travel in his orbit? How long to revolve around the sun? What are his diameter and density? 2. Why does he appear larger at one time than another?

scope. They appear and disappear, and afterwards reappear, alternately, indicating not only that he is constantly changing his surface next to us, but also, by their periodic return, the time of rotation on his axis, which would be the length of his day.

4. Like all the planets exterior to the earth, he does not present the lunar phases. Being outside of the earth from the sun, look at him whenever he is visible, and nearly the half of his whole surface will appear enlightened. His surface is diversified with hill and dale, island and continent, land and water; and his seasons are not dissimilar to our own.

5. Having a dense atmosphere, as some suppose, or soil of a peculiar color, he presents a ruddy appearance, and his temperate regions have been seen to change with the line of his seasons from a dark color to a brilliant white, indicating that in medium latitudes there is the alternation of summer and winter, and at his poles his lofty peaks are covered with perpetual snow.

6. He has no satellite or moon, but travels over the trackless field of space solitary and alone, yielding implicit obedience to those laws of force and motion which are inseparable from his vocation and his nature.

SECTION XX.

The Asteroids.

1. LEAVING Mars, and passing outward from the sun, we enter into the domain of other worlds of recent discovery. The asteroids are over ninety in number, and cannot be said to hold a very conspicuous place in the planetary system, as they are nearly all invisible to the

QUESTIONS.—3. How has his daily motion been discovered? 4. Why does he not present, like Venus, the lunar phases? Is his surface diversified? 5. What color is he, and does his color change? What does this change of color indicate? 6. Has he any moons?

SEC. XX.—1. What are the asteroids? Are they visible to the naked eye?

naked eye. They are small planets; whether the fragments of a stupendous world shattered by internal convulsions or external violence, or formed as other planets were, no one can tell.

2. Four years and one-half is about the average time that they require to revolve around the sun, and no doubt they follow the analogy of the primary planets, and have a daily motion on their axes. Some of them are very small, being only a few hundred miles in diameter, and travel in orbits which are very elliptical and very much inclined north and south. Only a few of them present sensible disks when examined by the telescope even under the most favorable circumstances.

3. Nearly all of them have a pale-ash color, except Ceres, which is of a reddish hue; and they are surrounded with atmospheres of great extent, some of which appear to consist of nebulous matter. Their average distance from the sun is about two hundred and sixty-one millions of miles, and all of their orbits are nearly the same distance from the sun: consequently the law regulating interplanetary spaces, suggested first by Kepler, a German astronomer, no doubt led to their discovery.

4. He saw that if the distance from the sun to Mercury was doubled, it would be nearly the distance from the sun to Venus, and that if it was multiplied by three, it would nearly give the distance from the sun to the earth, &c. But when he applied this rule to the distance between the sun and Jupiter, the space between Mars and Jupiter was too great to conform to this law. This apparent interruption led him to infer that there was an unknown planet in that interval, which is now known to be occupied by so many little worlds.

5. Early in this century this idea was actively re-

QUESTIONS.—2. What is the average time of their annual periods? What kind of orbits do they travel in? Do many of them exhibit sensible disks? 3. What is their average distance from the sun? What led to their discovery? 4. What was this law? 5. Who attempted to test its truth or falsity? Were their anticipations realized?

vived, and the science of the Old World attempted to test its truth or falsity by exploring those ethereal regions where conjecture at least pointed to another planet. This being done, their anticipations were realized, and new though infant members were found to belong to the solar family.

6. These discoveries led to closer and more protracted investigations, and, by the aid of the telescope, during the last half-century ninety-eight of these planetoids have been found, conforming to those laws which regulate their elder brethren in rendering their homage to the sun.

7. The first four asteroids—Ceres, Pallas, Juno, and Vesta—were discovered between January 1st, 1801, and March 29th, 1807; and all the rest were discovered between December 8th, 1845, and September 20th, 1868.

NAMES AND DISCOVERERS OF THE ASTEROIDS.

Names.	*Discoverers.*	*Names.*	*Discoverers.*
1. Ceres	Piazzi, Palermo.	31. Euphrosyne	Ferguson, Washington.
2. Pallas	Olbers, Bremen.	32. Pomona	Goldschmidt, Paris.
3. Juno	Harding, "	33. Polyhymnia	Chacornac, Paris.
4. Vesta	Olbers, "	34. Circe	" "
5. Astræa	Hencke, Driesen.	35. Leucothea	Luther, Bilk.
6. Hebe	" "	36. Atalanta	Goldschmidt, Paris.
7. Iris	Hind, London.	37. Fides	Luther, Bilk.
8. Flora	" "	38. Leda	Chacornac, Paris.
9. Metis	Graham, Sligo.	39. Lætitia	" "
10. Hygeia	De Gasparis, Naples.	40. Harmonia	Goldschmidt, Paris.
11. Parthenope	" "	41. Daphne	" "
12. Victoria	Hind, London.	42. Isis	Pogson, Oxford.
13. Egeria	De Gasparis, Naples.	43. Ariadne	" "
14. Irene	Hind, London.	44. Nysa	Goldschmidt, Paris.
15. Eunomia	De Gasparis, Naples.	45. Eugenia	" "
16. Psyche	" "	46. Hestia	Pogson, Oxford.
17. Thetis	Luther, Bilk.	47. Melete	Goldschmidt, Paris.
18. Melpomene	Hind, London.	48. Aglaia	Luther, Bilk.
19. Fortuna	" "	49. Doris	Goldschmidt, Paris.
20. Massalia	De Gasparis, Naples.	50. Pales	" "
21. Lutetia	Goldschmidt, Paris.	51. Virginia	Ferguson, Washington.
22. Calliope	Hind, London.	52. Nemausa	Laurent, Nismes.
23. Thalia	" "	53. Europa	Goldschmidt, Paris.
24. Themis	De Gasparis, Naples.	54. Calypso	Luther, Bilk.
25. Phocea	Chacornac, Marseilles.	55. Alexandra	Goldschmidt, Paris.
26. Proserpine	Luther, Bilk.	56. Pandora	Searle, Albany, N.Y.
27. Euterpe	Hind, London.	57. Mnemosyne	Luther, Bilk.
28. Bellona	Luther, Bilk.	58. Concordia	" "
29. Amphitrite	Marth, London.	59. Olympia	Chacornac, Paris.
30. Urania	Hind, London.	60. Echo	Ferguson, Washington.

QUESTIONS.—6. What did these discoveries lead to? 7. When were the first asteroids discovered? How many have been discovered?

Names.	Discoverers.
61. Danæ	Goldschmidt, Paris.
62. Erato	Forster, Berlin.
63. Ausonia	De Gasparis, Naples.
64. Angelina	Tempel, Marseilles.
65. Maximiliana.	" "
66. Maia	Tuttle, Cambridge.
67. Asia	Pogson, Madras.
68. Hesperia	Schiaparelli, Milan.
69. Leto	Luther, Bilk.
70. Panopea	Goldschmidt, Paris.
71. Niobe	Luther, Bilk.
72. Feronia	Peters, Clinton, N.Y.
73. Clytie	Tuttle, Cambridge.
74. Galatea	Tempel, Marseilles.
75. Eurydice	Peters, Clinton, N.Y.
76. Freja	D'Arrest, Copenhagen.
77. Frigga	Peters, Clinton, N.Y.
78. Diana	Luther, Bilk.
79. Eurynome	Watson, Ann Arbor, U.S
80. Sappho	Pogson, Madras.
81. Terpsichore	Tempel, Marseilles.
82. Alcmene	Luther, Bilk.
83. Beatrix	De Gasparis, Naples.
84. Clio	Luther, Bilk.
85. Io	Peters, Clinton, N.Y.

Names of 13 more, doubtful.

SECTION XXI.

Jupiter.

1. JUPITER and his attendant moons are a great planetary system of themselves. They are at a greater distance from the sun, manifest more wonderful movements, and exhibit more wonderful phenomena, than any of the heavenly bodies which have been noticed. This planet is about ninety thousand miles in diameter, is thirteen hundred times larger than the earth, and revolves around the sun in nearly twelve years, is four hundred and ninety-five millions of miles distant from him, and rotates once on his axis in nearly ten hours.

2. His density is four times less than that of the earth; and he may be regarded as having no seasons, in consequence of his axis being nearly perpendicular to the plane of his orbit. Perpetual summer reigns at his equator, and the temperature decreases in the direction of his poles, till cold more intense than was ever experienced by man holds its unrelenting sway.

3. Dark-colored belts cross his disk nearly parallel to his equator, and are supposed to be, by some astronomers, portions of the planet itself, brought into view by the removal of clouds and mists that exist in his atmos-

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QUESTIONS.—1. How far is Jupiter from the sun? How much larger than the earth? What is the length of his annual period? What of his daily? 2. What is his density? Has he a change of seasons Why?

phere, through which openings are made by currents circulating around him. Others suppose them to be atmospheric currents, in which is suspended cloudy matter, which, like our trade-winds or other currents, are constantly revolving around him. This conjecture has been in a measure confirmed by the recent discoveries which have been made in regard to the currents in our own atmosphere.

Fig. 16.—Telescopic View of Jupiter.

4. Aeronauts[1] inform us that only a few miles from

[1] Aeronauts—persons that ascend in balloons.

QUESTIONS.—3. What appear on his disk? What are they supposed to be?

the surface of the earth there are atmospheric currents on either side of the equator, and nearly parallel to it, blowing constantly in one direction. If these currents were filled with dense cloudy matter, it is probable, if we were on another planet with the facilities for observation that we have here, we might witness objects similar to those on Jupiter. But, whatever these may be, they are liable to slight fluctuations, which have been highly useful in obtaining a knowledge of the physical character of the planet, which we infer to be very similar to that of the earth.

SECTION XXII.

Jupiter's Moons.

1. FOUR moons attend this planet, and revolve around him in different periods. (See Fig. 3.) The first, or one nearest to Jupiter, is two hundred and seventy-eight thousand five hundred miles distant from him, is twenty-four hundred and forty miles in diameter, and revolves around him in a little over forty-two hours.

2. The second moon in point of distance from the planet is four hundred and forty-three thousand miles distant from him, is twenty-one hundred and ninety in diameter, and makes a revolution around him in about three days and one-half.

3. The third moon is seven hundred and seven thousand miles distant from its primary, is thirty-five hundred and eighty miles in diameter, and revolves around Jupiter in a little over seven days.

QUESTIONS.—4. What do aeronauts say concerning atmospheric currents? Are the belts of Jupiter changeable?

SEC. XXII.—1. How many moons has Jupiter? What distance is the first one from Jupiter? What is its diameter? What is the length of its period? 2. What is the distance of the second moon from Jupiter? What is its diameter? What is the length of its period? 3. What is the distance of the third moon from Jupiter? What is its diameter? What is its period?

4. The fourth moon from the planet is one million two hundred and forty-three thousand five hundred miles distant from him, is thirty hundred and sixty miles in diameter, and makes a revolution around him in nearly seventeen days.

5. These satellites were discovered by Galileo, in sixteen hundred and ten, and were the first-fruits of the invention of the telescope. They, like all the moons of all the other planets that have them, make only one revolution on their axes, while they revolve once around their primary. Their orbits, unlike the orbits of all the planets and satellites of the solar system, except the orbits of the moons of Uranus, are nearly circular, and the sum of all the light which they reflect is little in comparison with what is reflected on us in a moonlight night.

6. Sunlight decreasing in intensity in an inverse ratio as it recedes from him, as we had occasion to illustrate, would be twenty-seven times less on their surfaces than on the surface of the earth. Three of Jupiter's moons are eclipsed at every revolution around their primary, and very frequently the fourth. This takes place owing to the fact that they revolve nearly in the plane of their primary's orbit.

7. From these eclipses of the satellites of Jupiter the velocity of light has been discovered, and also by them terrestrial longitude may be determined. If the earth is between Jupiter and the sun, he would be one hundred and ninety millions of miles nearer to the earth than if the sun was between Jupiter and the earth, the difference of distance being the diameter of the earth's orbit. If Jupiter is either in opposition or conjunction, that is, at his least or greatest distance from

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QUESTIONS.—4. What is the distance of the fourth moon from Jupiter? What is its diameter? What is the length of its period? 5. Who discovered these satellites? What is the shape of their orbits? 6. How many of Jupiter's moons are eclipsed at every revolution? How much farther is Jupiter from the earth at one time than at another?

the earth, the exact time when any of his moons will pass behind him can be determined.

8. It has been discovered that at these two points the apparent and computed times of obscuration do not agree by about sixteen minutes, indicating thereby that it requires light that time to travel one hundred and ninety millions of miles, or the distance that it is across the earth's orbit. By computing this velocity, we find it to be one hundred and ninety-two thousand miles per second, or twelve millions of miles per minute.

SECTION XXIII.

Saturn and his Rings.

1. We will now take into consideration Saturn and his rings, together with his cortege of satellites, which constantly surround him. He is about eighty thousand miles in diameter, is ten hundred times larger than the earth, and revolves around the sun in nearly thirty years, is nine hundred and nine millions of miles distant from him, and rotates once on his axis in a little over ten hours. His density is about that of cork-wood, or one-seventh that of the earth, and he has seasons similar to our own.

2. This planet presents a pale-yellowish color, and, when examined by the telescope, belts are observed crossing his disk. From the fact that some of his satellites linger from fifteen to twenty minutes on his margin when passing behind him and emerging from their concealment, it is inferred that he has a very dense atmosphere, this delay being accounted for by the refractive influence

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Questions.—8. Has the velocity of light been determined by the eclipses of Jupiter's moons? In what way?

Sec. XXIII.—1. What is the diameter of Saturn? How much larger than the earth? What is the length of his annual period? What is his distance from the sun? How long to rotate on his axis? What is his comparative density? 2. What is his color and appearance?

of a transparent medium. Admitting the law that regulates the diminution of light, the sunlight which he receives is ninety times less than that which the earth receives.

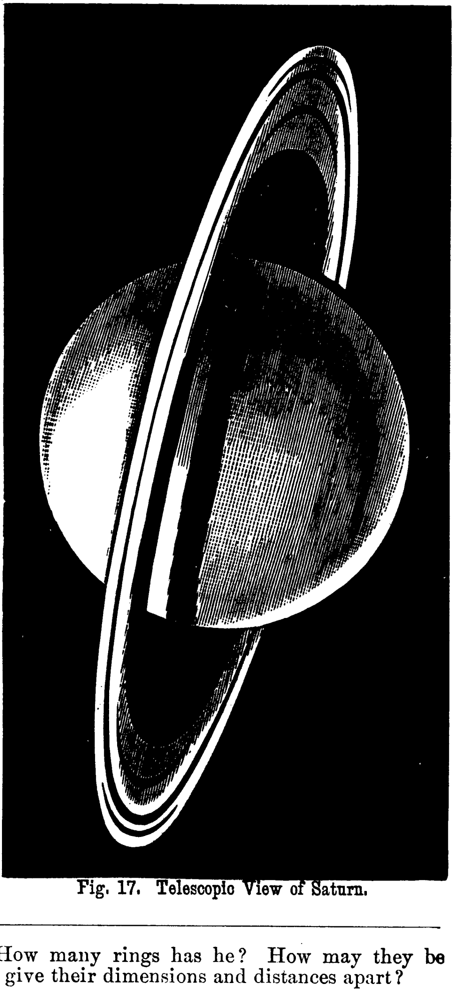
Fig. 17. Telescopic View of Saturn.

3. Five rings, which may be naturally divided into two grand divisions, surround him, and revolve with him in the plane of his equator, in the same length of time that he revolves on his axis. The two inner rings are of a darker color than the exterior ones, and the distance to the first from the body of the planet is about ten thousand miles, and the distance between the darker rings is about fifteen hundred miles. The second dark ring from the planet is about five

QUESTIONS.—3. How many rings has he? How may they be divided? Can you give their dimensions and distances apart?

thousand miles in width, and the distance between it and the first bright ring is about two thousand miles. The width of the inner bright ring is about twenty thousand miles, and the middle one ten thousand, and the outer five thousand miles. The space between these bright rings is about two thousand miles, and the thickness of each is about one hundred miles.

4. These wonderful appendages have been studied with great care ever since they were first discovered, and still comparatively little is known concerning them. Sometimes they appear to break in pieces and afterwards reunite, as if they were composed of fluids similar to water. At another time they appear to change their positions, and expand and contract alternately, as if acted upon by some periodic agency. Recently it has been inferred that they are gradually closing in upon the planet, and that ere long they will deluge its surface; but this is not yet fully confirmed.

5. They may ere long be acted upon by some compensating influence, by which they may be restored to their proper equilibrium and perpetuate their existence. It is known that mechanical forces are operating constantly on heavenly bodies; and it may be that they will not only forever sustain, but have actually produced, these anomalous appendages.

6. The form of a body often results from the forces which operate on it. If the earth was in the shape of a cube, and destitute of a daily motion, it would not remain so. Its outer parts would sink towards its centre, and other parts would be urged outwards, till equilibrium of gravity in its various parts would be restored.

7. So, also, if a sphere is made to rotate rapidly on its axis, its axis will grow shorter, and its length will always be in proportion to the density of the body and the ve-

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QUESTIONS.—4. Do these rings appear to change in form? What inference concerning them? 5. Are mechanical laws operating on the heavenly bodies? 6. If the earth was a cube, would it remain so? Why?

locity of rotation. This, no doubt, has been the case with the planets in assuming the shape which they have. By revolving on their axes they have swollen out at their equators and flattened at their poles, and they have swollen and flattened in proportion to their densities and velocities.

8. The lighter the body and the greater the velocity, the greater would be the tendency to throw off from its surface. Now, as Saturn is known to be composed of light material, and to rotate rapidly on his axis, the lightest particles may have been thrown off and assumed the annular form.

9. In this theory we assume what all no doubt will be ready to admit, that matter was created out of nothing by the fiat of Omnipotence, and that it is always accompanied by laws by which it is regulated and controlled. The fact is patent to all that natural causes are constantly producing natural results; and may it not have been so in the production of Saturn's rings?

10. Reason has not taught us the contrary, neither has revelation; for we are nowhere informed whether worlds were spoken into existence or formed by physical laws, which laws are of necessity the ordinances of the Great Architect of all things and Master-Builder of the Universe. But without a sufficient number of self-evident truths, from which we might deduce an irresistible argument, it is wisdom not to speculate too much on subjects suggested by discoveries made in the boundless field of space.

11. It is not for us to dictate, but to examine, to reflect, to reason, and confirm, if we can, what appears to

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QUESTIONS.—7. If a spherical body rotates rapidly on its axis, is there any tendency to a change of form? In what direction is this tendency? 8. May the rotation of Saturn on his axis account for his form and his rings? 9. Are natural causes constantly producing natural results? 10. Are we anywhere informed whether worlds were spoken into existence by the Creator or the result of natural laws? 11. What is the office of reason in the investigation of the works of nature?

be the teachings of the book of nature, on which is stamped the impress of divinity, and from which are reflected the natural perfections of an Infinite Creator.

SECTION XXIV.

Saturn's Moons.

1. SATURN is attended by eight moons, and they have received the names of Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, and Japetus. (See Fig. 3.) These bodies are only visible by the aid of powerful telescopes, and seven of them nearest to their primary revolve around the planet in orbits whose planes are nearly coincident with that of the rings. Their diameters vary from five hundred miles to thirty-three hundred, and their periodic times from twenty-two and one-half hours to seventy-nine and one-half days.

2. *Mimas.*—This satellite was discovered by Sir William Herschel in seventeen hundred and eighty-nine, and is seventy-eight thousand miles distant from Saturn, and revolves around him in about twenty-two and one-half hours.

3. *Enceladus.*—Sir William Herschel discovered this satellite also in seventeen hundred and eighty-nine. It is one hundred and twelve thousand miles distant from the planet, revolves around it in about one day and eight hours, and appears like a star of the fifteenth magnitude.

4. *Tethys*, the third moon from Saturn, was discovered by Cassini in sixteen hundred and eighty-four, and it resembles a star of the thirteenth magnitude. It is one hundred and forty-eight thousand miles distant from the planet, and makes a revolution around its primary in nearly two days.

QUESTIONS.—1. How many moons has Saturn? Are they visible to the naked eye? 2. What distance is Mimas from Saturn? What is the length of its period? 3, 4, 5, 6, 7, 8, 9. What is said of all the rest of Saturn's satellites?

5. *Dione.*—This satellite was discovered by Cassini also in sixteen hundred and eighty-four, and it resembles a star of the twelfth magnitude. It revolves around its primary in nearly three days, and is distant from it two hundred and forty thousand miles.

6. *Rhea.*—Cassini discovered this moon also in sixteen hundred and seventy-two. It appears to vary in magnitude. At one time it resembles a star of the ninth magnitude, at another the tenth, at another the eleventh, and at another time the twelfth. It is two hundred and ninety-six thousand miles distant from Saturn, and revolves around him in about four days and one-half.

7. *Titan*, the sixth and largest satellite of Saturn, was discovered by Huyghens in sixteen hundred and fifty-five. It is like a star of the eighth magnitude, is seven hundred and thirty-eight thousand miles distant from the planet, and revolves around it in nearly sixteen days.

8. *Hyperion.*—This satellite was discovered by Professor Bond, of America, and Lassel, of England, about the same time, in eighteen hundred and forty-eight. It resembles a star of the seventeenth magnitude, is nine hundred thousand miles distant from its primary, and revolves around it in about twenty-one days.

9. *Japetus*, the outermost satellite of Saturn, was discovered by Cassini in sixteen hundred and seventy-one. It is two millions two hundred and twenty-eight thousand miles distant from the body of the planet, and revolves around it in a little over seventy-nine days. The plane of its orbit is inclined to that of the rings about ten degrees, and the periodic changes in its light indicate that it makes one revolution on its axis while it is making one revolution around its primary.

10. All of these satellites revolve around Saturn exterior to his rings, presenting with them to the Saturnians, if there are any, one of the most wonderful displays of

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QUESTIONS.—10. Where in relation to Saturn's rings do all his satellites revolve? If Saturn is inhabited, what natural exhibition will the inhabitants witness every day?

physical grandeur that is anywhere witnessed in the natural universe. Imagine one moon rising and another setting, one entering into an eclipse and another emerging from it, one appearing as a crescent and another with a gibbous phase, and sometimes all of them full-orbed. Imagine also the rings of the primary at one time eclipsing the stars and illuminating the sky with their splendor, and at another casting a deep shade over certain regions of the planet and unveiling the wonders of the starry firmament. Imagine, I say, such scenes as these, and is it possible not to regard them worthy of a Divine Being to unfold and even angels to contemplate?

SECTION XXV.

Uranus, Herschel, or Georgium Sidus.

1. THIS planet has three names, and was discovered by Sir William Herschel in seventeen hundred and eighty-one, as if it were by accident, when engaged in a systematic examination of the heavens. He at first supposed it to be a comet, but subsequent observations established its planetary nature. It is of a pale color, and exhibits no marks whereby we may detect an atmosphere or daily motion; but, reasoning from analogy, we may infer that it has both.

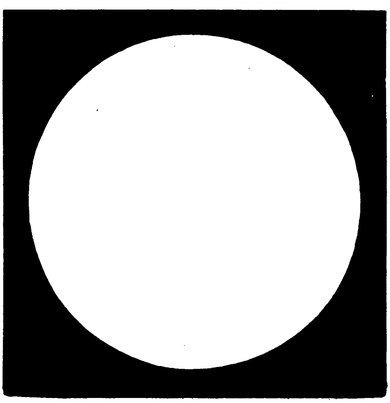

Fig. 18.—Uranus.

QUESTIONS.—1. Who discovered this planet? What did he at first suppose it to be?

2. It is one billion eight hundred and twenty-eight millions of miles distant from the sun, and revolves around him in a little over eighty-four years. Its diameter is thirty-three thousand miles, and its density is the same as that of Jupiter, or one-fourth that of the earth. Its inhabitants, if it has any, receive three hundred and sixty times less sunlight than we do, unless there is some agency (as there may be) associated with the planet itself to increase its intensity.

SECTION XXVI.

Satellites of Uranus.

1. Sir William Herschel discovered six moons attending this planet; but owing to the fact that it requires powerful telescopes, used under the most favorable circumstances, to see even some of them distinctly, little is known concerning them. (See Fig. 3.)

2. *Ariel.*—This satellite revolves around its primary in two and one-half days. *Umbriel,* the second moon in the order of distance from its primary, has a period of four and one-sixth days. *Oberon,* the third satellite, has a period of nearly eleven days.

3. *Titania,* the fourth satellite in point of distance from its primary, has a period of thirteen and one-half days. The periods of the fifth and sixth moons around their primary have not been determined, on account of the great difficulty of seeing them even under the most favorable circumstances.

4. The orbits of these satellites, like the orbits of the

Questions.—2. What is its distance from the sun? What is the length of its annual period? What is its diameter? What its relative density? What is the relative amount of light that it receives?

Sec. XXVI.—1. How many satellites has Uranus? Is it difficult to see them? What is the length of the period of Ariel? What of the period of Umbriel? What of the period of Oberon? 3. What of the period of Titania? What has prevented the periods of the fifth and sixth from being determined?

satellites of Jupiter, are nearly circular, and, contrary to all the motions of all the planets and satellites of the solar system, they revolve from east to west, and in a plane nearly perpendicular to the plane of the orbit of their primary.

SECTION XXVII.

Neptune.

1. SINCE Uranus was discovered by Sir William Herschel, it did not at times conform to the orbital motion which was anticipated by those who determined the elements of its orbit and calculated where it should be at any given time. In consequence of these deviations, it was conjectured that there was some unknown body belonging to the solar system, which was by its attraction producing these irregularities in the movements of Uranus.

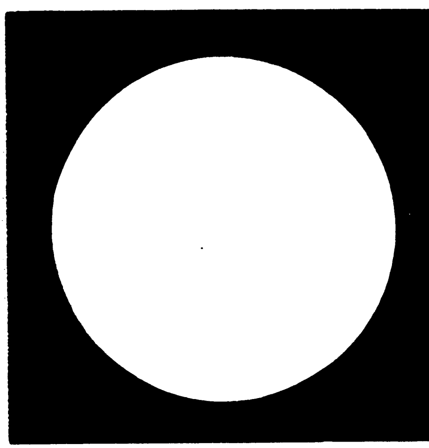

Fig. 19.—Neptune.

2. Mr. Adams of Liverpool, and Le Verrier of Paris, unknown to each other, attempted, by calculations

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QUESTIONS.—4. What is the form of their orbits? What is peculiar in relation to their motions?

SEC. XXVII.—1. Does Uranus ever leave his computed orbit? What was conjectured from his deviations? 2. Who attempted to account for these perturbations? Were they engaged at this work at the same time?

founded on the deviations of Uranus from his computed orbit, to determine where this disturbing cause was situated. Both of these mathematicians, nearly at the same time, succeeded in pointing out in the heavens where it should be found.

3. Le Verrier having completed his computation in eighteen hundred and forty-six, a little earlier than Adams, wrote to Dr. Galle of Berlin, directing him where to examine the heavens with his telescope for this conjectured body. The Dr., conforming to the request at the earliest convenience, employed his instrument in exploring that region of the heavens to which he had been directed, and, according to the prediction of Le Verrier, the planet Neptune was for the first time observed, as a planet.

4. This body is more than twenty-eight hundred millions of miles distant from the sun, and revolves around him in one hundred and sixty-four years. It is thirty-five thousand miles in diameter, and its density is the same as that of Saturn, or one-seventh that of the earth. He revolves nearly in the plane of the earth's orbit, and in all probability he has, like the other planets, a daily motion on his axis. Some observers supposed that they saw something that resembled a luminous ring around him; but this idea has not yet been fully confirmed.

SECTION XXVIII.

Satellites of Neptune.

1. Shortly after Neptune was discovered, Lassel of Liverpool discovered a satellite attending this planet and revolving around it in an orbit nearly circular. It

Questions.—3. Who succeeded first? Who was the first observer of Neptune? 4. How far is this planet from the sun? What is the length of his annual period? What is his diameter? What is his relative density? Are there any indications of a ring around him?

shines like a star of the fourteenth magnitude, is two hundred and thirty-two thousand miles distant from the planet, and completes a revolution around it in nearly six days.

2. Owing to the variations in its brightness, it is inferred that it rotates once on its axis while it revolves once around its primary. Some other astronomers have affirmed that this planet has at least one other satellite; and recent discovery corroborates their previous convictions by revealing the second satellite of Neptune.

3. The general characteristics of Neptune and his satellites are, as far as can be determined, similar to those of the other planets and satellites, and their physical constitutions are no doubt nearly the same.

SECTION XXIX.

Light and Heat on Neptune.

1. THE light and heat which Neptune receives from the sun are nine hundred times less than what we receive, unless they are intensified by certain elements or influences on his surface. That some substances have the power to intensify light and heat, and others power to diminish their influence, is a fact of which science is not ignorant. The atmosphere, together with the solid parts of the earth, even in the same latitude, modifies their effects to a very great degree.

2. Low lands in the torrid zone are visited with scorching heat, whilst up the slopes of mountains may be seen evidences of a temperate climate, and on their

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QUESTIONS.—1. Has Neptune any satellites? How many have been discovered? How far is the first from the planet? What is the length of its period? 2. Are there any indications of a second satellite? 3. What is the general character of Neptune and his moons?

SEC. XXIX.—1. How much less light and heat does Neptune receive from the sun than the earth? Have different substances different effects on light and heat?

tops perpetual sheets of ice and snow. These different degrees of heat almost in the same vicinity cannot be attributed to any difference of distance that we are away from the source of heat, but to the nature and relation of the material elements with which the solar rays are brought in contact.

3. The atmosphere gets rarer the higher we ascend, and thereby loses its power to refract, reflect, and retain heat, as is also the case with it in relation to the solar light. If we had no atmosphere capable of refracting and reflecting light, every thing here in the presence of the sun would be in one insufferable glare, and every thing not in his immediate presence would be surrounded by midnight darkness.

4. If the sun did not look directly into your chamber, it would be a dungeon, and the shade which is so inviting to the weary traveller would possess a gloom more palpable than was ever felt by man. No twilight would spread itself over the world to introduce the darker shades of night, neither would its mellow light introduce the brighter rays of morning. If we had no atmosphere, which can in a measure modify other physical agents, in spite of the grateful changes of seasons, the earth would be a barren waste, chained in eternal ice and entirely destitute of life and beauty.

5. Hence we observe the adaptation of one thing to another which tends to the comfort and happiness of our race. If we have susceptibilities of pleasure, there are objects corresponding whereby they may be gratified. If our appetites crave any thing, we have viands suited to the taste of the most fastidious; and if we desire to take a survey of natural scenery, and feast our eyes on the beauties of the landscape, or witness the

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QUESTIONS.—2. Why is it hotter on low lands than on high lands? 3. Does the atmosphere diminish in density as we ascend? Does the atmosphere absorb heat and reflect and refract light? 4. What would be the result if it did not? 5. Is adaptation manifested in nature's works? Might we infer from this that other worlds are inhabited?

plunging waves of the cataract, light is provided for our accommodation. If we are in need of any comfort, nature has it in her great storehouse adapted to our wants.

6. Hence, if the ministrations of nature to our wants are so abundant, may we not infer that there are millions of other intelligent beings on other planets, capable of enjoying the rich provision of comforts which, no doubt, crowd upon their surfaces?

SECTION XXX.

The Earth one of a Class.

1. THE earth is one of a class; and that class is the primary planets, whose physical constitutions are much the same. If the earth is composed of solid material, and is warmed by the heat of the sun, so are all the other planets. If the earth has an atmosphere, and is visited with rain and hail and snow and frost, so are they. If she has rivers, oceans, seas, and continents, in like manner do they possess the same. If she runs an annual course around the sun and is constantly bathing herself in light, so do they.

2. But it may be said that an inadequate quantity of light and heat to answer the purposes of life reaches some of these planets, and that they are buried in the abysmal depths of eternal night and winter. Follow the rays of heat and light which emanate from the sun to the farthest boundaries of our system, and still their influences are not entirely lost. A brilliancy equal to that of a hundred of our moons would be on Neptune,

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QUESTIONS.—1. Is the earth one of a class? What is that class? Why do we infer that the earth belongs to a class? 2. Does any sunlight or heat reach the outermost planet? How much more sunlight is received on Neptune than the moonlight that we receive? May he enjoy as much light and heat as planets that are nearer to the sun?

and, by a slight change in his atmosphere from ours, he might experience as much heat as we enjoy.

3. Science is familiar with the fact that the capacity of some substances on the earth to receive and retain caloric is greater than the capacity of others. Consider this to be the case with all the planets, and they may have different capacities for the same purpose, which may be conducive to their general well-being and the well-being of their inhabitants. The substance of caloric may be more abundant in bodies that are more remote than in those that are nearer to the sun, and it may be productive of sensible heat, even by a very slight influence of the solar ray.

SECTION XXXI.

Planets Inhabited.

1. On the hypothesis noticed above, which is corroborated by a great variety of facts and experiments, there may be a sufficient amount of heat even on Neptune to satisfy all the demands of animal and vegetable life. And if there should be no substance there to operate on light in a similar manner, provision to supply this want may have been made in the animated beings themselves.

2. The brilliancy of a day, or of light, depends to a very great degree upon the size of the pupil of the eye and the sensitiveness of the seat of vision. If the pupils of our eyes were comparatively small, and the pupils of the eyes of beings more remote from the

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Questions.—3. How might this be the case? Have some substances a greater capacity for caloric than others?

Sec. XXXI.—1. May Neptune have enough of light and heat to satisfy the demands of animal and vegetable life? 2. On what does the brilliancy of light depend? What would render the outermost planets, in relation to light and heat, suitable habitations for animated beings?

sun than we are, were comparatively large, their day might be more brilliant to them than ours is to us. A slight diversity in the composition and nature of the various bodies of the solar system, and also in the construction of the organs of sight, would render every known planet as suitable and comfortable a habitation as we ourselves enjoy.

3. In view of what is reasonable to suppose, and the striking analogy of the planets, not only in relation to their motions, but also in their physical constitutions, are we not led almost to the irresistible conclusion that there are not only worlds which declare the glory of their Maker, but immortal and intelligent beings not far distant, who adore the perfections and chant the highest symphonies of praise to the honor of the Most High.

4. Why is there such provision made, and such an adaptation of things to the comfort and happiness of life, as we observe pervading these worlds, if there are no beings to enjoy them? Why such an exercise of almighty power in their production? Why such a demonstration of divine wisdom in their adaptation? Why such a glorious display of infinite goodness in their arrangement, if they were to be uninhabited solitudes and forever destitute of rational and intelligent beings, who may magnify the perfections of the Creator in the contemplation of his wonderful works and in the fulfilment of the great end of their existence?

QUESTIONS.—3. In view of the analogy of the primary planets in relation to their motions, physical constitutions, and other characteristics, what may we infer? 4. In view of their creation, arrangement, and adaptation to the wants of intelligent beings, what may we infer?

SECTION XXXII.

General Configuration of the Heavenly Bodies.

1. THE general configuration of the earth's surface is spherical, or globular, which may be confirmed by the following considerations. 1st. When a ship is approaching land at a distance, the top of the mast comes first into view, and more and more of it becomes visible as she comes nearer, till the vessel itself is distinctly observed as she comes into port.

2. By travelling constantly in one general direction, which has been done by navigators, they arrive at the

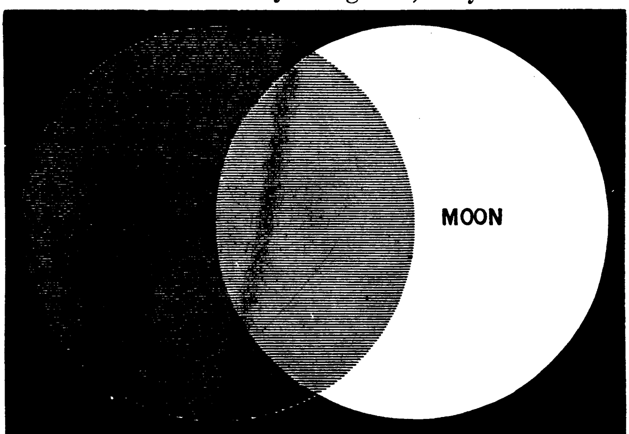

Fig. 20.—Earth's Shadow.

same place from whence they departed. Captain Cook and others have repeatedly demonstrated this fact by their voyages around the world.

3. The rotundity of the earth is also apparent from the phenomena manifested by eclipses of the moon.

QUESTIONS.—1. Is the earth globular in form? What is the evidence noticed in first verse? What in second verse? What in third verse?

When the earth intervenes between the sun and moon, she casts her shade on the moon's disc, and it makes a circular figure, indicating thereby that the body which produced it is globular in form. (See Fig. 20.)

4. The rotundity of the earth is more fully established by the mutual attraction existing between all the parts of it, and all the particles of matter that compose it. The tendency of every particle in a body is to sink towards its centre; and if it was of any other shape than spherical, the outer parts would crush inwards by their own weight or gravity, and other parts would be urged outwards, till equilibrium of gravity of all its parts would be arrived at; and this could occur only when all of the parts are to a very great extent equidistant from the centre.

5. In like manner may we reason in relation to the spherical form of all the heavenly bodies. As the law of gravitation exerts its influence on matter wherever it exists, and as its influence is always the same in kind, similar results would of necessity flow from similar causes. The attractive force being always towards the centre in all bodies, the particles which constitute them would so arrange themselves as to render their exterior surface convex or spherical in form.

6. Observation also fully confirms what we have already said in relation to the figures of the planets and other heavenly bodies. It matters not in what position they may be, or what relation they may sustain to each other, when viewed with the naked eye, or with the use of the best optical instruments, they appear uniform in their general configuration.

7. The various phases of the moon clearly indicate her figure, and that she shines by reflection. As she moves eastward after her change in her orbit faster

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QUESTIONS.—What in fourth verse? 5. From the effects of what law may we infer that all heavenly bodies in general are spherical in form? 6. Do they appear round to the naked eye? Do they with the use of the telescope? 7. What peculiar evidence that the moon is round? What more do we learn from her phases?

than the earth does in hers, her surface next to us day by day becomes more and more enlightened till she is full. These peculiar phases of light, which she manifests every successive night, as she and the earth change their relative positions, could not occur were it not that it is reflected by a body which is spherical in form.

8. The same is also true of Mercury and Venus. They, in consequence of revolving around the sun in orbits which are nearer to him than the orbit in which the earth revolves, exhibit similar phases when they are examined by the telescope. By these phases they exhibit their forms, which are evidently analogous to that of all the planets and satellites, and also to that of the sun himself.

9. He revolves on his axis in about twenty-five and one-half days, and in making this revolution exposes his whole surface to view. During this whole period no change of form is manifested, which of necessity would appear if he had not a surface which was uniformly convex. In view of the foregoing evidence, and other considerations almost as conclusive, it may be inferred that the general configuration of all heavenly bodies is now round or globular, whatever may have been their condition in time, or when first brought into existence.

SECTION XXXIII.

Specific Form of the Earth.

1. NOTWITHSTANDING the earth's general form is globular, still it is not a perfect sphere. It is flattened at the poles, and swollen out at its equator, making the polar

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QUESTIONS.—8. Do Mercury and Venus exhibit different phases, like the moon? What may we infer from them? 9. Does the sun exhibit any change of form as he revolves on his axis? Why not?

SEC. XXXIII.—1. Is the earth a perfect sphere? Where is it flattened, and where is the excess of matter? How much shorter is its polar than its equatorial diameter? A globular body, if rotated rapidly on its axis, has a tendency to assume what form?

diameter about twenty-six miles shorter than the equatorial. It assumed this peculiar form, probably, at the time of its formation, from the rapid motion which it has on its axis. By revolving a globular body on which water is placed at a certain rate of motion, the water will leave the poles of the body and accumulate about the equator, changing its form into that of an oblate spheroid.[1] This is now the form of the earth, as is evident from the following considerations.

2. If the earth was a perfect sphere, the pendulum of a clock which vibrates once every second at the equator would vibrate once every second at the poles. By experiment, its vibrations are found not to be uniform all over the earth, but they invariably increase as the clock is removed away from the equator. This increase of action in the clock is in consequence of its nearer approach to the centre of the earth as it advances towards the poles. The attraction of gravitation always increases inversely as the square of the distance, and as the distance decreases the attraction increases, which increases the vibration of the pendulum.

3. For the same reason, bodies weigh more near the poles than at the equator. The weight of a body is the measure of the earth's attraction for it, and the nearer that it is to its centre, so that it is on its surface, the greater will be its weight. It has been ascertained by actual experiment that bodies are not uniformly heavy all over the earth, but that they increase in weight as they are removed from the equator. This change of weight can only be accounted for on the principle that the earth's diameter is shorter in one direction than

[1] Oblate spheroid—is a solid figure slightly flattened on the opposite sides.

QUESTIONS.—2. Do the vibrations of the pendulum of a clock afford any evidence that the earth is not a perfect sphere? In what way? Why does it vibrate faster in the direction of the poles? 3. What is the weight of a body? Do bodies weigh as much at the equator as in the direction of the poles? What does this difference in weight prove?

in another, and that objects on its surface are not all equally distant from its centre.

4. But these are not the only facts that may be adduced to prove the peculiar form of the earth. It is ninety degrees from the equator to the poles. All of these degrees are known to vary more or less in their length. They have been discovered to increase more and more in length as they are measured from the equator. If they were measured on a perfect sphere, they would be uniform in length; but the opposite is true, it matters not where the experiment is made.

SECTION XXXIV.

The Planets Oblate Spheroids.

1. OBLATENESS[1] is manifested by some of the planets that are comparatively near to us, as well as others that are known to revolve rapidly on their axes which are more remote. Mars exhibits a difference between his polar and equatorial diameters of twenty-five miles; and if he revolved more rapidly on his axis than he does, no doubt it would be much more.

2. Jupiter illustrates this idea by his oblateness. He is about two hundred and seventy thousand miles in circumference, and, in consequence of his making a rotation on his axis in about ten hours, the parts at his equator must revolve with great velocity. As a result of this, he is very much flattened at his poles.

3. Each extremity of his polar axis is shortened at least three thousand miles; and those of the polar axis

[1] Oblateness—flatness at the poles.

QUESTIONS.—4. What additional evidence that the earth is flattened at the poles?

SEC. XXXIV.—1. Is Mars flattened at his poles? How much? 2. Is Jupiter flattened much or little at his poles? 3. How much shorter is his polar than his equatorial diameter?

of Saturn are shortened still more, and very much more, considering his relative size, but no more when we consider his relative density. From these observations, made on some of the most prominent planets, under the most favorable circumstances, it is altogether probable that the same is true of all heavenly bodies that rotate rapidly on their axes.

4. The laws of force and motion will always produce similar results under similar conditions, whether they operate on the earth or in the heavens. Their power and influence are felt by all worlds, and unto them do they conform, not only in their general movements, but also in their individual and specific forms. Nature's laws always operate uniformly in shaping and controlling the material universe, and in satisfying the will of Him who is the Author of them all.

SECTION XXXV.

Position of the Solar System in relation to the Starry Heavens.

1. As has been already noticed, the clusters or groups of stars that are visible are named constellations. All of these constellations, for the sake of convenience, are divided into three grand divisions,—the Northern, the Southern, and the Zodiac. As the first two divisions are not so intimately connected with our present subject, we will refer to them hereafter, and consider only that division which has a direct relation to it. (See Fig. 21.)

2. The zodiac is composed of twelve signs, and with each sign is associated a constellation. Each sign is

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QUESTIONS.—Is Saturn flattened at his poles more or less than Jupiter? Does oblateness appear to be common to all the planets? 4. Of what natural laws is it the result?

SEC. XXXV.—1. Into how many grand divisions are the starry heavens divided? What are they called? 2. How many signs constitute the zodiac? How many constellations?

thirty degrees in length, or east and west, and sixteen in width, or north and south; each constellation is coextensive with each sign,—that is, the one in area is equal to the other. These twelve constellations are so

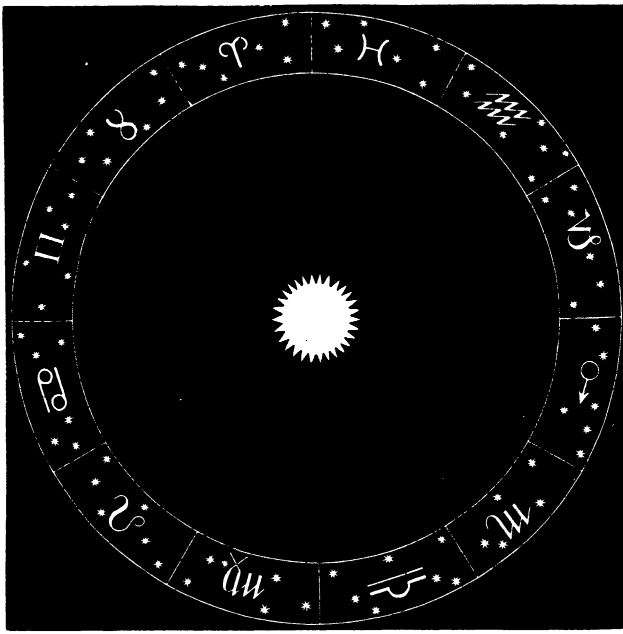

Fig. 21.—Zodiac.

arranged as to form a great belt or zone of stars which extends clear around the heavens, east and west, and divides them into two equal parts, known as the northern and southern divisions.

3. Hence these divisions are not separated by one

QUESTIONS.—What is the length and width of each sign? Is each constellation coextensive with each sign? What is the form of the zodiac, and where is it situated in the heavens? What divisions does it separate? 3. To which of the three grand divisions is the solar system most intimately related?

common circular line, but by the zodiacal division, which lies between them, and is sixteen degrees in width. To this latter division the solar system may be regarded as being more intimately related, not in consequence of its contiguity to any part of it,—for they are millions of millions of miles apart,—but in consequence of the astronomical connection of the one to the other.

4. The plane[1] of the earth's orbit, if extended inwards from the earth towards the sun, would divide him into two equal parts, and if extended outwards into the heavens it would not only divide them into two equal parts, but the zodiac also, with eight degrees on either side of it. Therefore, since it has been shown that the planes of the orbits of all the primary planets are at very small angles with that of the earth, hence none of them, if extended into the sidereal[2] heavens, will pass beyond the limits of the zodiac, either north or south.

5. In view of these conceded relations, the system to which our earth belongs may be regarded by us, if we are at or near the equator, as occupying a vertical position, similar to a wheel standing on its rim on a level plain, in an easterly and westerly direction. The centre of the wheel would represent the place of the sun, and the rim the orbit of Neptune, the intermediate space being occupied by the orbits of all the other planets, not many of which deviate far from the general plane of the zodiac.

6. But if we were situated at or near either of the

[1] Plane of an orbit—an imaginary surface in which the orbit wholly lies.
[2] Sidereal—starry.

QUESTIONS.—4. How would the plane of the earth's orbit, if extended into the starry heavens, divide the zodiac? Would the planes of the orbits of any of the primary planets, if extended into the starry heavens, extend north or south of the zodiac? 5. What is the position of the solar system to the zodiac? How illustrated? 6. If at either pole, what then is the position of the solar system, and where would the zodiac appear?

poles, then the solar system may be regarded as having a horizontal position, since the zodiac, instead of being always nearly overhead, would appear all around the horizon. Viewed as already stated, the sun would not at any time appear to rise high in the heavens as it does, neither would we have day and night every twenty-four hours, but he would appear to circulate around the earth not far above its surface for six months together, and below it the same length of time; and each of the days and nights would be six months long.

7. Hence it may be observed that the position of our system is not absolute, but relative, as it depends entirely upon the place that we occupy when we observe it, and the divisions of the heavens that surround it. As we change our place by going north or south, in like manner do they also appear to change; and the one is in the same ratio as the other.

8. But in going east or west there is no perceptible change in either, as we always travel in the same plane, and hold not only a common relation to the planetary system in general, but also to all the grand divisions of the heavens with which it is surrounded.

SECTION XXXVI.

Motions of the Planets around the Sun.

1. THE planets have two motions, when considered as parts of the solar system, the one around the sun, and the other on their axes. Each revolves around him from west to east, in periods varying from eighty-eight days to one hundred and sixty-four years. Mer-

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QUESTIONS.—7. Is the position of the solar system absolute, or relative? 8. Would these apparent changes take place by travelling east or west?

SEC. XXXVI.—1. How many motions have the planets? What are they? In what direction do they travel around the sun? Which has the shortest period? Which the longest?

cury, the planet nearest the sun, has the shortest period, and Neptune, which is at the greatest distance, has the longest, and those that are intermediate have periods varying according to their distances from the sun, and the speed at which they travel.

2. The planet that has the least orbit moves with the greatest velócity, and as their orbits increase in size their velocities diminish, throughout the whole series that compose our system. These facts were discovered by observing the planets from time to time and noting their places in the heavens, when compared with the stars that are apparently fixed.

3. At each successive period when observed, they were all found to have moved in one general direction; and these observations being frequently repeated, the same results were always obtained. They pass apparently through one constellation after another in the zodiac, till they make a complete circuit around the heavens, always maintaining their easterly direction and relative motions.

4. From this uniformity of direction of all the planets, and motions of each, their places in the heavens at any time can be accurately determined, their transits and occultations[1] can be safely predicted, and the true time when eclipses of both sun and moon shall take place can be definitely known. Such precision characterizes their movements that they are not one second of time too early or too late in their annual periods, but they constantly repeat them with perfect exactness.

5. They are true to time not by chance, but by the

[1] Occultation of a planet—its concealment by the moon coming between it and us.

QUESTIONS.—2. Which travels with the greatest velocity? Do they increase or diminish in velocity as their distances increase from the sun? How is this fact known? 3. How is it known that they all travel in an easterly direction? 4. Can the place of each planet be determined at any time, and eclipses be predicted? Can their transits and occultations be accurately foretold?

order of Him who can work by second causes as accurately and efficiently as he can directly by the power of his might.

SECTION XXXVII.

Centripetal and Centrifugal Forces.

1. IF a ball is projected upwards in a vertical line, it will come to rest at a certain point in the air, and then it will descend in the same line till it comes in contact with the earth. Give it next an oblique motion, and it will not move in a straight line, but will commence and continue from the place where it received its first impulse, to describe a curved line till it comes to rest.

2. In view of these facts, it is evident that more than one force operates on it, or it would have continued in a straight line in the direction which was given it by the projectile force. And it is further apparent that the force that brought it to rest was greater than the one that was at first imparted to it, as it entirely arrested its motion. This inequality of forces brought it to rest; for, were it possible to give a body such an impulse as to carry it clear round the earth to the same point exactly from which it left, it would continue to revolve perpetually, since the two forces, the one given to it and the earth's attraction which now operates on it, are equal.

3. Under such conditions are the planets retained in their orbits. They are subject to these two laws, known

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QUESTIONS.—5. Are the motions of the planets the result of chance, or according to the order and arrangement of the Creator and upholder of the universe?

SEC. XXXVII.—1. What causes a ball or body to fall to the earth when thrown up into the air? What kind of a line will a body describe if thrown in an oblique direction? 2. How many forces operate on a body that is thrown into the air? What are they? Which is the stronger force? If an impulse could be given to a body sufficient to carry it round the earth to the point that it left, would it continue to revolve perpetually? 3. How are the planets retained in their orbits?

as the centrifugal[1] and centripetal[2] forces. The centrifugal force would always cause them to move in straight lines, if there was no impediment in the way, or other disturbing cause, to change their course. It is the initial

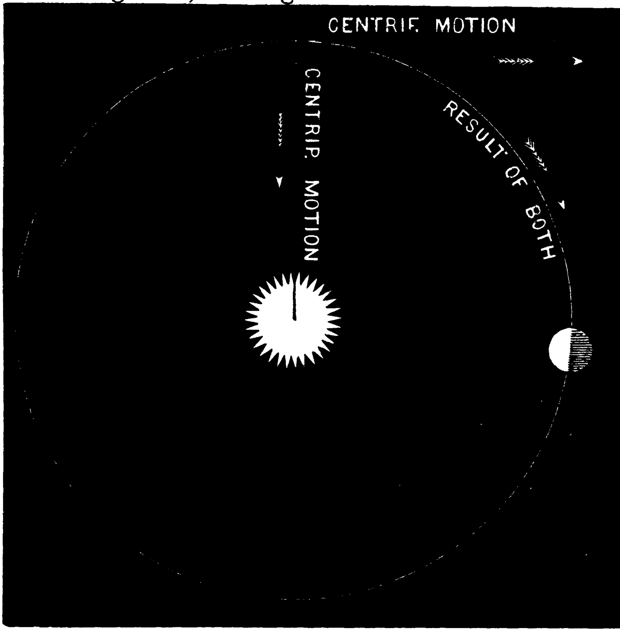

Fig. 22.

impulse which they received in the beginning when they came new from the Divine hand, or in time by the united force of natural laws. Whichever of these causes produced it, it matters not, inasmuch as each

[1] Centrifugal force—is the force which is given to a body that causes it to move in a straight line.

[2] Centripetal force—is the force which draws a heavenly body towards its centre of motion.

QUESTIONS.—What are the centrifugal and centripetal forces?

planet has received it in a degree suitable to its position and the end for which it is designed.

4. This centrifugal force is impressed on the planets near the sun to a greater degree than on those at a greater distance, and must necessarily be so to counteract his attraction for them, which is the centripetal force. He draws them constantly towards himself with forces corresponding to their distances and their masses, and would sooner or later bring them to himself, if there was no other influence to counterbalance his attraction for them. (See Fig. 22.)

5. But, the centrifugal and the centripetal forces being equal, the planets are not permitted to depart from their orbits by flying off into space or falling upon his surface. These two forces are so arranged not only in relation to the planets, but also to every scheme and system of heavenly bodies, as to counterbalance each other, and thereby perpetuate their harmony and existence.

6. Motion is essential to the plan of the universe, and upon the equality of the centrifugal and the centripetal forces does it constantly depend. If the latter should fail or grow weak, physical anarchy would reign throughout the habitable empire of space; and if the former should lose its influence, all worlds would dash together, and form the funeral pile of nature. The whole universe stands upon them; and to detract from either would be to unhinge all nature and turn it back to chaos.

QUESTIONS.—4. Which planets in relation to the sun have the greater centrifugal and centripetal forces? Do they in relation to the planets counterbalance each other? 5. If the centrifugal force was greatest, what would result? If least, what would result in relation to the planets? 6. Is motion essential to the plan of the universe? What would be the result in nature if either should fail?

SECTION XXXVIII.

Motion of the Planets on their Axes.

1. THE daily motion of the planets, like their yearly motions, is from west to east, and is always the same. Whether it has resulted from the operation of natural laws in time upon the matter that composes them respectively, or is the effect of a Divine impulse as the planetary system was being constructed, no one can tell.

2. By observing certain portions of their surfaces concealing and revealing themselves alternately, the diurnal motions of six of them are known; and analogy would lead us to believe that they all rotate in the same direction on their axes. In this respect they may be divided into two classes,—those that have a faster and those that have a slower motion. The former class embraces Mercury, Venus, the Earth, and Mars, and the latter Jupiter and Saturn, the daily motions of all the rest being unknown. The four former planets rotate on their axes in nearly equal periods of twenty-four hours each, and the two latter in periods of about ten hours each.

3. Now, as this daily motion causes a part of the surface of each to turn constantly into its own shade, and other parts at the same time to present themselves to the sun, light and darkness must occur alternately on each of them at each rotation. Consequently, daylight at the equators of the former would continue about twelve hours, and night would continue the same length of time; and on the latter, at their equators, each day and night would be about five hours in length.

QUESTIONS.—1. In what direction do the planets rotate on their axes? Is it known definitely how they received this motion? 2. What evidence have we of it? Do they all rotate with the same velocity? Which planets have the slow motion? Which the fast? 3. Does this motion produce day and night on these bodies? How? What would be the length of one of Jupiter's days? What of one of his nights?

4. Leaving the equators of the planets, and going towards their poles, the days and nights vary in length, though not by any changes in their motions, but on account of their spherical form and the various inclinations of their axes. As their poles decline from the sun, their days decrease and their nights increase in length; and as their poles incline towards him, the order in the length of their days and nights is reversed. Corresponding with these changes in the length of day and night on the different planets is the change of their seasons, to which we will hereafter refer.

SECTION XXXIX.

Weight of Objects on the Sun and Planets.

1. It is a well-known fact that some objects on the earth weigh more than others. A cubic foot of water weighs more than the same volume of air. This difference in weight results from a difference in the amount of matter that each of these bodies contains, one of them being more compact or dense than the other. If the earth was less dense than it is, both of them would weigh less than they do, as the weight of each of them is the measure of the earth's attraction for each; and if it was more dense than it is, each of them would weigh more.

2. It is now apparent that there are two causes which may, under certain conditions, cause objects of the same bulk or volume to weigh more or less. One is a difference in the amount of matter that may be in each of

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QUESTIONS.—4. Does the length of day and night on the different planets vary more at the equator or at the poles?

SEC. XXXIX.—1. Does a cubic foot of air weigh as much as a cubic foot of water? What causes the difference? If the earth was denser than it is, what effect would it have upon their weight? What, if rarer? 2. What two causes may change the weight of bodies?

them, and the other is a difference in the degree of attraction which the body has for them on which they may be found. If they belong to bodies that contain more matter than the earth, they will weigh more; and if they belong to bodies that contain less matter than the earth, they will weigh less.

3. Now, as the sun and planets are of different magnitudes and different densities, they attract objects that are on their surfaces with different forces, which would cause even the same object, if it could be transported from one to the other, to vary in its weight. An object weighing a pound on the surface of the earth would weigh a little more than a pound on the planet Mercury. The material of which he is composed being nearly as compact as lead, his attraction for objects that may be on his surface is greater than the attraction of the earth is for objects on its surface.

4. This is not so with the attraction of Venus and Mars for objects on their surfaces. Either of them being less than the earth, and having about the same density, objects on them would weigh more or less in proportion to their magnitudes. As Venus is only a little less than the earth, the weight of an object there would be only slightly reduced when compared with what it would be here. In the case of Mars it would be only about half as much on his surface as on the earth's, since he is so much less in size.

5. On Jupiter and Saturn it would be the reverse, as either of them is much larger and contains more matter than the earth. If these bodies were dense according to their magnitudes, the difference in the weight of objects on the earth's surface and theirs would be greatly increased; and, even as it is, a pound on the earth would be increased in weight if transported to

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QUESTIONS.—3. Does the attraction of the sun and planets differ in degree? What causes this difference? Will a body that weighs a pound on the earth weigh as much on Mercury? 4. More or less on Venus or Mars? 5. More or less on Jupiter or Saturn?

either of them. On Jupiter it would be increased more than double, and, though Saturn is not denser than cork-wood, the pound would still weigh a number of ounces more, owing to the magnitude of the body, which gives it its increase of weight.

6. On the sun there would be a much greater difference in the weight of objects than on any of the planets, as he is thousands of times larger than any of them, though he is not denser than water. His magnitude being so great, a body weighing one hundred pounds on the earth would weigh twenty-eight hundred on the sun, as his attraction is that much greater on objects that are on his surface than that of the earth for objects on its surface.

7. It is now evident that the weight of any body, whether small or large, depends upon the force that is exerted upon it outside of itself; and, in view of these results, as manifested by the sun and the planets, how perfect is the adaptation of man to his present abode! The earth attracts him to herself in a degree suitable to his physical nature, and the general adaptation of all natural objects here below conspires to enhance his happiness and enjoyment.

SECTION XL.

Earth's Atmosphere.

1. THE globe on which we dwell is in the centre of a great ocean of rare, ethereal, fluid matter, the general surface of which is supposed to be about fifty miles distant from the surface of the earth. This fluid substance

QUESTIONS.—6. How much will a body that weighs a pound on the earth weigh on the sun? Why will it weigh so much more? 7. Upon what does the weight of a body that weighs a pound on the earth depend if transported to any of the planets? Is our physical strength adapted to the amount of attraction which the earth has for us?

SEC. XL.—1. What surrounds the earth? What is its average depth?

is called the atmosphere, and is composed principally of two gases, viz., oxygen and nitrogen, combined in different proportions. The former of these gases is essential to the health and growth of both animal and vegetable life; and were it not for its presence everywhere, the earth would be a barren waste.

2. We inhale it every moment, and by its influences animal heat is generated, and the functions of all organized bodies stimulated to the accomplishment of those ends for which they were designed. In combination with other elements, it is the vivifying principle in the atmosphere in which we live, and to which we are indebted as an agent for the comforts of life. Though it may differ in some of its characteristics from other objects in nature, still it has properties and qualities that are common to them all.

3. It is visible if viewed through a body of itself of sufficient depth to develop its color: hence the bluish tinge that it manifests when observed at a distance. As the eye penetrates it, its hues grow deeper, till the whole heavens appear as a canopy of azure suspended from above. But the attribute of color is not the only one that the atmosphere exhibits: it is also possessed of weight. This is evident from a number of considerations.

4. By taking two vessels of equal weight, and forcing more air into one of them with a condenser than it ordinarily contains, and then weighing them separately, they will be found to differ in weight. This difference of weight is the weight of the excess of atmosphere that one vessel contains over the other. So, also, if the air is exhausted from a vessel (which can be easily done with an air-pump), it will diminish its weight. But this idea may be more clearly exemplified by the gene-

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QUESTIONS.—Of what is it composed? Is it essential to the health and growth of vegetable and animal life? 2. What element in it is the vivifying principle, or is the generator of animal heat? 3. Is the atmosphere visible? What is its color? Has the atmosphere weight? 4. How can this be proved?

ral pressure of the atmosphere, which results from its actual weight.

5. It exerts a heavy pressure on all bodies that are on the surface of the earth. At the level of the sea it is about fourteen pounds to the square inch, and below this it is still more. It will balance a column of mercury—as may be seen in the case of the barometer—twenty-nine inches high, or a column of water thirty-three feet. So great is its pressure even on our bodies that it would instantly crush them, were it not that there is an equal corresponding internal pressure outwards, which preserves them from destruction.

6. Like water, it exerts this force in every direction, and always to that degree which corresponds to its general weight. If separated, as it is frequently by lightning, it dashes together with a report often louder than the heaviest explosion. And often, when it is disturbed by the heat of the sun and other causes, it forces the oak of a hundred years from its roots and leaves desolation in its path. The particles of which it is composed being at liberty to move freely among themselves, it enters every habitation, and by its gravity it is caused to pervade every crevice and opening in the earth.

7. Notwithstanding it may be very much reduced in bulk by pressure, still, as a natural body it occupies space and retains its original qualities, as before. Notwithstanding it may be rarefied by heat so that it ascends, yet it satisfies every demand that is made upon it by the animal and vegetable kingdom. Though its

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QUESTIONS.—5. Does the atmosphere exert a heavy pressure on the surface of the earth? What is it to the square inch at the level of the sea? How high a column of mercury will it balance? How high of water? Why does it not crush us by its pressure? 6. Does it press in every direction, like water? If separated by lightning, what is the result? What effect has it sometimes on the forest? 7. Is it capable of being compressed? Is it elastic? Can it be rarefied? Does it move from one place to another? By what influence?

currents are numerous and flow often in opposite directions, still, as an ocean without a shore, it is indispensable in the present economy of nature.

SECTION XLI.

Refraction.

1. WHEN we wish to take observations of celestial bodies, we are compelled to look out through the entire depth of the atmosphere; and were it not that it is transparent and allows the rays of light to pass through it, they would be forever invisible. Hence, by their own inherent light which they emit, or by the light of the sun which some of them reflect, have we arrived at our present knowledge of their phænomena.

2. Their light travels in straight lines, unless diverted by some medium through which it passes, or by some surface with which it comes in contact. As it cannot reach us without penetrating through the whole depth of the atmosphere, as a legitimate consequence their rays will be bent from their natural course. This is called the refraction of light; and its tendency is to change the direction of every ray that enters it obliquely, downwards, or towards the centre of the earth.

3. Now, since all heavenly bodies that are visible are visible only by the light that emanates from them, and since the atmosphere increases in density as the rays of light descend into it, they will necessarily deviate farther from a straight line as they approach us; for, according to a well-known principle in science, the denser the medium through which light will pass, the greater is

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QUESTIONS.—1. Through what transparent substance must we look when we wish to see a heavenly object? Through what agency do we see celestial objects? 2. Do the rays of light travel in straight lines if not disturbed? Do they travel in straight lines through a transparent medium? What is this change of direction called? Oblique rays are turned in what direction by the atmosphere?

its refractive power. On account of this deflection of the light that reaches us from all of the heavenly bodies that are visible, they are seldom seen in their real positions. (See Fig. 23.)

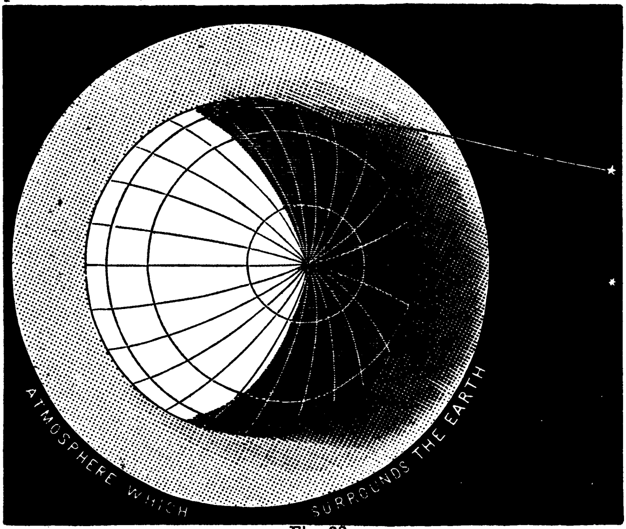

Fig. 23.

4. Being always observed in the direction of that section of the ray that is nearest to us, which is always refracted most, their altitudes are increased, except when they are at the zenith,[1] where no refraction occurs. When in the zenith, their rays fall perpendicularly upon the atmosphere, and, consequently, suffer no change in direction in coming to the earth. But, as every heavenly

[1] Zenith—is a point in the heavens directly above us.

QUESTIONS.—3. Is a ray of light refracted more near the earth by the atmosphere than in its upper regions? What results from this in viewing heavenly bodies? 4. Are their altitudes generally increased thereby? When are they not? When a heavenly body is in the zenith, is it seen in its real position? How when seen on the horizon?

body that is visible recedes from this point, they are more and more displaced by refraction, till when on the horizon it amounts to about thirty-three minutes, where it is most. This being the case, they always appear higher in the heavens than they are; and in relation to the sun and moon, they are elevated so much that they appear wholly above the horizon when they are actually below it.

5. By this refractive influence of the atmosphere on light, the length of the day is increased a few minutes, and right ascension[1] and declination[2] are affected. The declination of heavenly bodies is diminished, and their right ascension is either increased or diminished, as they are either east or west of the point from which it is measured. If they are east, it is diminished, and if they are west, it is increased, as it is reckoned clear round the circuit of the heavens in an easterly direction.

6. Besides the general effect of elevating heavenly bodies above their true places, refraction appears to change them sometimes in their figures. When the atmosphere is very dense, both the sun and moon, when near the horizon, appear oval in form. They appear to be elongated horizontally, or to be shortened in the direction of their vertical diameters at least one-sixth of their length. This is the result of unequal refraction of the atmosphere that intervenes between them and us. As it is denser at the horizon than a little above it, the rays of light proceeding from the lower edges of either of them are refracted more than those that emanate from above. This seems to flatten them vertically, while their horizontal diameters are not sensibly diminished.

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[1] Right Ascension—is the distance east of a given point, and is measured on the equinoctial clear round the heavens.

[2] Declination—is distance either north or south of the equinoctial.

QUESTIONS.—5. What effect has refraction on the length of the day? What on declination? What on right ascension? 6. What effect has refraction sometimes on the figures of the sun and moon?

SECTION XLII.

Twilight.

1. TWILIGHT is also another phenomenon which depends upon the agency of the earth's atmosphere. It is partly due to refraction, but chiefly to the irregular reflection of the sun's rays by the particles of the atmosphere when he is below the horizon. Were it not for the power which the atmosphere has of displacing the solar light and scattering it in various directions, no objects would be visible to us out of direct sunshine.

2. Differing as it does in its density as we ascend into it, and also in its temperature, it is kept in a state of constant agitation, whereby the light is constantly scattered and diffused. If it was destitute of this power, every shadow would be thick darkness, and every place out of the sun's immediate presence would be filled with the obscurity of night. Through this dispersing influence of the atmosphere, the solar light is turned from its direct course and diverted to the purpose of general illumination.

3. It is a well-known fact in relation to the laws of reflection, that if a ball is dropped in a perpendicular line upon a plane surface it will bound up along the line that it described in its fall, or if it is thrown against a plane surface obliquely it will leave this surface at the same angle that it approached it. The same is also true in relation to light, unless the body with which it is brought in contact is of such a nature as to absorb or transmit it.

QUESTIONS.—1. What substance produces twilight? In what way? What effect have reflection and refraction on the rays of light? 2. Does the motion of the atmosphere aid in producing twilight? In what way? Would there be any twilight if there was no atmosphere? What would every shade be? 3. If a ball falls on a level surface, in what direction will it rebound? How if thrown obliquely against a plane surface? Does light follow the same law if not absorbed or transmitted by the body with which it is brought in contact?

4. The atmosphere being possessed of the power of reflection and refraction, the light of the sun when he is below the horizon passes into it obliquely, and is reflected on portions of the earth from which he is concealed. And owing to the mobility of the particles which compose the atmosphere, and the countless directions in which they reflect the light, when it reaches us it is so intermingled that no specific ray can be observed. This commingled, reflected, and less and more refracted light is twilight; and it ceases to be visible when the sun is more than eighteen degrees below the horizon, in a vertical line.

5. It differs in different places on the earth in its duration, being shortest at the equator and longest at the poles. At the equator, where the circles of daily motion are perpendicular to the horizon, it continues only a little over an hour; while at the poles it continues for nearly four months. Between these points it varies less or more in its length as the pathway of the earth is inclined more or less to the horizon.

6. At either pole, where it is daylight for six months and night for the same length of time, the twilight is very much prolonged. For as the horizon of a person at either pole would be only a little above the apparent pathway of the sun at any time, and as he never sinks more than twenty-three and one-half degrees below this horizon, twilight would not be entirely withdrawn for more than ten weeks out of the six months of night. And, as if Providence designed expressly to relieve the darkness that would then occur, the moon is constantly above the horizon, and the Northern Lights very frequently exhibit their fantastic coruscations, turning the night almost into day.

QUESTIONS.—4. How, then, does this apply to the production of twilight? When does it cease? 5. Does it differ in length on different portions of the earth? Where is it shortest? Where longest? What is its length near the equator? What near the poles? 6. For what reason does it continue so long near the poles? Is there any natural provision to relieve the darkness at the poles when there is no twilight? What is it?

SECTION XLIII.

Aurora Borealis.

1. THE aurora borealis, or, more properly, the aurora polaris,[1] is a luminous phenomenon, which frequently appears in the heavens to persons that are in high latitudes, both north and south. It is also called the Northern Lights, and sometimes the Northern Morning, on account of the advantageous position which we have in the north for observing it, and from the close resemblance that it frequently has to the dawn which ushers in the day.

2. These lights are more brilliant in the arctic regions during the winter season than at any other place or time; and they consist of luminous rays of various colors, which converge towards one common point in the heavens. At first they commonly appear as a foggy cloud near the horizon, and sometimes they continue in that state for several hours without any sensible motion.

3. This mist frequently assumes the form of an arch, the convex surface of which soon becomes luminous with a pale, uniform light, after which jets and rays of light, variously colored, issue forth in wonderful contrast. Increasing in number and brilliancy, they shoot up towards the zenith with great velocity, emulating at times the vividness of lightning and the colors of the rainbow, till at their maximum[2] splendor they come together in a crown of inimitable beauty.

4. In a moment they begin to fade, and in another

[1] Aurora polaris—polar light.
[2] Maximum—greatest.

QUESTIONS.—1. Are the polar lights ever seen near the south pole? By whom? By what other names are they known? 2. Where are these lights most brilliant? During what season of the year? Of what do they consist? How do they appear at first, and where? 3. What shapes do they sometimes assume as they develop themselves? 4. Do they suddenly disappear and reappear?

they are gone, frequently to reappear in a form apparently durable and immovable, and yet as evanescent as before. Like a ponderous arch, this phenomenon appears again. Though composed at first of whitish light, it soon begins to manifest its meteoric coruscations.[1] (See Fig. 24.) Quick almost as thought, these lights break

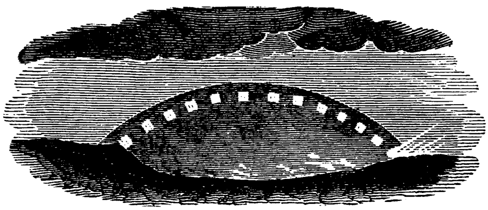

Fig. 24.

out again, without either uniformity of figure or motion With great diversity of color, they move fitfully and fantastically over a whole hemisphere in a moment, astonishing the spectator with the rapidity of their changes.

5. Soon they partially subside, and grow dim, as if to recuperate, when suddenly they manifest themselves, vigorously as before, in places where they had not been visible. Trembling and vibrating, and sometimes uttering hissing and crackling sounds for a few moments, they gather themselves into a more definite form, like a scroll when it is rolled loosely together. (See Fig. 25.) Apparent uneasiness still attending them, they abandon both their positions and their forms, and rise up like pillars and pyramids, standing on the horizon and supporting the archway of heaven.

6. Observed as they have been by persons of scientific

[1] Coruscations—brilliant flashes of light.

QUESTIONS.—What is said of their motions? 5. Do they ever produce hissing sounds? What special forms do they sometimes assume, and where do they appear to stand? 6. Are their colors ever very brilliant?

attainments, who have attempted to describe them, they are represented as tinged sometimes with so deep a red that the stars appear as if they were dipped in blood, and at other times so variegated that they present all the colors of the rainbow; and, as if to add to this chromatic[1] picture by introducing into it the symmetry of architectural beauty, they form their columns, arches,

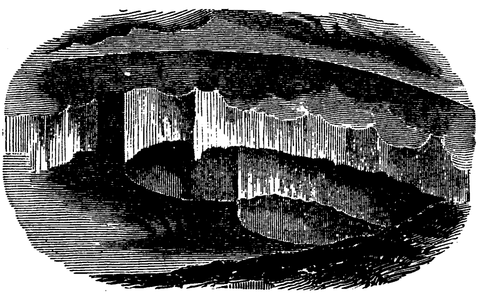

Fig. 25.

cones, pyramids, and spires, whereby they enhance their inimitable grandeur, and enchant the eye with their splendor.

7. These lights may be regarded as being within the limits of the atmosphere, and in all probability do not extend many miles above the surface of the earth. If they were outside of the atmosphere and the earth's influences, they, like the stars, would appear to have an hourly motion westward; but their altitude and distances do not undergo these hourly changes to which celestial objects are subject. Neither have they any motion in reference to the zenith and horizon, as would result from the daily motion of the earth.

[1] Chromatic—pertaining to color.

QUESTIONS.—Are they frequently variegated? What architectural forms do they sometimes assume? 7. Are these lights within the limits of the atmosphere? How can this be proved?

8. From these facts, together with others which may be adduced, it is evident that they are associated with the atmosphere, or some matter suspended in it, which partakes of the diurnal motion of the earth. In further confirmation of what has been said, we may also refer to the manifest relation which these phenomena sustain to the magnetic poles of the earth. They are influenced by them; and it is highly probable that it is terrestrial magnetism and atmospheric electricity that actually produce them.

9. When the aurora commences to form, it generally rises slowly at first, in the shape of an arch, with its middle not in the direction of the true north, but in that of the magnetic needle at the place of observation. And if its lines of light extend themselves, they cross the heavens at right angles to the plane that would be formed by a perpendicular line rising from the horizon to the vertex of the arch, and the line of the magnetic needle as it points towards the magnetic pole from the position of the observer.

10. If they pass the zenith, as they do sometimes, they converge to the same plane, and not to the true magnetic meridian; and during very brilliant displays of the auroral light the magnetic needle itself manifests great uneasiness, and is unwilling to settle till they in a measure subside.

11. But the magnetic influence is not alone in producing these wonderful exhibitions of natural grandeur. As electricity is always in company with magnetism, and as it is known to be a powerful agent in producing some very mysterious results, it is highly probable that

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QUESTIONS.—8. Is there any relation between these lights and the magnetic poles of the earth? Through what agency is it probable that these lights are produced? 9. Where is the middle point of the auroral arch? When the auroral rays of light extend themselves, where do they cross in the heavens? 10. To what place do they converge when they cross? What is said about the magnetic needle during brilliant displays? 11. Does electricity always accompany magnetism, and magnetism electricity?

it is the more active and efficient of the two in creating these auroral displays. Though naturally invisible, it manifests itself under certain conditions by its qualities of heat and of light. If it is passed into a partial conductor, both heat and light are evolved; and if it is passed into rarefied air, the latter appears.

12. Now, as the atmosphere is rarer in proportion to its altitude, and as its strata[1] are in different conditions, and its particles always in motion, and the electricity unequally distributed through it, the reflection of its light might be reasonably expected to be what is witnessed in the various exhibitions of the Northern Lights.

SECTION XLIV.

Shooting Stars.

1. SHOOTING stars have been witnessed, probably, in all ages of the world, and in every inhabited country. They were noticed and considered by astronomers centuries before the Christian era; and ever since its beginning they have occupied the attention of those who were anxious to know more of their character. Though an occasional one might be seen some place in the heavens almost any clear night, yet their recurrence when they appeared in great numbers was generally known.

2. For thousands of years the dates of their more brilliant displays have been recorded, and since they have been carefully compared, they appear to be confined to certain months of the year. Since the year

[1] Strata—layers of atmosphere.

QUESTIONS.—Which is supposed to exert the greatest influence in producing these lights? 12. Is the electricity equally distributed in the atmosphere?

SEC. XLIV.—1. Are shooting stars of recent origin? Did they occupy the attention of the ancient astronomers? Did they discover their periodic return? 2. Were their dates recorded?

seven hundred and sixty-three, anno Domini, and probably before that date, more than three-fourths that took place occurred in the month of August, whilst nearly the whole of the other fourth occurred in the month of November.

3. At intervals of about thirty-three years they gave their grandest exhibitions,—which periodical return may yet lead to a more definite knowledge than we now possess of these somewhat mysterious phenomena. One of the most brilliant displays of shooting stars was on the night of the thirteenth of November, one thousand eight hundred and thirty-three. It commenced about nine o'clock in the evening, became strikingly brilliant at eleven, increased in splendor till four, and continued, with slight variations, till morning.

4. During this period, nearly the whole of the visible heavens was covered with stars, differing in size and brilliancy, shooting generally in an oblique direction towards the earth. Some of them were so small that they were scarcely visible, except by the line of light that they left behind them as they passed through the air. Others were large, luminous bodies, irregular in form, and almost stationary till they disappeared; whilst a few of them were thousands of feet in diameter, nearly globular in form, and appeared to light up that region of the heavens in which they were, as if composed of the most brilliant flame.

5. Nearly all of these large bodies that traversed the air would leave a stream of light, more or less bright, which in some instances would remain visible for more than an hour. These streams of light no doubt emanated from particles that were detached by the atmosphere as they passed through it; and they frequently

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QUESTIONS.—In what month do most of them occur? 3. What is the length of the periods at which they occur? When was a great display witnessed? 4. Did the meteors vary in size? Were they all regular in form? Were some of them very large? Were any of them very brilliant? 5. Did they leave streams of light behind them as they passed through the air?

manifested different prismatic[1] colors, the red, yellow, blue, and green predominating. Hissing and crackling sounds issued from some of them; and others, of the larger class, after traversing the heavens for a considerable distance, would explode with a report loud as that of a cannon.

6. These meteors appeared to emanate from one particular point in the heavens, which was located in the constellation Leo; and though many of them shot in an easterly and other directions, yet the great majority of them described their lines towards the west. This point was stationary, and could not have been within the limits of the atmosphere, as it would then have had a corresponding easterly motion with the earth on its axis, but it had an apparent westward motion with the constellation in which it appeared to be.

7. This is universally the case in all those great exhibitions of meteoric showers that occur: they emanate more particularly from some specific point in the heavens which is stationary, and are never very far distant from where it was on previous occasions. From this fact, together with others to which we will hereafter refer, it may be inferred that they have their origin outside of the atmosphere, and though they may come in contact with it, it only ignites them, or adds to their brilliancy, as they tend towards the earth.

8. The height at which many of them manifested themselves is not definitely known, neither are the elements of which they are composed; but, from their

[1] Prismatic colors—colors that are produced by a prism when it decomposes light.

QUESTIONS.—Were these streams sometimes of different colors? Did any make any noise? Did any of them explode? 6. From what point in the heavens did they appear to issue? In what direction did they shoot? Was the point from which they issued in the atmosphere, or outside of it? What evidence that it was outside? 7. Is there any similarity in all of these periodic displays? Do the meteors enter the atmosphere? What effect has it on them? 8. Have we a knowledge of what they are composed of?

diversity of color, it is probable that they are constituted of matter that differs slightly in its nature. As meteors[1] and meteorites in all probability have one common origin, we will refer to them again in the sequel of the next subject.

SECTION XLV.

Meteorites, Aerolites, and Fireballs.

1. METEORITES, aerolites, and fireballs, though differing more or less in their manifestations, may be considered as parts of the previous subject. Notwithstanding the fireballs frequently appear here and there over the earth, they generally accompany the periodic exhibitions of shooting stars which we have in a measure described. (See Fig. 26.) Some of them are apparently as large as the moon, and move rapidly in an oblique direction towards the earth, generally producing some noise in their course, till they finally burst asunder, casting their fragments of stony matter often in every direction.

2. These bodies are generally less or more globular in form, and vary somewhat in their color and brilliancy as they traverse the atmosphere, leaving in their wake a stream of luminous matter, which gradually diminishes till no trace of it is left. Though these phenomena characterize some of them, others totally disappear when they explode, as if they were composed of gas or some rare ethereal substance analogous to it.

3. Often, when aerolites fall to the ground, there are no manifestations of light accompanying them whatever.

[1] Meteor—shooting star.

QUESTIONS.—1. Do fireballs generally accompany the shooting stars when they appear in great numbers? How large do some of them appear to be? Do they generally burst as they approach the earth? 2. When they burst, do they always disappear? 3. Do aerolites ever fall to the ground without manifesting any light?

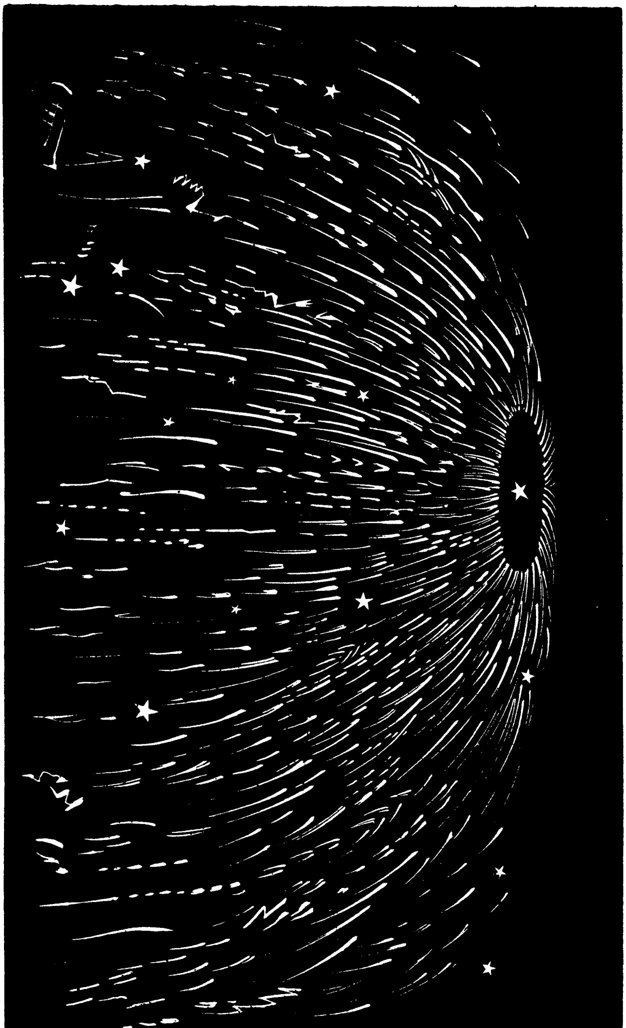

Fig. 26.

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They visit us, sometimes, unheralded by any celestial phenomena, except the hissing noise that they make as they fly towards the earth. Again, they are betokened by small, dark clouds, in which are a number of successive reports like that of cannon, intermingled with that of the drum and the musket. At another time the cloud appears like an ashy mist, projected on the blue, clear sky, from whence issues a low, murmuring noise, accompanied with sounds more distinct, shortly after which a shower of meteoric stones descends upon the earth.

4. These fragments are generally very hot when they reach it, and are incrusted with a dark substance, as if their surfaces were blackened by burning. They are of different forms and different weights, varying from a few ounces to hundreds of pounds. The whole number of simple elements that have been discovered in them is eighteen; but this number is not found in any one of them. Most of them are composed principally of malleable iron and nickel, having intermingled sometimes with them traces of sulphur, copper, and carbon.

5. These elements are not combined in definite proportions, but partake more of a mechanical mixture, forming masses which are not analogous to any that are known to belong naturally to the earth. The character of the iron and nickel that they contain clearly manifests that they are not of terrestrial origin, as these metals exist in the earth as oxides, and not in their metallic form, as they do in the aerolite.

6. Hence, if they have not their origin in the earth

QUESTIONS.—What kind of noise do they generally make? At other times what kind? 4. Are aerolites generally hot when they reach the earth? What is their color? Do they vary in weight? How many simple elements have been discovered in them? Which of the elements are most abundant in them? 5. How are these elements combined? What kind of iron do they contain? What is the inference in relation to their origin? 6, 7. Are they planetary in their nature and character?

or the atmosphere, the inquiry naturally arises, From whence do they come? Are they from the moon, or are they composed of the tails of comets, some portions of which may be detached in their perihelion passage around the sun and afterwards condensed? Are they constituted of nebulous matter unequally condensed, which is supposed by some astronomers to be diffused irregularly throughout all space? or are they planetary in their nature and general motion?

7. These are questions which have presented themselves during the history of these phenomena; and all of them may be regarded as having been satisfactorily answered in the negative, except the latter, which appears to be, what is claimed for it, an explanation of the origin of all the objects to which we have referred in the present and previous section. Though they manifest great diversity in their nature and character, —some small, others large, some luminous, others non-luminous, some apparently gaseous, others solid, some noiseless, others producing heavy reports,—still some of these manifestations may result from the change of circumstances which they experience when they arrive in the region of the earth.

8. Assuming now, what is practically demonstrated by the fall of the aerolite, that there are small bodies within the limits of the planetary system that are not visible to us, may it not be that they revolve around the sun, or the moon, or the earth, as these bodies revolve around each other? A small body, or even a ring or a zone composed of atoms, is as much the subject of the centrifugal and centripetal forces as one of the planets; and were their orbits very eccentric, so

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QUESTIONS.—May a change in their condition account for some of these phenomena? Is it probable that they revolve around the sun or the earth or the moon? 8. Would a ring of atoms be as much under the influence of the centripetal and centrifugal forces as a planet? Might some point in the orbit of the earth be near to such a ring?

that they would cross or come near the pathway of the earth, unusual phenomena might readily occur.

9. If small bodies, or the richer portions of a revolving ring composed of very small bodies unequal in size, should cross or come near the ecliptic as the earth arrives at that point, its greater attractive force would naturally collect some of them to itself. Entering on new conditions as they leave their orbits, and coming in contact with the atmosphere, the compression of which has a tendency to expand and ignite them, all that we witness in the shooting stars, the meteorites and fireballs should not be considered as beyond these causes to produce.

10. Oxygen, which is an element of the atmosphere, is the supporter of combustion, and by its action on rare and denser bodies which suddenly enter into it they are rendered, no doubt, the mysterious and wonderful objects that sometimes are seen to fall on and in the direction of the earth.

SECTION XLVI.

Zodiacal Light.

1. THE zodiacal light was discovered between two and three centuries ago, and was particularly described some time afterwards by Cassini, who gave it the name by which it is known, because of its being within the limits of the zodiac. When viewed from our latitude, it has the appearance of a faint light which is conical in form and is inclined a few degrees towards the horizon.

QUESTIONS.—9. If the earth and a zone of small bodies should come near together, what would result? 10. What element in the air is the supporter of combustion?

SEC. XLVI.—1. When was the zodiacal light discovered? Who gave a particular description of it? What is its appearance as seen from our latitude?

2. In the torrid zone it appears more brilliant and better defined, owing to greater facilities that are afforded in point of location and clearness of the atmosphere for observing it. The twilight obscures it when the sun is less than eighteen degrees below the horizon; and, as it follows the pathway of the earth, it is visible at the equator during most of the time, while in either of the temperate zones it can be seen only at certain seasons of the year.

3. The most favorable time for observing it outside of the torrid zone is in the months of April and May, October and November. During the first two months it becomes visible in our climate after the twilight, in the evening, with its base resting on that part of the horizon where the sun at this time sets. In the months of October and November it may be seen in the eastern sky before the dawn, extending upwards in an oblique direction, as before; and throughout the month of December it manifests itself before sunrise and after sunset.

4. It appears in form like a pyramid or cone, owing to the fact that we see only a portion of its edge, a part of it always being concealed. (See Fig. 27.) Its real shape is probably that of a double convex lens, the circumference of which is supposed to be in the plane of the equator of the body around which it revolves. It appears to change both east and west in its distance from the sun, and also in its length, and in the width of its base.

5. It varies from forty to one hundred degrees in its height, and from eight to forty on the plane of the horizon at its base. But these are not the only changes

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QUESTIONS.—2. How does it appear when seen from the torrid zone? For what reason? How far below the horizon must the sun be before it is visible? From what place is it almost constantly visible? 3. When is the most favorable time for observing it from the temperate zones? Where may it be seen, and what is its position? 4. What is its apparent shape? What is its real shape? 5. Does it appear to vary in its height and width?

that this object is known to undergo. It changes suddenly in the intensity of its light. These luminous variations are very obvious in tropical climates, especially on the Andes, in South America. Whether they

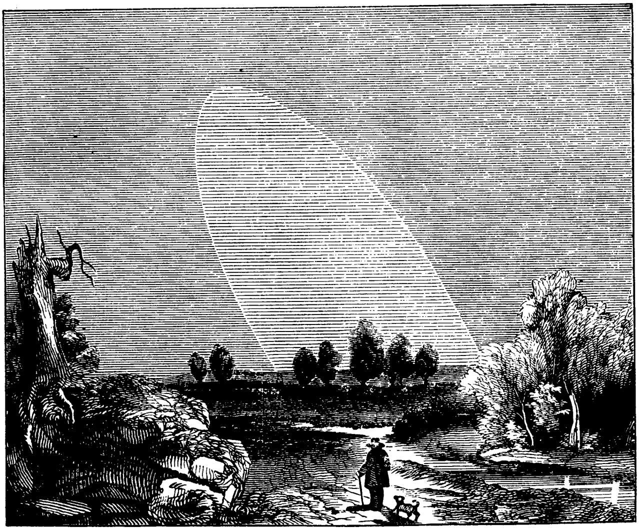

Fig. 27.

are only pulsations produced by the motion and inequality of density of the atmosphere, like what is witnessed in the tails of comets, or are coruscations arising from physical causes within itself, no one can tell.

6. Neither is it known whether it is self-luminous or shines by reflected light; but the latter is most probable, as it is only under certain conditions and in peculiar relations to the sun and the observer that it is visible. Uncertainty also exists in relation to the place that it

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QUESTIONS.—Does it ever change in the intensity of its light? Where are they very obvious? What produces them? 6. Is it self-iuminous? What is its place in the planetary system?

occupies in the planetary system, and whether it is in motion or at rest.

7. Some astronomers have supposed it to be uncondensed, nebulous matter in the shape of a ring, which revolves in the vicinity of the earth's orbit around the sun, in accordance with the laws that control the planets in making their annual periods. Others have imagined it to be a ring or zone of the same composition, which belongs to the earth and revolves around it, like the rings of Saturn, as she rotates on her axis.

8. These theories appear to harmonize better with the character and motions of the various bodies that are known to belong to the solar system than any other that has been presented, as either of them would answer the conditions and account for the phenomena manifested by the object now under consideration. May it not be that there is revolving freely in space, between the orbits of Venus and Mars, an annulus of unsolidified matter, which is capable of reflecting dimly the light of the sun, and which is the material cause of the zodiacal light?

SECTION XLVII.

Light.

1. THE sun is the great source of natural light. He emits it constantly in every direction, and in such immeasurable quantities that the most intense artificial light is comparative darkness when contrasted with it. It is the universal medium through which we obtain by our organs of sight a knowledge not only of the existence of objects with which we are not in direct contact, but also of some of their properties and qualities.

QUESTIONS.—Does it revolve? 7. What suppositions by astronomers concerning its real shape and motion, and laws that control it? 8. Would either of these theories account for its phenomena?

SEC. XLVII.—1. What is the great source of natural light? Through what medium are we enabled to see objects?

2. They disclose themselves to us, if they are opaque, by reflecting the light with which they are surrounded in the shape of their own images on the retina of the eye, the seat of vision, from which photographic likenesses their forms and character are revealed to the mind. In this manner we discern luminous bodies that are at a very great distance, as well as non-luminous ones that are comparatively near to us; and though we are familiar with the use of this medium through which we see them, under various circumstances, yet it is not a misnomer when we call it a mysterious agent.

3. Notwithstanding its source is the sun, so meagre is the knowledge that we have of its origin and manner of its motion that it scarcely transcends the limits of theory and conjecture. Some philosophers have imagined it to consist of exceedingly small particles of matter which are constantly being thrown off by the sun to the enormous distance at which he is visible. Others have supposed it to originate from a vibratory motion of the sun's photosphere which produces an undulatory motion in an ethereal fluid infinitely rarer than air, which is regarded as filling all space, whereby we experience the sensation of light.

4. In support of the former theory, an analogical argument is adduced from the method by which we obtain knowledge of an odor. As it is recognized by the material particles which are sent forth by the body that produces them to the organs of smelling, in like manner visible objects are supposed to send forth particles of light which enter the eye, whereby vision is produced and perception of things at a distance obtained. And in confirmation of the latter theory an analogy is drawn between the eye and the ear. As

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QUESTIONS.—2. How do opaque bodies reveal themselves to us through the medium of light? Where are their images formed? Is light perfectly understood? 3. Have we a perfect knowledge of its origin and motion? What are the conjectures of some astronomers? What of others? 4. What analogy is adduced in support of the former theory? What in support of the latter?

the undulations of the atmosphere produced by a sounding body pass through the air to the ear, so are the vibrations or undulations of the ethereal medium supposed to pass through the space intervening between the visible objects and the eye that perceives it.

5. This analogy, though insufficient in itself to satisfy the inquiring mind in relation to the truth of the principle on which it is founded, still has its weight in the scale of moral evidence in favor of the theory in question, as no phenomenon has yet been discovered decidedly at variance with what it contains. Nearly all of the phenomena of light, instead of being at variance with its principles, flow from them with remarkable ease, and in many instances consequences deduced from this theory have been found to be accurately true when brought to the test of experiment.

6. But notwithstanding nearly all of its conditions are at least apparently fulfilled, as discovered by analysis and observation, still it must forever remain what it is, a theory, unless nature shall disclose to us facts in the case which are now beyond the present acquisitions of science. This wave or undulatory theory, as it is sometimes called, is the one that is now most generally received by scholars of the highest scientific attainments; and, that it may be better understood, we shall notice more particularly what it assumes, and what is claimed as flowing therefrom.

7. It supposes that there exists throughout all space, and in all bodies, an exceedingly attenuated and highly elastic fluid, called ether. It also supposes that the particles of a luminous body are in a state of rapid vibration, and that these vibrations are communicated to the ether. And as a consequence of these vibrations,

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QUESTIONS.—5. Which theory should have the precedence? Do the phenomena of light correspond with the latter theory? Do they appear to flow naturally therefrom? 6. Is the wave theory generally received by astronomers as the most scientific? 7. What does it assume? What next? What as a consequence is supposed to flow therefrom?

waves of the ether are propagated from the luminous body to the eye, which enter it, and, acting on the nerves that constitute the seat of vision, produce the sensation of light.

8. The motion and form of these waves may be familiarly illustrated by dropping a pebble or stone into a pool of water which is perfectly at rest. Circular waves or undulations move off in every direction from the point at which the stone entered the water, and continue to flow outwards until they are lost on the shore, or gradually disappear in the distance by counteracting influences which have a tendency to bring them to rest. In these waves the water does not actually travel; it is only the swell that travels: hence the rapidity with which they move from one place to another.

9. This is the method by which we obtain a knowledge of sound. The vibratory motion of the sonorous body, acting on the atmosphere, creates undulations in it, which go out in every direction, carrying with them the notes or sounds that it produces. These waves, coming in contact with the organs of hearing, give rise to the sensation of sound; and its tone is attributed to the frequency of the aerial vibrations, and its loudness to their amplitude.

10. In like manner is light supposed to be propagated from luminous bodies. It comes by a quick succession of ethereal waves that intervene between us and the body that gives them their motion, and, in consequence of the millions of them that impinge upon the eye in a moment of time, its regularity and uniformity are constantly maintained. So rapidly do they follow each other that the eye is not capable of observing the time that

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QUESTIONS.—8. How are the motion and form of the ethereal waves or undulations illustrated? What travels in these waves,—the water, or the swell? 9. How is sound communicated to the ear? What is the tone attributed to? What the loudness? 10. Is light supposed to travel in a similar manner? What is supposed to give it regularity and uniformity? Are the ethereal waves very rapid in their movements?

elapses between them, neither of discerning any periodical dimness of impression in the object that it has attempted to behold.

11. The impression of an object on the eye, after it is removed, lasts about the one-seventh part of a second: consequently, if an object was turned out of and into our presence say every tenth of a second, it would be constantly visible, as if no motion had been given it. Hence, if a few ethereal undulations, comparatively, should occur every second of time, the light of bodies from which it emanates would not be periodical; but, as millions of them reach us in that length of time, the light that we daily enjoy can never fail to be steady, and will always appear as we see it.

12. Though the sunlight does not appear at all times uniformly brilliant, yet its changes cannot be attributed to any variation in the mode by which it is propagated. The atmosphere through which it must pass before it reaches the earth often turns it out of its course, and the clouds and mists frequently obscure it by intercepting its rays.

SECTION XLVIII.

Colors of Light.

1. LIGHT, according to the best authorities, is composed of three different colors,—red, yellow, and blue; and all other colors are considered as being formed by a union of two or all of them in different proportions. The natural appearance of light is white; but if a ray

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QUESTIONS.—11. What length of time does the impression of an object last on the seat of vision after it is removed? If the ethereal waves were more than seven per second, would the light be steady and uniform? Are there millions of them per second impinging upon the eye? 12. Does the sunlight appear at all times uniformly brilliant? Is it dimmed and brightened by the mode in which it is propagated? What changes it?

SEC. XLVIII.—1. How many primary colors are in light? What is the natural color of light?

of it is permitted to pass through a triangular piece of glass, called a prism, seven different colors may be seen, which correspond to the colors of the rainbow. (See Fig. 28.)

2. This white ray is both refracted and decomposed,

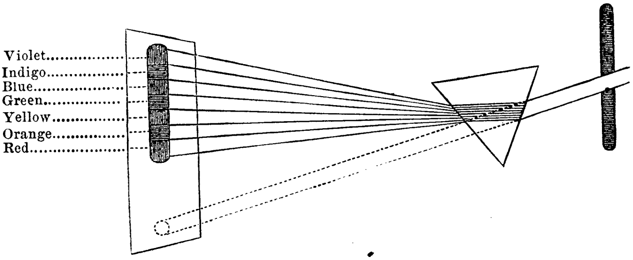

Fig. 28.

and each color leaves the prism, diverging not only from the original ray of which they are elements, but also from each other, as may be seen by observing the spectrum[1] which they form. This spectrum exhibits these colors in the order of their susceptibility of refraction, the red being refracted least, and the violet most. Judging from its appearance, it might be inferred that there were actually seven primary or distinct colors in the composition of light; but, by a most critical investigation and analysis, it has been determined otherwise. The orange, green, indigo, and violet are discovered to result from a blending of the primary colors in different degrees of intensity as they form the spectrum.

3. If a ray of red light is permitted to fall obliquely

[1] Spectrum—different colors that proceed from a prism, as seen on a plane surface.

QUESTIONS.—How is light decomposed? 2. What two effects has the prism on light? How does the spectrum exhibit these colors? Which color is refracted most? Which least? How many colors does the spectrum exhibit? How many are simple colors? How many are compounds? 3. What effect has the prism on a red ray of light that enters it obliquely?

on a prism placed in a small, circular hole in a wall, it will be refracted by it, and pass out of it not as it entered it, in a round form, but it will extend the whole length of the seven-colored spectrum. This ray will have a greater intensity at some certain point on the spectrum, and will grow gradually dimmer in either direction, till it fails to be perceptible. The results are the same in relation to the yellow and blue rays, if they are dealt with in the same way: each one covers the whole spectrum which would be formed by the seven colors when they reach it, though differing, like the red color, at every point in its intensity.

4. From these and similar experiments it has been ascertained that light is a compound, the elements of which alone give beauty of color to the various objects with which we are surrounded. The natural color of an object when exposed to sunlight depends upon the peculiar nature and arrangement of the particles of which it is composed, and not upon any inherent quality in itself.

5. If a body appears red, or blue, or yellow, it is not because it is naturally so, but because it is so constituted as to reflect the red, or blue, or yellow elements of the light, and dispose of the remaining ones either by absorption or transmission. When bodies appear white, they reflect the light just as they receive it, because they have no preference for reflecting one of its elements more than another. But if they appear black, their molecular arrangement is such as to absorb all of the light without reflecting any of its colors.

6. In relation to bodies that are neither white, nor black, nor red, nor yellow, nor blue, but exhibit some

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QUESTIONS.—Has this ray a greater intensity on the spectrum at one point than another? Is it so with the yellow and blue rays? Does each ray cover the whole spectrum? 4. From the above facts, would we infer that light is a compound? On what does the color of an object depend when exposed to sunlight? 5. Why does a body appear of any particular color? When a body appears white, what effect has it upon light? When black, what effect? 6. Does it differ in its molecular arrangement when it reflects a variety of colors?

other color, or are variegated, their nature is such as to absorb or transmit some of the colors, or a less or greater portion of them, while other colors, or portions of them, are reflected to the eye of the observer.

7. Besides these various conditions in nature, whereby a great variety of colors are constantly manifested by natural objects and objects treated artificially, there are other colors, also, that are produced by contrast or by bringing one in juxtaposition to the other. Every color placed beside another color is changed, and appears differently from what it does when seen alone. They are either rendered dimmer or brighter, or some of them are changed apparently from one color to another.

8. If a white color is placed close to a red one, and observed at a distance, the white will appear bluish green; or if a white color is placed near a blue, the white will apparently change to orange. White contrasted in the same way with yellow changes to indigo; with green, to reddish violet; with blue, to orange red; with indigo, to orange yellow; and with violet, to yellowish green.

9. Colors that are produced in this way—that is, by bringing one near to another—are called complementary; and we are less or more influenced by them every day, in the color of the clothing that we wear, the enchanting scenery of the landscape, and the variegated hues that everywhere adorn the world with beauty.

Questions.—7. Are colors produced in any other way than by the nature of the objects that reflect them? In what other way? Does one color appear to change another by bringing them near together? 8. When white is brought near to red and viewed at a distance, what is the effect? When white is placed near blue, what then? White near yellow? White near green? White with blue? White near indigo? White near violet? 9. What are these new colors called? Are we influenced by them every day?

SECTION XLIX.

Refracting Telescope.

1. It is a well-known fact that some substances will transmit light, or allow it to pass through them. The rays of the sun penetrate through the whole depth of the atmosphere in coming to the earth; and if they enter it obliquely they will constantly change their direction a little as they approach us. So also is it when they come in contact with glass; they are changed in direction as they travel through it, by the refractive influence which it has upon them.

2. When parallel rays of light enter a piece of glass that is concave on both sides, they are dispersed, or rendered divergent; but if they enter a piece of glass that is convex on both sides, they are collected or caused to converge to a point, called a focus. The latter kind of glass in form is generally used in the construction of the refracting telescope, and is called a double convex lens.

3. For telescopes which are employed in viewing heavenly bodies, only two lenses are used; but those used for observing terrestrial objects generally have four. This latter number is necessary only when we wish to see the objects not inverted; but in the case of heavenly objects the observer is indifferent as to the relative place of any of their parts, if their general appearance remains unchanged: hence the use of only two.

4. The telescope with only two lenses, one eye-glass and one object-glass, is the most simple in form, and is generally used for astronomical purposes. It is made

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Questions.—1. What substances are transparent? Do transparent substances change the direction of the rays of light, if they meet them obliquely? What kind of substances change the direction of the rays of light most? 2. What effect has a double concave lens on parallel rays? What effect has a double convex? Which kind is used in the refracting telescope? 3. How many are used in some? How many in others? 4. Which is the most simple? Which is used for astronomical purposes?

by placing two double convex lenses in a tube, at a distance from each other equal to their two focal distances, so that if an observation is taken of a star, or planet, or any other heavenly body, its image is formed at the focal point of either glass. This being the case, the image is then magnified by the eye-glass, and this in effect is brought near the eye.

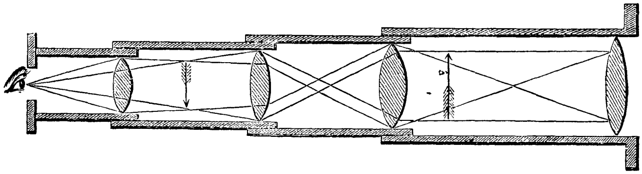

Fig. 29.

5. The telescope with four glasses is called sometimes the double telescope; and the three lenses nearest the eye are called eye-glasses, and the one furthest from the eye is called the object-glass. The eye-glasses are placed at equal distances from each other, and these distances, respectively, are equal to double the focal length of each glass: so that when the image of an object is formed in the telescope by the object-lens, it is transmitted through the other three lenses to the eye.

6. The two middle lenses placed between the object- and eye-glasses in the refracting telescope are employed to change the direction of the rays of light as they travel to the eye, so that the observer may see the images of objects erect and not inverted. This kind of optical instrument may be properly named a terrestrial telescope, as it is generally used for viewing objects that are on the earth. (See Fig. 29.)

QUESTIONS.—Where do we place the glasses? At what distance apart? Where is the image formed? What magnifies it? 5. What are four-glassed telescopes called? How are the glasses named? 6. What is the use of the two middle glasses? What might this kind of instrument be properly called?

SECTION L.

Reflecting Telescope.

1. THE plane mirror which is in general use is employed for the purpose of reflecting the image or likeness of the object that is placed before it. If parallel rays of light fall perpendicularly upon it, they are reflected back in lines which are perpendicular also to its surface.

2. Mirrors with convex surfaces disperse or cause parallel rays of light that fall upon them to diverge as they are reflected; while concave mirrors cause parallel rays of light that fall upon them to collect or converge to a point as they are reflected from their surfaces. The action of each kind of mirror is uniform in its effects on light, it matters not of what it may be composed, providing it is well adapted to the purpose for which it is designed, and properly constructed.

3. For the reflecting telescope two concave mirrors are frequently employed; and they are generally composed of highly-polished metal. These reflectors, a small and large one, are placed in a tube some distance apart, which is open at the end most distant from the eye. The large reflector, or speculum, has a hole in its centre, and is placed nearer the observer than the small one, with its convex surface in the direction of the large end of the tube.

4. The small reflector is placed near the open end of the tube, with its concave surface facing the concave surface of the large one. In the small end of the tube a plano-convex lens is placed, which magnifies the image

QUESTIONS.—1. What is a plane mirror used for? How are parallel rays of light reflected back? 2. What effect have convex mirrors on parallel rays of light that fall upon them? What have concave mirrors? 3. How many mirrors are used for reflecting telescopes? In what are they placed? What is the hole in the large mirror for? Of what are the mirrors generally composed? 4. How are these two placed in the tube? Where is the lens placed?

which is formed in the telescope by the small reflector, by increasing the visual angle. (See Fig. 30.)

5. When the observer wishes to use this instrument, the larger end is directed towards the object to be examined, and the rays of light coming from it pass

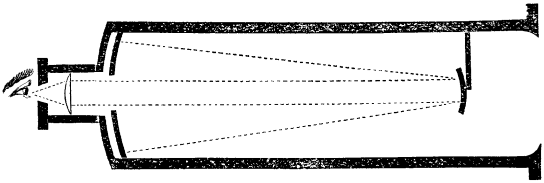

Fig. 30.

down the tube and fall first on the large reflector. From thence they are reflected upon the small mirror, which reflects them back again, and forms an image of the object between itself and the lens that is in the smaller end. As the rays of light that bear the image pass through the lens to the eye, it is magnified by the lens, and makes the vision also more distinct, as the distance in effect to the object is shortened.

6. Telescopes in general have many different forms, notwithstanding they are all constructed on one principle, which is that of the human eye; and through their discovery new themes and subjects for the contemplation of the astronomer have been opened up, which beckon him on to the investigation of worlds and schemes and systems of heavenly bodies which were hitherto unknown.

7. By their use the moon has revealed its true nature and character. Jupiter has been found to be a con-

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QUESTIONS.—For what purpose is it used? 5. How is this instrument used? What is the use of the large reflector? What the small? What the lens? 6. Are telescopes of different forms besides the two described? On what principle are they constructed? Have they been of great use in astronomical discovery? 7. Name some of the objects that were discovered by the telescope.

trolling centre around which circulate a number of satellites. Saturn has portrayed to us a series of rings and moons. Uranus and Neptune, with their subordinate worlds, have come into view; and more than ninety asteroids, which belong to the solar system, have asserted its descrying power. So also have the starry heavens, and the nebulæ, and the Milky Way, whose enchanting grandeur, when viewed with aided vision, baffles all description, borne testimony to its wonderful revelations.

SECTION LI.

Comets—Their Early History.

1. THE early history of comets, like that of the grouping of the stars and discovery of some of the planets, is involved in much obscurity; but that they were known to exist hundreds of years before the Christian era, is fully attested. In the literary records of the Greeks, Romans, Chinese, and other ancient nations, they are mentioned with other heavenly bodies; and the constellations through which some of them passed were at least circumstantially noticed.

2. At the extreme end of the thread of their history, and for thousands of years afterwards, whatever information was obtained concerning them appears to have been that which could be known only by the naked eye, and not that which would result from a studied analysis or mathematical calculation.

3. Their relation to the solar system was unknown. None of the elements of their orbits were determined. The causes of their near approach to us were un-

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QUESTIONS.—May others still be discovered by their use?

SEC. LI.—1. Is it known when comets were first observed? Were they known to exist centuries before the Christian era? By what nations? 2. Early in their history, what was known concerning them? 3. Was it known that they belonged to the solar system?

accounted for; and their mysterious forms sometimes filled the world with dread, and sometimes with reverence. Whence they came, or whither they went, were problems unsolved; and whether they belonged to the material or the spiritual world was often the subject of serious conjecture.

4. But this condition of things was not always to exist. Intellect has been gradually unveiled, and the lawless wanderer has been discovered to be a loyal subject. The apparent fugitive has been found to travel in the pathway assigned it, thereby fulfilling the end of its existence in the economy of nature.

5. The erratic comet, so long appalling in its advent, and nearly as much so in its departure, is no longer the disloyal subject, abandoned to some unknown and mysterious fatality, but, like the kind visit of a friend, it is known to return from the invisible depths of space, to greet us with its presence. (See Fig. 31.)

6. Though it is not positively known that they all return through the attractive influence of the sun, yet, from what we know of many of them, we may infer that nearly all are members of the solar system. If it could be accurately determined to which of the four great conic curves, sections of their orbits nearest to the sun belong, at once the problem would be solved.

7. If they travel in circles or elliptical curves, their return is certain, no matter how long they may be absent or to what distance they may go. But if they move in curves possessing other properties, they will depart from our system forever, unless arrested by some

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QUESTIONS.—Were any of the elements of their orbits determined? Was it known from whence they came, or whither they went? Had the ancients a knowledge of what they were? 4. Have astronomers obtained a more definite knowledge of them? 5. Have they been found to be subjects of natural laws? What two forces control them? 6. Do they all revolve around the sun in certain periods? If it was known in what kind of curves all of them travelled, what could be determined? 7. If they travel in circles or elliptical curves, is their return certain? If they travel in curves with other properties, what then?

other cosmical body within whose sphere of attraction they may happen to enter.

8. Though these curves necessarily deviate from a straight line, yet they are as immeasurable as space itself; and, were a heavenly body to enter on one of them, eternity alone could tell the history of its journey.

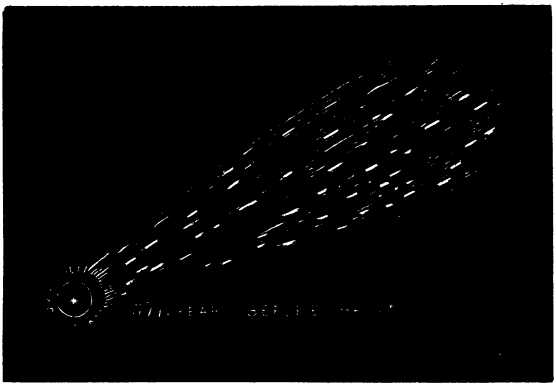

Fig. 31.

This may be the case with the orbits of a few of the comets: still, the orbits of the great majority of them resemble a hoop that is pressed in on the opposite sides, and, consequently, lengthened.

SECTION LII.

Encke's Comet.

1. The orbit of the body which is known as Encke's comet lies inside of the orbit of Jupiter, and its length

QUESTIONS.—8. Are the latter kind of curves as immeasurable as space? What is the form of the orbits of the great majority of them?

SEC. LII.—1. Where is the orbit of Encke's comet situated?

is about double its breadth. In like manner is it with the orbits of five other comets, which do not extend beyond the outermost planet; and it may be the case with the orbits of others, which have not yet been discovered.

2. Encke's comet, to which we have just referred, was discovered by Professor Pons, in 1818; and subsequently the elements of its orbit were calculated by him whose name it bears. It revolves around the sun in about twelve hundred days, nearly in the plane of the solar system. Its general appearance is that of a mass of nebulous vapor, so transparent, even at its densest part, that small stars may be seen distinctly through it. (See Fig. 32.)

3. Nothing peculiar has been discovered to belong to this body, except that its orbit is constantly growing less, and, consequently, its yearly revolutions becoming shorter. To account for these phenomena, Professor Encke, after having exhausted all causes known to exist in the solar system, announced the theory of a resisting medium. He took for granted that there is an extremely subtle, ethereal fluid, which pervades the infinitude of space, and notwithstanding it is so refined as to be almost spiritual in its nature, yet to bodies of such extreme tenuity as comets it offers a resisting influence which may be perceptible.

4. This theory was no doubt suggested by the undulatory theory, employed to account for the phenomena of optics; and whether it is the true cause of shortening the annual periods of this comet, no one can tell; but I think it should be received with great distrust.

5. If we admit the existence of such a repelling

QUESTIONS.—What is its length to its breadth? Are the orbits of any other comets entirely within the orbit of the outermost planet? 2. When was Encke's comet discovered? What is the length of its period? What is its general appearance? 3. What is said of its orbit? How did Encke account for this? What did he take for granted? 4. What suggested this theory? Should this theory be received with distrust? 5. Why?

force, what would be the result? The centrifugal force of every body in the solar system would be weakened, and the centripetal force increased, till in the course of ages the satellites would fall upon their primaries, and

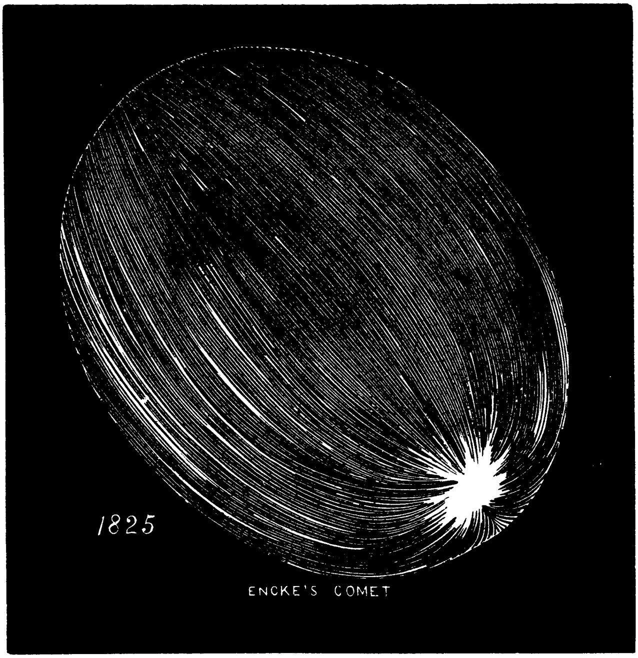

Fig. 32.

they, in turn, upon the sun, destroying forever the harmony and order of this great brotherhood of worlds with which we are surrounded.

6. Though this catastrophe might be long delayed,

QUESTIONS.—What effect would this medium have on the centrifugal force? What would, through time, result from its growing weaker? 6. Would such a result betray the wisdom of the Creator in the construction of the solar system or universe?

yet it would be inevitable; and the instability of the works of a Divine hand would betray the wisdom of the Great Author of the universe. But this is not to be anticipated; for the history of the universe shows that whatever apparent irregularities have occurred in nature, it has always maintained its harmony, which evinces that it possesses the elements of its own stability.

SECTION LIII.

Biela's Comet.

1. BIELA'S comet, like Encke's, is a telescopic object, and in some respects is similar, and in others very dissimilar, to it. It does not appear to have any nucleus,[1] or to contain any solid substance; neither to indicate that it is composed of any thing except mere vaporous matter of exceeding tenuity.

2. This was evident from its passage over groups of fixed stars without concealing them from view. Though it was fifty thousand miles in diameter, yet its transparency was such, even at its centre, that they were only slightly dimmed, and then not so much by the intervention of its matter as by the contrast of its light with theirs.

3. It is one of the six interior comets which are known not to go beyond the limit of Neptune's orbit, neither to deviate far from the general plane of the solar system. In consequence of it being so near the

[1] Nucleus—the densest part, or head.

QUESTIONS.—1. Is Biela's comet a telescopic object? Has it a nucleus? Of what does it appear to be composed? 2. From what is this inferred? What was its diameter? What caused the stars that it passed over to appear slightly dimmed? 3. In what direction does the plane of its orbit lie? Were any fears entertained that it would come in contact with the earth?

planets, fears have been entertained, at times, that it would come in collision with the earth and shatter it to pieces, or arrest it in its course. But science has dissipated these gloomy apprehensions, by informing us that it has never been nearer to the earth than fifty millions of miles, and probably never will be nearer, unless when summoned up at the end of time to attend the final conflagration.

4. This comet manifested no peculiar changes till recently, when it was observed to separate into two parts, unequal in their size and also in their brilliancy. (See Fig. 33.) This discovery was first made by Professor Herrick, in 1845; and in 1848 it was fully confirmed by other astronomers, in Europe and America.

5. It was observed to increase in width, and present points near either side more luminous than that part which lay between. In time, these luminous parts diverged, and still continued to diverge, till, when seen in 1848, they were one million of miles apart, and when last observed they were more than one million and a half miles apart.

6. Though this body had separated, even the parts did not cease to change. They alternate in size and brilliancy, at one time one preponderating, and at another time the other, thereby strengthening the opinion of some astronomers, that planets, and other bodies considered opaque, do not shine alone by borrowed light. If they do, how shall we account for the bright and dimmer shades of light which they sometimes exhibit, when change of distance from the sun cannot be the cause! And how also shall we account for the dividing asunder of the original body?

QUESTIONS.—Has science dissipated these fears? How near has it been to the earth? Is it probable that it ever will be nearer? 4. What is peculiar in this comet? Who made this discovery? By whom was it confirmed? 5. What took place at first? Did it divide into two parts? How far apart were they in 1848? 6. Did the parts themselves undergo any changes? Have bodies that are considered opaque any inherent light?

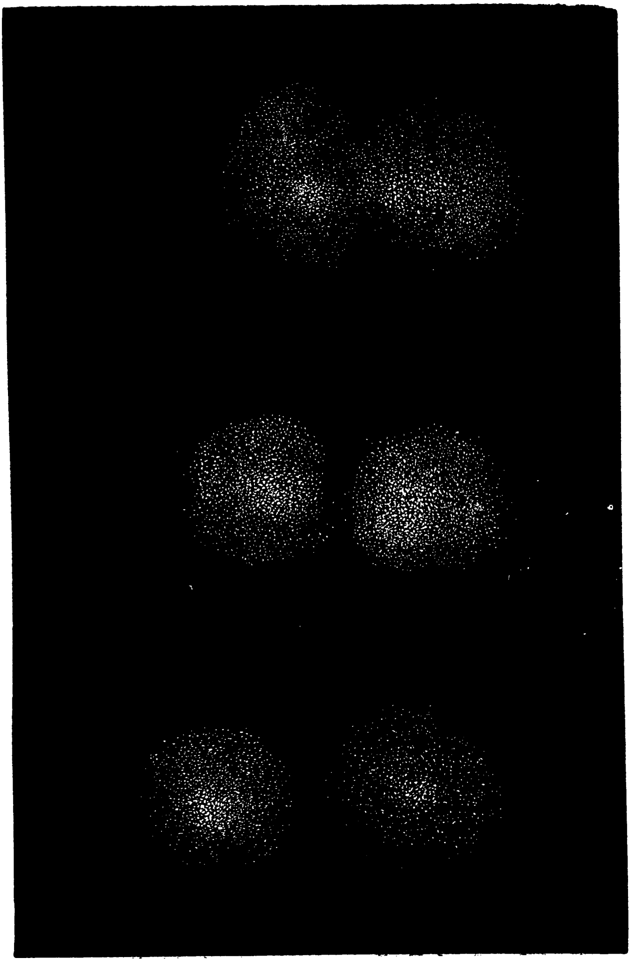

Fig. 33.

7. Many theories have been suggested by which an attempt has been made to explain this wonderful phenomenon; but we shall have occasion to refer to them, in connection probably with the true cause, in the sequel of this subject.

SECTION LIV.

Halley's Comet.

1. THE next extraordinary comet which claims our attention is Halley's, a faithful representation of which you may see by observing Fig. 34, as drawn by Professor Struve in 1835, when it was last in view. It derives its name from the name of the person who calculated the elements of its orbit and determined the periods of its revolution. They are about seventy-five years in length; and it can be traced back with certainty through nine of them, and with much probability through a period of more than two thousand years.

2. Before the Christian era it was observed, and was equal to a star of the first magnitude, accompanied with a tail of wonderful dimensions; but in later times it appears to have decreased both in size and brilliancy. At its last return it appeared to be constantly undergoing changes, and also to oscillate in its orbit, as the feathered end of an arrow is sometimes observed to do in its hasty flight.

3. At one time rays of light would dart out in front of its nucleus, and turn back on either side, like hair which is supported by the wind. At other times the nucleus would grow dim, and the tail, at the most distant end from the body, would divide through one-third

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SEC. LIV.—1. From whom did this comet take its name? What is the length of its periods? 2. When was this comet first observed? What then was its size? Had it a tail? Has it undergone any change? 3. What manifestations were made by its nucleus?

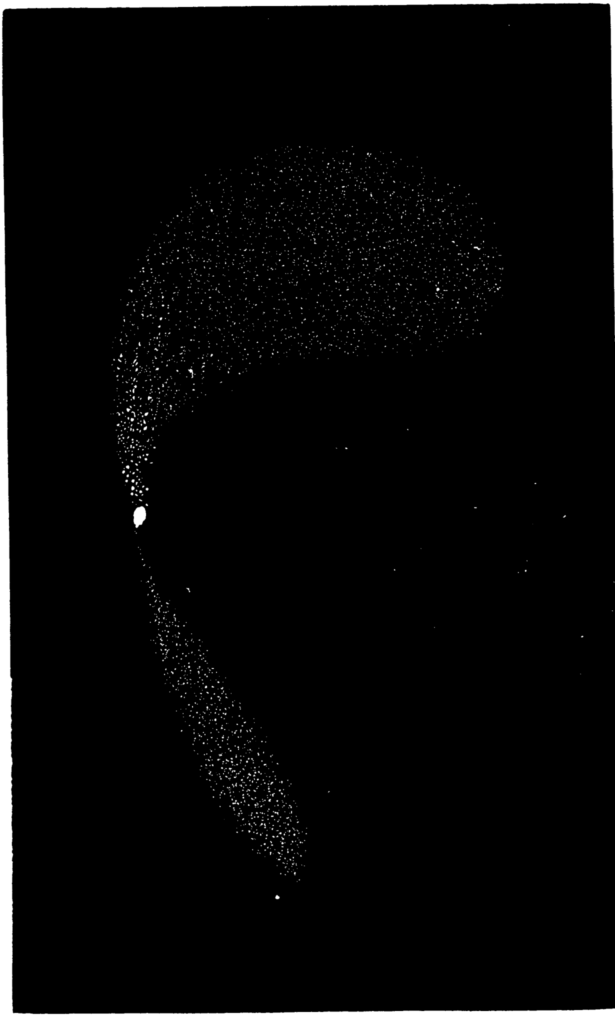

Fig. 34.

of its length into three unequal parts, each terminating in a point.

4. Again, it might be seen with a double emanation, one in the direction of the sun, and the other opposite, with its outer end turned to one side as if blown by the wind. But, wonderful as these transformations were, they were no more so than other peculiarities with which it was attended. Contrary to the general motion of the planets, it revolves from east to west, sweeping beyond the known limits of Neptune's orbit five hundred and fifty millions of miles, into the monotonous solitudes of space.

5. Such is the journey and such is the journeying of this wanderer. Solitary and alone, it speeds its endless way, satisfying the demands and obeying the will of Him who knows its end from its beginning.

SECTION LV.

The Comet of 1744.

1. THERE are two other comets which demand our attention before we proceed to discuss the general characteristics which are common to this class of heavenly bodies. The comet of 1744 is one of them. When first observed, in 1743, it was globular in form, and was entirely destitute of a luminous tail.

2. In 1744 it seemed to change in form and increase in splendor, till it rivalled the brightest star and also the brightest planet,—when it became visible in the presence of the sun, even at mid-day. As it approached the centre of our system, it lengthened nearly in the

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QUESTIONS.—What by its tail? 4. Had it ever two tails? In what direction does it revolve? How far beyond Neptune's orbit does its orbit extend? 5. Is it accompanied by any other body?

SEC. LV.—1. What was the appearance of the comet of 1744 when first observed? 2. What changes did it undergo in 1744? Was it visible at noonday?

direction of the line of its orbit, and a dark streak appeared to divide it longitudinally. From one of these parts issued brilliant spires of light, and outside of them were semicircular lines of light, alternating with dark spaces between.

3. Soon these odd phenomena disappeared, and the comet returned to its original form, but only to undergo a far more mysterious and wonderful transformation. Apparent uneasiness attended it; and shortly afterwards it exhibited in miniature the figure which it in a few days assumed.

4. Dilating in its hinder part, or the one opposite to the sun, and becoming more elongated, it separated into six distinct branches behind its head or nucleus. (See Fig. 35.) These branches were short at first, but continued to increase in length as the comet came nearer to the sun. When at the nearest point to him, they were at their greatest length, and they manifested phenomena never witnessed before or since.

5. Dark spaces intervened between these streams of light, and sparks resembling fire travelled back and forth in their most luminous parts. These sparks grew dim and bright as these branches changed in color, till after the comet began to urge its flight away from the source of heat and light.

6. Such were some of the manifestations of this anomalous body; but, as they shall recur again, we will now proceed to examine the peculiarities of another comet, which appeared in 1843.

QUESTIONS.—As it approached its perihelion, what were its changes? 3. Did the comet return to its original form? Did it remain so? 4. What form did it shortly assume? Did the branches increase in length? When were they at their greatest length? 5. What peculiar manifestations did they exhibit? Did the sparks grow dim and bright? Did the branches change in color? 6. Were these manifestations usual for comets?

Fig. 35.

SECTION LVI.

The Comet of 1843.

1. It was visible for forty days, during which time it underwent many changes in magnitude, form, and color. When first observed, its appearance to the naked eye was that of a luminous, globular body, shining with a mild but brilliant light even at noonday. Shortly afterwards a train commenced to go out from the head, possessing a paler hue; and the nucleus itself, at times, became partially obscured by a misty envelope, which appeared occasionally to surround it.

2. It also assumed another color, changing from a grayish white to a fiery red, and afterwards changing back again to the color it was before. At its last return its atmosphere nearly grazed the sun, and its velocity was at least five hundred thousand miles per hour; while that of the outer extremity of its tail was four millions of miles per minute. During this rapid flight its whole body was manufactured, by the heat and power of the sun, into tail, till it was over one hundred millions of miles in length. (See Fig. 36.)

3. Probably no body that has visited our system has ever experienced the same degree of solar heat, or ever will again,—as it has bid adieu to us forever, to speed its way to new immensities; for as it receded from the sun it entered upon the arm of a curve from whence there is no return.

4. Is not this an astounding thought,—never to return? Yet can we doubt the laws of force and motion?

Questions.—1. How long was the comet of 1843 visible? What was its form when first observed? Was it visible in the daytime? Did it soon acquire a tail? What is said of its nucleus? 2. Did it change its color? Did it come near to the sun? What was the velocity of its nucleus? What of the extremity of its tail? Did its body change into tail? What was its length? 3. Has it left the solar system, never to return? 4 Are the natural laws of force and motion uniform in relation to heavenly bodies?

Can we doubt the harmony of the infinite wisdom that directs and omnipotent power that urges it on in its

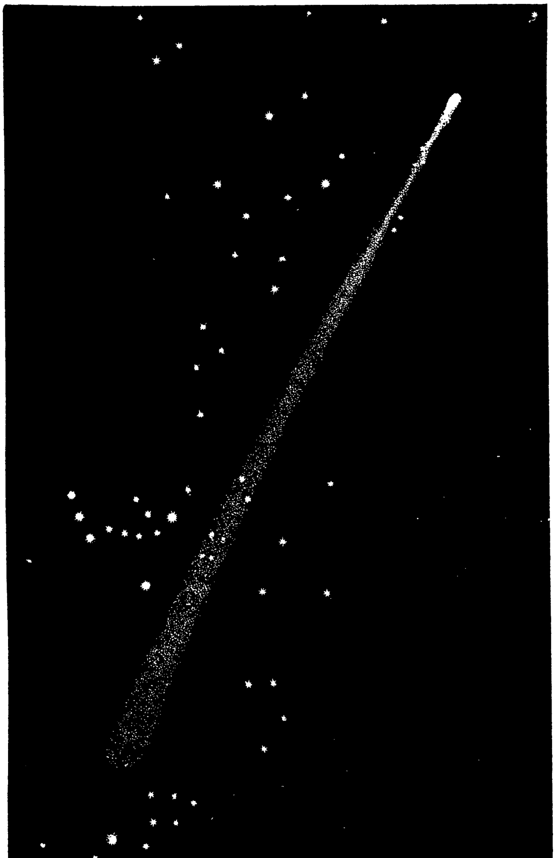

Fig. 36.

flight? Our reason intuitively decides in the negative, and our moral natures answer, No.

5. But are we done with mysteries profound? Others are still suggested by it to our view. On what message was this flaming wanderer sent? or to what distant world does it now wing its way? What is its office in the economy of nature? or what page in the book of the universe does it disclose?

6. These are questions at which reason falters and the imagination itself is confounded. Science staggers in their contemplation, and points the bewildered mind onward to the light of another world, for their solution.

SECTION LVII.

General Form and Properties of Comets.

1. HAVING noticed some of the peculiarities of a few of the most extraordinary comets that have made their appearance, we will now consider those that are most common, and speak of them in general. (See Fig. 37.) They are small, comparatively, and nearly globular in form. Their light is of a grayish white, gradually diminishing from the centre in some, and in others fading away in a similar manner, but in concentric[1] waves or rings.

2. They often change in the intensity of their light: yet their variations are never so great as to cut them off from the most simple type to which they all belong. In ages past they may have been accompanied by luminous tails; but by the waste of time, and contending

[1] Concentric ring—is one that is equally distant from a centre in all its parts.

QUESTIONS.—5. Can we imagine the design of this body? What can be its office in the economy of nature? 6. Can we answer these questions with any degree of certainty?

SEC. LVII.—1. Are comets in general comparatively small? What is the color of their light? How does their light appear in form? 2. Do they change in the intensity of their light? Are their changes so great as to cut them off from the most simple type?

of nature's forces, they may have been driven off, leaving the more solid parts in globular form.

3. About seven hundred comets have been discovered, and the elements of the orbits of nearly one hundred

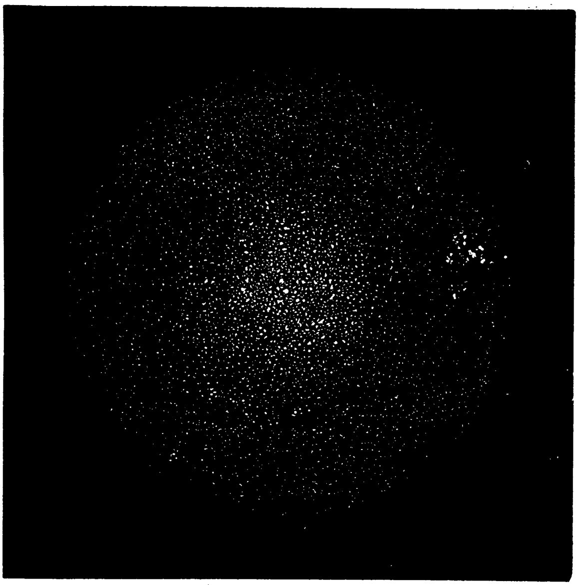

Fig. 37.

of them determined. They naturally divide themselves into three classes, by a difference in their constitutions, and their effects on light. The first have no nuclei,[1] and are uniformly transparent, permitting luminous objects to be seen through them without the slightest dimi-

[1] Nuclei—the plural of nucleus, which has been defined.

QUESTIONS.—Had they ever tails? 3. How many comets have been discovered? The elements of how many of their orbits have been determined? Into how many classes do they divide themselves? On what is this division founded? What is said of the first class?

nution of their light. The second class has nuclei; and they permit light to pass through them with equal facility.

4. The third class have star-like centres, differing in magnitude and density. The nuclei of only two of this class are well defined and truly planetary in form, while those of all the rest resemble brilliant points of light. Though these classes differ in some respects, still they manifest various characteristics which are common to them all.

SECTION LVIII.

Gravity of Comets.

1. COMETS are not, as some suppose, the result of reflection; neither are they of an auroral nature; but they have a real, material existence. This fact has been established by observing their strict obedience to the laws which regulate the planets and other heavenly bodies in their annual motions. They obey these common laws, which prevail throughout the boundless empire of the material universe, and return according to prediction.

2. True to time they come into view, and true to time they pass out, attracting and being attracted by one great, central, solar force, and also by other bodies, less or more, which may be near to them, or more remote. Through these contending influences Lexell's comet lost its balance, and wandered for a time among the moons of Jupiter; but, by the natural laws of com-

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QUESTIONS.—What of the second? 4. What of the third? The nuclei of how many are known to be planetary in form? What is said of the nuclei of others?

SEC. LVIII.—1. Have comets a real, material existence? How is that proved? Have any of them returned according to prediction? 2. Do the great majority of comets revolve around the sun, like the planets? Are comets more liable to be drawn from their orbits than other bodies? Why?

pensation, it was let free, that it might fulfil the endless task assigned it.

3. Yielding as it did to the greater attractive force, it proved itself material, as others have done, by the curves which they describe when sweeping round the sun.

SECTION LIX.

Rarity of Comets.

1. It being now evident that the comets are material, we may inquire concerning the character of their composition and nature of their elements. Are they such as compose the crust of the earth, or the atmosphere by which it is surrounded? Are they similar to those that enter into the composition of the animal or vegetable kingdom? Would they be precious if we had them, or worthless? Are they dense, or are they rare? (See Fig. 38.)

2. Concerning some of these questions we may theorize and conjecture, but concerning others we may arrive at more definite and intelligent conclusions. Judging from their magnitudes, we might infer that they were very massive,—even thousands of times larger than the earth. The diameters of some of them are over one hundred thousand miles; and then we do not include the luminous train, which is sometimes over one hundred millions of miles in length.

3. Were these bodies dense in proportion to their bulk, what would be the force of such flying worlds? What would their erratic wanderings produce, in the

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QUESTIONS.—3. Do they always yield to the greater attractive force? What does that prove?

SEC. LIX.—1. What are some of the inquiries made concerning comets? 2. Might we infer that comets are very massive? What is the diameter of some of them? How long is the tail of some of them? 3. If their density was in proportion to their magnitude, what might they do?

economy of nature? are questions on which we dare scarcely venture a conjecture. They might unhinge all worlds, and seal forever the destiny of the universe. But this is not to be anticipated.

4. Though comets occupy the largest space, they have

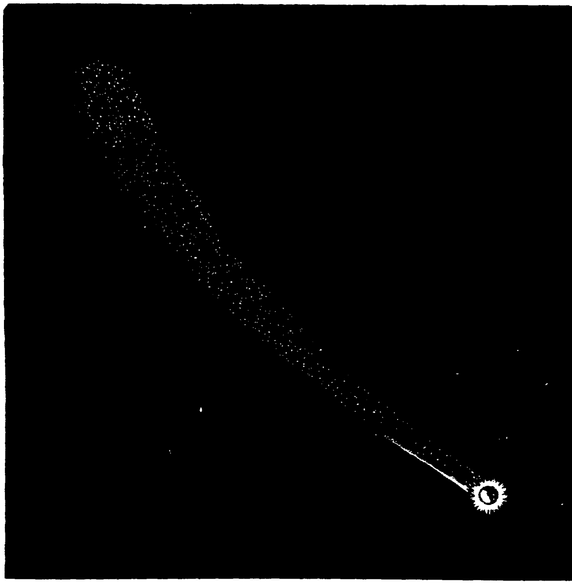

Fig. 38.

the smallest masses, of all the cosmical bodies that are known to exist. The amount of matter which they contain is almost nothing, when compared with what is known to be in other heavenly bodies. If calculations are correct, their mean average weight would fall even below the one-hundred-thousandth part of that of our earth; that is, if one hundred thousand of them were

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QUESTIONS.—4. Is less matter in any one of them than is known to exist in any other heavenly body? How much heavier is the earth than one of them?

collected into one, it would weigh still less than the earth on which we dwell.

5. This fact is rendered even more conclusive when we view them through the telescope, and also in connection with the light of fixed stars when it passes through them. They appear, even in their denser parts, to be composed of transparent, vaporous matter, suspended in an infinitely rarer atmosphere, which extends sometimes thousands of miles in every direction.

6. This atmosphere contains the nuclei of these bodies, and sometimes intermingles with the apparent cloudy matter that is collected near their centres. Generally this apparent cloudy matter decreases in density, going from the nucleus till it becomes invisible near the outer limits of the body. The tenuity of these outer parts, and the great distance to which they extend, may be accounted for by the small amount of gravitating force exerted upon them. This force is in proportion to the size and density of the nuclei; and as they are exceedingly rare, there is not sufficient attractive force to draw their atmospheres into a small compass.

7. If the earth was a shell, with the interior parts removed, our atmosphere would expand; and if it contained more matter than it does, the atmosphere would condense into smaller bounds, by the increased force of gravity at the centre. This principle is also manifested by comets in the formation of their tails. Their lighter parts are driven off, when in the vicinity of the sun, by some exterior or interior influence, and they increase in size, the particles which compose them being so far away from their central attractive force.

QUESTIONS.—5. How is this known? How do the stars appear as they pass between us and them? How do they appear in their denser parts? 6. Do they appear to get rarer in their outer parts? How is the rarity of their outer parts accounted for? 7. Would our atmosphere expand if the earth was only a shell? What of the atmosphere if it contained more matter than it does? Is it probable that the tails of comets are formed out of their bodies? In what way?

8. This exemplifies the exceeding subtleness of the substance of which these bodies are composed, and may account in part for the wonderful developments of some of their elements, which we are sometimes permitted to behold.

SECTION LX.

Nature of Comets.

1. FROM investigations which have been made, it is evident that rarity is not the only peculiar characteristic of comets. They appear to be neither gaseous nor fluid; or, if they are, their substances are infinitely refined, as is evident from the principle of refraction. Terrestrial objects which are transparent, as comets are, change the direction of the rays of light when they pass through them, and the denser the transparent medium the greater is its refractive power.

2. This is invariably true with all transparent, solid, fluid, or gaseous substances with which we are acquainted; but this principle appears to fail when light passes through the bodies of comets. It does not manifest the least refrangibility; from which we would infer that the elements of which they are composed are not analogous to any of those with which we are familiar.

3. Atmosphere a thousand times rarer than what we breathe has the power of producing a refraction which is perceptible; and if comets were composed of any thing similar to it, they would produce the same effect on this agent when it penetrates their bodies. But such phenomena are never manifested by them: therefore we

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QUESTIONS.—8. What does this change of form prove?

SEC. LX.—1. Do comets appear to be either fluid or liquid? Are they transparent? What is said of the refraction of terrestrial bodies? 2. Does a dense transparent body refract light most? Do comets refract light as it passes through them? What would this show? 3. Must they differ in their elements from any of those on the earth, or be more than a thousand times rarer than our atmosphere? Why must this be so?

would infer that the elements that compose them must differ in their nature from any of the elements of the earth or atmosphere.

4. This being the case, what can they be? What is the nature of their elements? Perhaps they are primordial,[1] dust-like particles held in equilibrio[2] by their native repulsive power, and the mutual attractive influence which they have for each other. This appears to be the character of their composition; but, if it is not, science must await her appointed time to solve the mystery, and be satisfied to converse only about such properties and qualities as are known to belong to them.

SECTION LXI.

Comets Shine by Reflected Light.

1. COMETS are opaque,[3] or at least as much so as other cosmical[4] bodies that are recognized as non-luminous, and would never be visible were it not for the solar light which they reflect. In like manner is it with the moon and satellites; neither would the planets be visible were it not that they reflect to us the light which is shed upon them by the sun. We incidentally alluded to this fact before, but did not fully explain the method whereby we may be convinced of its truth.

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[1] Primordial—existing from the beginning.
[2] Equilibrio—held by two forces that are equal.
[3] Opaque—without light.
[4] Cosmical—pertaining to heavenly bodies.

QUESTIONS.—4. Of what, then, are comets composed? Have particles of matter, in general, two forces operating on them as particles? What must be the effect of either force on particles of matter when they are in equilibrio? Is it necessary that they touch each other to be in equilibrio?

SEC. LXI.—1. Are comets opaque bodies? Are the moon, satellites, and planets also opaque? How can we see them, if they are so? Is the sun self-luminous?

2. It has been discovered that light exists in two states,—natural and polarized. The former is invariably emitted from a gaseous, ethereal substance when heated to a certain temperature, and the latter from a liquid or solid substance when in the same state. But this inquiry has been carried further, and it has been ascertained that all reflected light, whether thrown off by rare or solid substances, is polarized. Now, this is the kind of light that we receive from all the bodies that are known to revolve around the sun, comets not excepted. Hence we may infer that they are opaque, and never would be visible were it not that they reflect

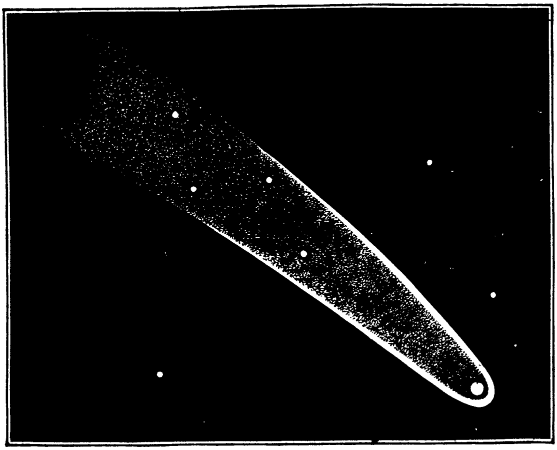

Fig. 39.

to us the rays of light that fall upon them from the sun. (See Fig. 39.)

QUESTIONS.—2. How many states do we find light in? What kind of substance emits natural light? What kind polarized? Is all reflected light polarized? Is this the kind that we receive from the comets? What does this prove? Would they ever be visible, without sunlight?

3. But this fact may be further exemplified by an established property which is common to all self-luminous bodies that have a sensible disc. If the sun were seen from the outermost planet, he would seem as bright as if beheld by us; and the only difference that we could observe would be in his size. True, the amount or volume of light would not be the same at these unequal distances: still, what would be received by observing him from Neptune would appear as bright as what we are, day by day, permitted to enjoy.

4. This principle holds in regard to all self-luminous bodies that have an angular magnitude, but fails when applied to those that shine by borrowed light. They decrease in brightness the farther they are removed from the source of light, till they become invisible for want of a sufficient amount of reflected light whereby they may be seen. This is an accredited result, obtained by actual experiment, and is conclusive in proving the opacity of the comets.

5. Their light increases and diminishes in brightness as they approach or recede from the source of light. This is obvious in the most brilliant, as well as in those that are scarcely visible. They reflect most when nearest to the sun, and least when at the greatest distance; which confirms the fact that they receive their light from him.

QUESTIONS.—3. Are all self-luminous heavenly bodies that have sensible discs equally brilliant? Wherein do they differ in relation to their light? 4. Is this a known principle in relation to all self-luminous bodies that have an angular magnitude? How is it when applied to bodies that shine by borrowed light? Do their rays diminish in brilliancy as they recede from us? What does this prove in relation to comets? 5. Does the brilliancy of their light increase and diminish as they approach and recede from the sun? Is this the case with all the comets that are visible?

SECTION LXII.

Anomalous Aspects of Comets.

1. NOTWITHSTANDING it is true that the denser parts of comets, which are the most brilliant, decrease in size as they approach the sun and expand as they recede from him, still, they are not outside of every analogy in their manifestations. These phenomena apparently contradict the general laws of heat, whereby objects increase in volume as they increase in temperature. This is one of its fundamental laws; and its expansive effects may be observed by applying it to any substance that we may select. They all expand under its influence, except the denser parts of comets, which appear to contract as they approach the source of heat.

2. To decipher this anomaly,[1] many theories have been invented and many speculations suggested. Professor Encke attempted to explain it by assuming the existence of an ethereal fluid which pervades all space and grows denser in the vicinity of the sun. As the comet travels into these denser regions, it would be under greater pressure, which would reduce it in its volume. This might be true if it was elastic, and impervious to the medium through which it moved; but this is entirely unknown.

3. In like manner did others attempt to solve the query by assuming an inherent power of condensation and expansion in the comets themselves; but this was also objectionable; for the change of volume always corresponds to their change of distance from the sun. The nearer they approach the source of heat, their

[1] Anomalous—contrary to rule.

QUESTIONS.—1. What is anomalous in the appearance of the heads of comets? Do objects generally increase in size as they increase in temperature? How is it with the heads of comets? 2. How did Professor Encke explain it? 3. How did others attempt to solve the problem?

nuclei grow less, and at the greater distance they expand. Though this is anomalous, yet it corresponds to some things on the earth with which we are familiar.

4. Aqueous vapor, which is invisible, may be condensed by cold into a visible fog, and dissipated again by the application of heat. Heat renders it wholly invisible, and cold converts it into a visible object. May not a process somewhat analogous to this be carried on in the comets by the unequal degrees of heat and cold which they experience? May not the nebulous matter which reflects the light be dissipated, when in the vicinity of the sun, into an invisible gas or vapor, thereby diminishing the bulk of reflective matter in their nuclei? And may this invisible matter not gradually condense by attraction as they recede from the sun, thereby increasing the nebulosity as rapidly as it was diminished?

5. It is probable that this is a true explanation of these anomalous changes; but there is another change observable, which is constantly in one direction. They are all becoming smaller at every revolution, diminishing both in bulk and brilliancy. Halley's comet, and others whose histories are known for hundreds of years, are growing less, and ere long some of them will be lost even to telescopic view. This fact is fully confirmed; and it now addresses itself to us for a truthful and rational solution.

6. If the tails of comets emanate from their bodies, this proposition may not be so difficult to solve. We are all familiar with the fact that some of them are of enormous length, extending sometimes more than one hundred and fifty millions of miles from the nuclei.

QUESTIONS.—4. Will heat dissipate aqueous vapor? Will cold condense it? Is it visible when dissipated? Is it when condensed? Might the sun's heat on the heads of comets cause them to appear less as they approach him? Might cold cause them to appear larger as they recede from him? 5. What other change are comets undergoing? What is said of Halley's comet? 6. What is the length of the tails of some of the comets? Is it probable that portions of their tails are detached from their bodies and lost in space?

This being the case, the outer part of the tail may be thrown beyond the attractive power of the body to bring it back again by some exterior or interior influence, and it may be irretrievably lost in the infinitude of space.

SECTION LXIII.

Tails of Comets—How Formed.

1. THE inquiry may naturally arise, What power urges the particles of matter, of which the tails of comets are composed, so far away from the nuclei? or are the tails at all material? To this inquiry we may respond more in the language of theory and probability than in the language of absolute truth and certainty.

2. Some have supposed them to be produced by the rays of the sun passing through the nucleus, which is transparent and operates as a lens. Others thought that they were produced by the atmospheres of the comets being driven backward from the sun by an impulse of his rays.

3. Sir Isaac Newton imagined that they were a thin vapor rising from the heated nucleus, as smoke ascends from the earth; while Dr. Hamilton supposed that they were streams of electricity excited and dispersed by the influence of solar heat. (See Fig. 40.)

4. Whatever these conjectures may be worth, they have not satisfied the inquiring mind; neither can any one of them be maintained by any principle in science or natural phenomena, as they have been presented. It may be that the exterior parts of comets, which are almost spiritual in their nature, are rarefied when near the sun, and fall behind the more solid parts as they speed

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QUESTIONS.—1. Are there different theories in relation to the formation of the tails of comets? 2. What have some supposed them to be? What have others? 3. What was Sir Isaac Newton's theory? What Dr. Hamilton's? 4. May it be possible that they have an inherent power in themselves excited by the heat of the sun as they approach him, whereby they are formed?

Fig. 40.

their way through space. Or it may be that there is an inherent power in the comets themselves, excited by the solar heat; or a repulsive power in the sun, which drives from their bodies the lighter parts, both luminous and transparent.

5. But the inquiry may arise, What can this force or power be which counteracts the force of gravity? Is it material, or immaterial? Is it electrical, or magnetic? or is it produced by a combination of them both? Probably it is the result of their united influence, as they are mutually productive of each other.

6. By disturbing the magnetic fluid, electricity manifests itself; and by causing a current of electricity to flow through a conductor, magnetism is observed to accompany it. These fluids appear to be productive of each other; and this circumstance may account for the polarity of the earth.

7. Electricity will flee from heat, or heat will cause the fluid to circulate or pass from one point to another; and if electricity circulates around a piece of iron, it will become magnetic. Let us apply this principle to explain the magnetic phenomena of the earth. The earth is the great reservoir of electricity, and is constantly, by its daily motion, turning its cold side to the sun, which creates currents of electricity at its equator, by which the magnetic poles of the earth are produced.

8. But, besides the mutual influence of these fluids, they are possessed of antagonistic forces. By a simple change in the arrangement of the plates of a galvanic battery, its positive pole becomes negative, and its negative becomes positive. So also is it with the magnet.

QUESTIONS.—5. What can this inherent power be which in a measure counteracts the law of gravity? Is it electric, or magnetic? 6. If the magnetic fluid is disturbed, does electricity manifest itself? If a current of electricity is created, does magnetism always accompany it? 7. From these circumstances may we account for the magnetic poles of the earth? By what method? Does magnetism manifest itself at right angles to a current of electricity? 8. Are magnetism and electricity possessed of repulsive forces?

By reversing its poles in relation to the circulating current of electricity, they assume opposite magnetic conditions.

9. Now, it may be that there is an opposite force of polarity between the sun and the comets (which being increased by the heat of the sun), that produces their tails. Or it may be that as they approach him his heat creates opposing electro-magnetic influences in the comets themselves, which are productive sometimes of a plurality of tails.

10. Their particles may be in different electric or magnetic conditions, and may be stimulated to separate by an increase of temperature as they approach the sun. Polarity, electric or magnetic, conditioned by heat, may account for the origin, expansion, and contraction of these mysterious appendages, which have so often terrified not only the ignorant, but many also who profess to believe in the unbounded wisdom of an infinite Architect.

SECTION LXIV.

Nebular Hypothesis.

1. Sir Wm. Herschel, in the exploration of the heavens with his great refracting telescope, beheld various objects of surprising interest. Besides stars and clusters of stars, ill-defined chaotic patches of hazy light, and some of greater regularity of outline, and apparently of greater density, entered into his field of view. He also saw well-formed stars surrounded with envelopes of dim nebulous fluid matter, together with other objects, each of which was greater in extent than the whole solar system, having circular disks and with bright nuclei in their centers. These various manifesta-

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Questions.—9. How is the polarity of a magnet changed from positive to negative, and *vice versa?* 10. Might magnetic or electric repulsion between the particles of the comets, or between them and the sun, conditioned by heat, produce their tails?

tions of celestial objects seemed to indicate to him that nebulous matter is constantly coalescing into globes and suns, and that all these heavenly bodies were originally "without form and void," and that they gradually arrived at their present degree of perfection.

2. The celebrated La Place extended this theory to the formation of the solar system. It considers the primordial condition of all the matter that composes all suns and worlds to have been nebulous and diffused through space; that the particles of matter tended by gravity in different directions, and with different velocities, towards certain centers, which originated in the entire mass a rotary motion; that all the matter that composes the sun, planets, and satellites was expanded to such a degree with heat, that its diameter was much greater than the diameter of the orbit of the outermost planet; that this nebulous body parted gradually with its heat, which increased its rotary motion till the centrifugal force generated by its velocity equalled the gravity of the lighter particles at the equator: hence, the parent mass continuing to lose its heat and decrease in volume, a ring of nebulous fluid matter was formed, which coalesced into a globular body, which is the outermost planet. The planet, in turn, gradually parting with its heat and condensing, and consequently increasing in its rotary motion, generated a ring of nebulous fluid matter at its equator which coalesced into a globular body, which is a satellite. By a successive repetition of this generating process the planets and satellites were formed, when the central body, becoming too dense to generate further by its velocity of axial motion, became the great controling solar orb of the planetary system.

3. This theory seems to explain the motions of the sun, planets, and of most of the satellites. The sun revolves from west to east on his axis, and the planets have their daily and yearly motions in the same direction, revolving nearly in the plane of the sun's equa-

tor. The satellites, as far as discovered, with one exception, revolve on their axes and around their primaries in the same direction and nearly in the planes of their equators. The planets are swollen out at their equators. Saturn has rings, and they revolve around his equator and in the direction of his axial rotation.

4. Some of the phenomena which seem to be at variance with this theory are as follows: The planets are opaque and the sun is self-luminous. Some of the planets have a greater density than the sun. Herschel's moons have a retrograde motion, and the planes of their orbits are at large angles with the plane of the ecliptic.

5. A brief statement, also, in this connection, of La Place's theory of the origin of comets, may not be uninteresting to the reader. It considers, as noticed above, that the matter that is in all suns and worlds was originally nebulous and diffused through space; that the particles of matter tended, with a greater or less gravitating force, towards certain centers, and that the filmy masses of nebulous fluid intermediate between these centers were held for a time almost in equilibrio; but, slowly yielding to the greater attractive force, began to form and circulate as comets around those bodies which had become their controling centers.

SECTION LXV.

Distances of Fixed Stars.

1. WE propose now to take leave of the planetary system, all of the members of which are comparatively near to us, and extend our thoughts to the contemplation of the fixed stars, which are far beyond its limits. When we pass outside of the solar system, we arrive at a tremendous vacuity, the general depth of which is at least sixty millions of millions of miles in every direc-

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SEC. LXV.—1. Are the fixed stars near the planetary system? How far distant may we reckon some of those that are nearest to us?

tion. It is a great open space, destitute of glittering stars and glowing worlds to animate the solitude or take part in the economy of the universe. This is evident from a number of considerations.

2. All material bodies attract each other with forces equal to their masses and the distances that they are apart. If the fixed stars were near to our solar system, some of the outermost planets at least would be sensibly affected by their attractive influence; but no such result has ever been observed. Much more so would it be with the periodic comets which travel far beyond the utmost verge of the planetary system. They would be detained in their journey, and would not return according to prediction, as we find they do.

3. Neither would the stars themselves appear to keep their relative places, were it not for the enormity of their distances from the earth. The earth, in making her annual revolution around the sun, changes her place in every six months one hundred and ninety millions of miles: still, it effects no sensible change in their relative positions. From these circumstances, and evidence noticed elsewhere of the modes of approximating at stellar distances, we may infer that our planetary system is at an almost inconceivable distance from the starry heavens with which it is surrounded.

4. Passing beyond this abysmal void, we reach the nearest of the fixed stars, or those heavenly bodies which are called fixed, because they do not appear to change their places. They always manifest the same relative positions, and, in consequence of their apparent magnitudes and juxtaposition of some of them, they

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QUESTIONS.—What occupies the space between them and us? 2. What evidence have we that the fixed stars are not near the planetary system? 3. Do the stars appear to change their places with each other? What does that prove? What distance does the earth change in six months? Does this change of distance make any sensible change in the relative positions of the stars? What conclusion can we safely arrive at from the foregoing evidence? 4. Why are the stars called fixed?

have been classified and grouped into clusters, which clusters are named according to the fancies of their early observers. By these imaginary divisions and classification they are known when we wish to describe them or make them the special objects of investigation.

5. In this way, if we are familiar with what is termed by some the geography of the heavens, we can as readily know the relative place of any star or constellation as we can determine any natural division on the earth. With these facilities to direct us, and the telescope to aid us, we will now enter into the boundless domain of the stellar universe, to contemplate the nature and number of its shining inhabitants, also their physical and optical relations, and the laws by which they are governed.

SECTION LXVI.

Classification of Fixed Stars.

1. THE stars, in contradistinction to planets, satellites, and comets, which are visible to the naked eye, are arranged into six classes, according to their different degrees of brightness; and those that are visible only by aided vision are divided by some into ten classes, in a similar manner; making, in all, sixteen divisions. (See Fig. 41.)

2. The first class embraces all of the largest stars that are of the same brightness; and they are about twenty in number. The second class, or those of the second degree of brightness, contains about sixty; the

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QUESTIONS.—Have they been classified, and the heavens divided into districts by imaginary lines? Were certain names given to the clusters of stars that are in these divisions? 5. Are these divisions readily distinguished by their names and appearance? How have we obtained the principal part of the knowledge which we have of the fixed stars?

SEC. LXVI.—1. How many classes of stars are visible to the naked eye? How many classes visible only by aided vision? 2. What does the first class embrace? What the second?

third, one hundred and ninety; the fourth, four hundred and twenty-five; the fifth, eleven hundred; the sixth, four thousand; the seventh, twenty-six thousand; the eighth, one hundred and eighty thousand; the ninth,

STARS OF DIFFERENT MAGNITUDES.

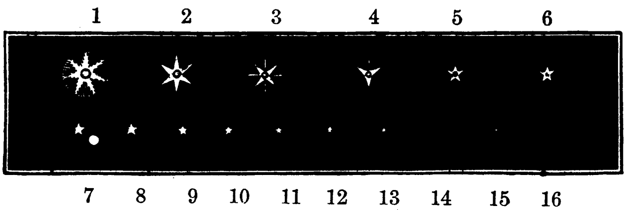

Fig. 41.

eleven hundred thousand; the tenth, seven millions; the eleventh, fifty millions; the twelfth, three hundred millions; the thirteenth, five hundred millions; and the smaller ones appear to be innumerable.

3. From this table it may be observed that as the stars decrease in magnitude they increase rapidly in number, and more than nineteen-twentieths out of the many millions that belong to our astral system are under the tenth magnitude. This decrease of magnitude and increase of number is what we might anticipate when we consider our position in relation to them.

4. We are surrounded on all sides by the stars; and if we were to draw a circle touching those that are nearest to us, and one at double the distance from us,

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QUESTIONS.—What the third? What the fourth? What the fifth? What the sixth? What the seventh? What the eighth? What the ninth? What the tenth? What the eleventh? What the twelfth? What the thirteenth? What is said of the number of smaller ones? 3. Do the stars increase in number as they decrease in magnitude? What proportion is under the tenth magnitude? How is this accounted for? 4. If the stars were equally distributed in space, and a series of circles drawn among the stars, exterior and equidistant from each other, near which circle would be the greatest number of stars?

fewer stars would be found on the nearer circle than on the one more remote, even if they were equally distributed in space. This would be true no matter how many circles should be drawn at equal distances apart exterior to each other. At each successive exterior circle the magnitudes of the stars would decrease and their number would increase, even to the outermost limits of the stellar system,—if it has any limits. By

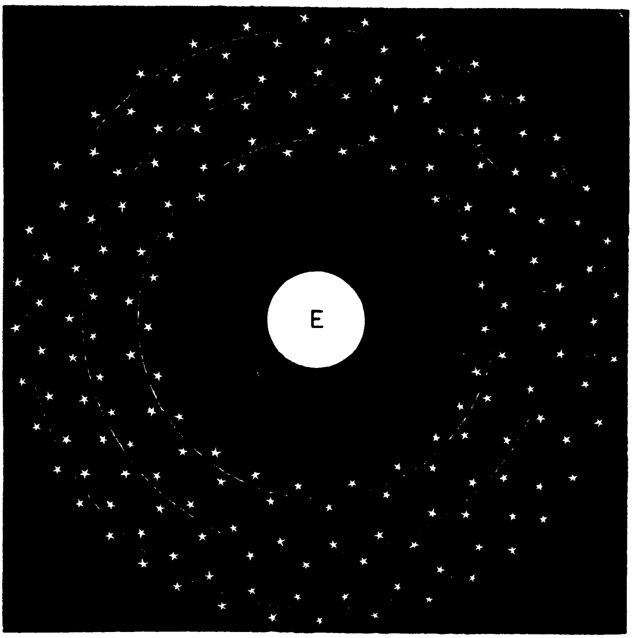

Fig. 42.

referring to Fig. 42, these facts may be readily understood.

5. This universal classification of astral bodies as noted above is not based on their actual magnitudes, but

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QUESTIONS.—5. On what is the above classification of stars based?

on their different degrees of brightness, and these degrees of brightness are supposed to be in proportion to the different distances that they are away from the point at which we observe them.

SECTION LXVII.

Stars have no Sensible Discs.

1. STARS do not appear like planets when seen through the telescope. Planets present distinct, circular discs, similar to that which the moon offers to the naked eye, and their light appears to be in a measure diluted. With stars it is different. Telescopes with a magnifying power of six thousand, instead of increasing their size, appear to diminish even the largest of them to a mere brilliant point, having no sensible magnitude at all.

2. This result is not because the lenses of the telescope do not magnify, but because the distances of these objects are so enormous, compared with their actual magnitudes, that their magnitudes at such great distances are more than six thousand times less than that which the naked eye is capable of perceiving; that is, with all the facilities which have been employed for observing them, they appear to have no real magnitude at all. Glasses with low magnifying powers produce stellar discs; but they are spurious, and are entirely dissipated by those of higher power.

3. Their occultations by the moon manifest also that they have no sensible discs. When she intervenes between us and a planet, the light of the planet is gradually obscured; but this is not so when she passes between us and the stars. They preserve all of their

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QUESTIONS.—What do we infer in relation to the distance of a star from its brilliancy?

SEC. LXVII.—1. What effect has the telescope on planets? What on the stars? 2. Why do the stars appear so? 3. What do their occultations manifest?

lustre until the moment they come in contact with the dark edge of the moon, and then their light is instantly extinguished, without the slightest appearance of a gradual diminution of brightness.

4. By this sudden transition, and other facts already noticed, we discover that their masses have to us no perceptible magnitudes, notwithstanding they have been made the subjects of the most rigid scrutiny.

SECTION LXVIII.

Real Magnitudes of Stars.

1. SINCE the stars present to us nothing except mere points of light, is it true that they are nothing else, and have no substantial magnitudes at all? This question propounded itself long since, and was satisfactorily answered by Dr. Wollaston and others, who instituted a series of observations which terminated in an estimate of the brightness and magnitude of some of the fixed stars in comparison with the sun.

2. To aid them in the accomplishment of their designs, they brought into requisition the Photometer, an optical instrument the use of which is to ascertain the comparative brightness of luminous objects. By this instrument the numerical ratio of two lights emitted from shining bodies is determined, whether near at hand or afar off.

3. Prosecuting these investigations in relation to Sirius (the Dog-star) and the sun, it was discovered that the light received by us from the star was twenty

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QUESTIONS.—In what manner? 4. Would it be reasonable to infer that the stars are nothing but lucid points, without further evidence?

SEC. LXVIII.—1. Who undertook to prove that the stars are large, massive bodies? 2. What optical instrument did they use? What is its special use? 3. What two heavenly objects did they select?

billions of times less than that received from the sun. This fact being obtained, and knowing from fixed principles in science that the farther luminous bodies are removed from us the less will be their apparent magnitudes and brightness, it may be readily determined how far the sun would have to be removed back in space till his light would be only equal to that of the star in question.

4. Light decreases in intensity in an inverse ratio as it recedes from the luminous body; for if the sun was removed to twice its present distance from us its light would appear four times less, at three times its present distance it would be nine times less, and at ten times its present distance it would be one hundredfold less; and so on, in the same ratio.

5. Having computed the actual diameter of the sun, and being assured by this conceded principle in optics of the rapidity with which light decreases passing out from a luminous object, it was discovered by a simple calculation in arithmetic that the sun would have to be removed to one hundred and fifty thousand times its present distance that it might appear to us as the Dog-star.

6. Now, if this change of distance produces such results in relation to the sun, may it not be reasonably inferred that the Dog-star is greater in magnitude, since it has been determined that it is more, far more, than one hundred and fifty thousand times his distance from us? In like manner is it with all the stars. They are suns,

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QUESTIONS.—How much less is the light of the Dog-star than that of the sun? Do luminous bodies appear to grow less the farther they are removed from us? From known principles, could it be discovered how far the sun would have to be removed from us till he would appear equal in size to the Dog-star? 4. If the sun was removed to twice his present distance from us, how much would his light be diminished? Light is governed by what law, as the luminous body changes its distance from us? 5. How far would the sun have to be removed before he would appear only the size of the Dog-star? 6. Is the Dog-star more than one hundred and fifty thousand times the distance to the sun?

the majority of which are no doubt many times larger than our sun, but apparently less, in consequence of their great distance from us.

SECTION LXIX.

Method of Computing Distances to Fixed Stars by Trigonometry.

1. FROM what has been said in the preceding section, the inquiry may arise, How is it known that the distance to Sirius is more than one hundred and fifty thousand times the distance to the sun? or, in other words, How can we determine the distance to any fixed star? We determine the distances of the sun, moon, and planets from the earth, by the principles of plane trigonometry;[1] and by the same principles do we determine the distances of some of the nearest stars.

2. Suppose this curved line in Fig. 43 to represent the orbit of the earth, which is one hundred and ninety millions of miles in diameter, and S a fixed star, the distance of which we wish to determine. If we will take an observation of the star when the earth is at one side of its orbit, and in six months afterwards also when it arrives at the opposite side, then we will have a triangle, two lines of which are visual lines, and the third the diameter of the earth's orbit. Now, from the known elements of this triangle, or those that may be readily known, viz., the angles and one side, which is the diameter of the earth's orbit, those lines that are un-

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[1] Trigonometry—that science which teaches how to determine the several parts of a triangle from having certain parts given.

QUESTIONS.—What may we infer in relation to his size in relation to that of the sun?

SEC. LXIX.—1. What mathematical principles are involved in finding the distances to the sun, moon, and planets? Can we determine the distances of some of the nearest stars on the same principles? 2. What kind of a figure would we form in finding the distance to a star? What would we use as a base-line?

known are easily determined, either of which would be the distance to the star in question.

3. By this method the distance to some of the nearest fixed stars have been discovered; and were it not that

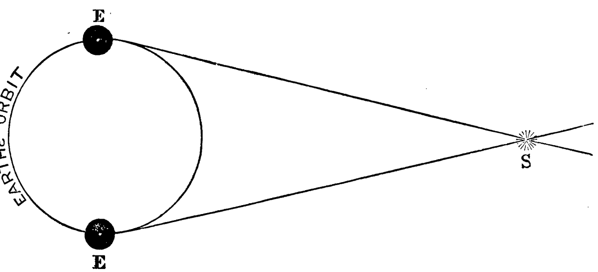

Fig. 43.

the visual lines of observation appear to coalesce before reaching the object, the distances of at least some of those that are more remote might be known. If the diameter of the earth's orbit were increased, greater distances into space could be mathematically measured, and many heavenly bodies, now in point of distance outside of computation, would fall within its limits.

SECTION LXX.

Telescopic Method of Computing Distances of Heavenly Objects.

1. Assuming now, what may not be rigorously true, but what may not be very far from it, that the stars would appear equal in magnitude if they were at the same distance from us, we arrive at this astonishing re-

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Questions.—What elements in the triangle are known, or can easily be known? 3. If the diameter of the earth's orbit was greater, could we measure the distances of objects more remote?

Sec. LXX.—How long would it take light, travelling at its usual rate, to reach us from the nearest fixed stars?

sult, that it would take light ten years to reach us from those of the first magnitude, and one hundred and twenty years from those of the sixth magnitude, travelling at the rate of twelve millions of miles in a minute. But the inquiry may arise, Have we any knowledge of the distances of telescopic stars, or those that are sunk so deep in space that they are invisible with unaided vision?

2. Sir William Herschel attempted to explore the unknown regions of the heavens with his gigantic telescope, and did not fail to reveal much that was hitherto unknown. That he might be able to accomplish his purpose, he first tested the space-penetrating power of his instrument by the power of the human eye. In order that we may see an object, it is necessary that a sufficient number of rays of light enter the pupil of the eye to make a sensible impression on the seat of vision. When this is not the case, the object will be invisible. In like manner is it with the telescope. If a sufficient amount of light sent forth from a body does not enter the object-glass so as to make an impression on the retina of the eye after it is concentrated by the lenses, the object will be invisible even with the use of the instrument.

3. From this it may be observed that the telescope is constructed on the principles of the eye, and that by the one we are able to measure the power of the other. This may be illustrated by the use of objects with which we are familiar.

4. If we should observe letters written on an object one mile distant, and be no more than able to read them, this would give us the measure of the power of our

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QUESTIONS.—How long from those of the sixth magnitude? Can the distance to telescopic stars be determined? 2. Who was the first great explorer of the heavens? How is the power of the telescope tested? What is necessary that an object may be visible by the eye or the telescope? 3. On what principle is the telescope constructed? Can the power of the telescope be ascertained? 4. How can we ascertain the power of the eye?

eyes. To read the same letters twice the distance would require eyes increased in power to correspond with the increase of distance, or, in other words, with pupils of larger apertures for the admission of more light. But, as the pupils cannot be enlarged, the object-glass of the telescope answers the same purpose as if they were; and as its dimensions, in comparison with those of the pupil of the eye, can be readily determined, we at once may ascertain how much farther it can penetrate into space.

5. With this information gained, Herschel undertook to explore the heavens, and, if possible, to fathom the depths of that zone of light familiarly known as the Milky Way. Arranging the visible stars according to their magnitudes into six classes, and considering the smallest to be at the greatest distance, he reached out still farther into the fathomless abyss of space, and descried other worlds glowing with light and beauty.

6. Pursuing these investigations, many things wonderful passed in hasty review before him. Instead of a comparatively few brilliant points of light which we may witness in starlight nights, thousands of worlds moved over his field of view, and that arch of milky light which encircles the heavens resolved itself into innumerable stars glowing with their own inherent splendor. Its hazy appearance was dissipated before the great pupil of the telescopic eye, and he witnessed realms of solar light so far away that it could not reach us, travelling at its usual velocity of twelve millions of miles per minute, in less than five hundred years.

7. Such are some of the results arrived at by these instruments of science and art; yet there are others more astounding. The nebulæ are at a still greater distance. Some of them are so far removed that the telescopes of

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QUESTIONS.—In the telescope, what represents the pupil of the eye? By knowing the power of the telescope, can we discover the distance that we can see with it? 5. What portion of the heavens especially did Herschel explore? 6. What did he witness when examining it? How long would it take the light of some of the objects that he saw, to reach us? 7. What other objects did he discover? Did he resolve them by his telescope?

the highest powers cannot perfectly resolve them into stars. This being so, and knowing the distance to which the telescope will penetrate, we may safely infer that they are so far away that their light would only reach us after a journey of thirty thousand years.

8. But this is not all. There are other nebulæ which manifest no signs of resolvability, though they may be telescopically scrutinized under the most favorable circumstances. Immutable as they are under the most rigorous tests that science can employ, or art construct, what can be their distance from our earth? From Herschel's computations, his great reflecting telescope would follow some of them if they were plunged so deep in space that their light would require fifty thousand years to reach us; and the great telescope of Lord John Rosse would pursue them to ten times this inconceivable distance.

9. Does not reason stagger at these results, and is the imagination not confounded? Yet these are only a part of nature's works; and no one can know them to perfection, much less the infinite wisdom and power of Him who is the Builder of them all.

SECTION LXXI.

The Stars are Self-Luminous Bodies.

1. HAVING considered briefly the apparent magnitudes and distances of the stars, both visible and telescopic, we will now notice their physical character, also their relations and their general distribution in space. They are self-luminous bodies, shining by their own

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QUESTIONS.—How long would it take the light of some of them to reach us? 8. Are there nebulæ in the heavens which have never been resolved? How long would it take the light of some of them to reach us? 9. Have we a conception of the extent of the physical universe?

SEC. LXXI.—1. Are the stars self-luminous? How has this fact been discovered?

inherent light, similar to our great orb of day, to which we are indebted for so many comforts. This fact has been made apparent by photometrical observations, which have been made on light emitted and reflected from various objects, as well as other considerations.

2. The light of the planet Venus, when the greatest amount of her enlightened surface is next to us, is considered three thousand times more feeble than the light of the full moon; and the light of the full moon is ascertained to be three hundred thousand times less than the light of the sun. From these results, it may be inferred how feeble the light must be which is reflected from bodies that are comparatively near us, when contrasted with the light of the sun, which is at such a great distance from us. But it has been shown that the stars are many millions of times farther away than the sun: consequently, if they were not suns themselves, and were shining by reflected light, they could not be seen even if they were millions of times nearer to us than they are.

3. All bodies, no matter what their sizes might be, if they were destitute of a light-generating principle, would disappear in darkness even before they would have travelled over more than an infinitesimal part of the distance to the nearest of the stars. They would fade away from our view, never again to smile upon the earth or reveal to man, through the medium of light, that they still retained an existence. (See Fig. 44.)

4. But the stars, even to the sixth magnitude, are visible to the naked eye, and the heavens near those of the first magnitude, when viewed through a large telescope, exhibit the appearance of an eastern firmament

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QUESTIONS.—2. How much more feeble is the light of Venus than that of the moon? How much more feeble is the light of the moon than that of the sun? Are the stars millions of times farther away than the sun? If they were not self-luminous, could they be seen at this great distance? 3. Would they be visible if they were millions of miles nearer to us, if they were not self-luminous? 4. How do some of the stars appear when viewed through a telescope?

at the approach of sunrise. And when some of the most brilliant enter into the field of view, the eye is almost overpowered by their dazzling light, unless protected by the interposition of some translucent substance.

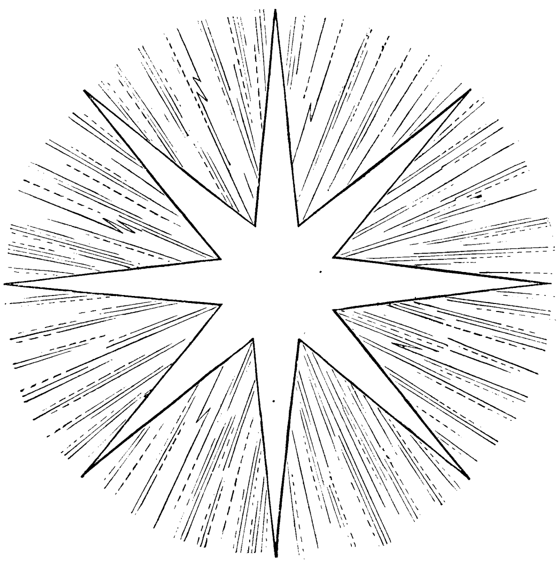

Fig. 44.

5. These facts, together with the fact that their light is natural and not polarized, are sufficient of themselves to satisfy even the inquiring mind that they are suns, some of which are no doubt hundreds of times larger than our own, and far more glorious in their splendor. Did I say glorious in splendor? Yes, glorious; for, wherever we may happen to turn the great eye of the telescope, suns of every class and color greet us with their glory.

QUESTIONS.—5. What other evidence is there that the stars are suns like our own? Are the stars of different colors?

SECTION LXXII.

Color of Fixed Stars.

1. THE fixed stars are of a great variety of colors, and all of these colors are either natural or complementary. The red star is in contrast with the green, the yellow with the blue, the rose-colored with the sapphire, and the greenish-white with the orange, all blending their variegated hues into one common spectrum, exhibiting, in certain instances, a scene equal, if not superior, in beauty, to any thing that we were ever permitted to behold.

2. Some of them are white, or blue, or red, or green, or yellow, varying in color, no doubt, according to the nature of the substances in which their light is generated or through which it is transmitted. This is evident from the fact that when they are viewed singly they universally present the same colors, which would not be the case if any of them were produced by contrast. The natural color of a star may be changed by the light of another star mingling with its own light.

3. It is a well-known optical phenomenon that a faint white light appears green when a strong red light is brought near it, and that a white light becomes blue when the stronger surrounding light is yellow. This is frequently manifested by multiple stars, or those that are comparatively near together. If the light emitted by a red star commingles with a feebler light from a white star, the white star will appear green; and if the light from a yellow star commingles with the light of a white star, the light of the white star will be blue. These new colors which are produced in this way are called complementary, as has been previously noticed,

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QUESTIONS.—1. Are these stars of nearly every color? 2. What is the probable cause of their difference of color? Does the color of one star change the color of another? 3. In what class of stars is this manifested? What are the new colors formed in this way called?

and vary in degree according to the relative quantities of light of different kinds that enter into their composition.

4. Consequently, some stars lose their natural colors and assume the complementary hue, not by any physical change in their photospheres, but simply by the union of the variegated rays which unite from different sources. But notwithstanding we are often deceived as it regards the natural color of stars, owing to these complementary hues, still there are stars, apparently isolated, which are possessed of positive colors, some of them being as red as blood, and others as blue as indigo. Sirius, the Dog-star, is one of them, and is the only one of this class which is known to have undergone any permanent change in the color of its light. Notwithstanding many of those stars that are complementary in color have lost in a measure their brilliant hues, yet it is the only one of its class known to have changed from its original ruddy color to a white, which is the most common color of these self-luminous bodies.

SECTION LXXIII.

New Temporary Stars.

1. SOMETIMES new stars burst forth into view, and old ones are observed to go out in darkness. Within the last two thousand years about twenty stars, hitherto unknown, have made their appearance in various parts of the heavens, but more especially along the Milky Way. This class of stars generally come sud-

QUESTIONS.—4. What causes the change of color to take place? Have some stars positive colors? What colors do some of them present? Do any that have positive colors change in color? What was the color of the Dog-star? What is its color now?

SEC. LXXIII.—1. Do new stars ever appear in the heavens and others disappear? How many new ones have made their appearance within the last two thousand years? What is said of the magnitude and brilliancy of this class of stars?

denly into view, increase rapidly in splendor, and are of different magnitudes when at their greatest brilliancy. A few days frequently, and sometimes only a few hours, are necessary for their full development.

2. In a majority of cases they scintillate more than other stars, and occasionally change in color as they change in brightness. Some of them become very brilliant, rivalling in splendor stars of the first magnitude as well as the larger planets, and are sometimes visible even at noonday. No motion or change of place is manifested by any of them; but the majority of them soon begin to fade away, and are invisible in a few days, whilst others are diminishing in brilliancy for twenty years before they totally disappear.

3. These stars go out in darkness, probably never again to be resuscitated, whereby the sense of vision may be awakened that we may be able again to behold them. In like manner is it with other stars whose advents are unknown. A few are known to have vanished from the heavens, and the places which they once occupied are now voids in the map of the starry vault. They are lost to our view, not likely by a destruction of their physical constitutions, or by annihilation, but probably by a cessation of an electrical process in their atmospheres which may be productive of their light.

QUESTIONS.—2. Do these stars scintillate more than other stars, and do they ever change in color? Are any of them ever visible in the daytime? What is said of the disappearance of these stars? 3. Do any of these stars ever reappear? Have any of the old stars ever disappeared from the heavens? What is the probable cause of their disappearance?

SECTION LXXIV.

New Permanent and Periodical Stars.

1. ANOTHER class of stars known to astronomers has come into view which is apparently permanent. Only a few of these stars have been discovered; yet they are sufficient in number to confirm the fact that they actually exist. They are similar to other stars, and are of various magnitudes. As comparatively little is known concerning them, we will now refer to those in which there is a periodical variation in their light.

2. They are generally of a reddish appearance when at their maximum magnitude, but change sometimes to a yellow, and then to a white, as they decrease in brightness; and the order is reversed as their light again increases. These are more numerous than those of any of the unusual classes which we have noticed; and they vary in their periods from three to five hundred days, and, it may be, even hundreds of years. Some of them are regular in their variations, and others very irregular,—so much so that no law appears to be applicable to them.

3. The star Algol, in the constellation Perseus, is an instance of those of regular periods. It changes from a star of the second magnitude to one of the fourth in three hours and a half, and returns to the same magnitude in the same length of time. Remaining stationary in magnitude for two days, it again goes through the same variations.

4. Other stars appear to oscillate back and forth in magnitude, diminishing from one magnitude to another,

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QUESTIONS.—1. Have stars made their appearance which are apparently permanent? Do they resemble other stars? 2. What are variable stars? What is their color when at their maximum magnitude? Do they change in color? Are their periods of variation of equal length? Are they all regular in their variations? 3. What is the period of Algol? 4. Are there other stars that are very irregular in their variations in magnitude?

and again increasing, afterwards diminishing and becoming totally invisible, and then rekindling and returning again to their original brightness, only to enter on a greater diversity of temporary phases. Stars of every degree of brightness that can be distinctly observed are subject to these fluctuations; but they are confined more especially to those embraced between the sixth and ninth magnitudes.

5. To account for these peculiarities has occupied the attention of men of science ever since their discovery. Some have conjectured one cause, and others another. The circulating of opaque bodies around them, as the planets revolve around the sun, partially obscuring them at every revolution, is one theory. Another is that these stars may revolve on their axes, and may have very large dark spots on one side, and when the side which has the spots on is turned towards us their light would be diminished.

6. May it not be that their light is generated by electrical currents in their atmospheres, and may the variations of brilliancy not be accounted for by the increased or diminished activity of this invisible agent, which probably pervades all worlds in greater abundance than it does our own? Discovery and experiment seem to direct us to these conclusions, and untiring research may yet unfold more fully not only the secrets of their nature, but also of their relations.

QUESTIONS.—Stars of what magnitude are more especially subject to these variations? 5. What are some of the theories concerning these fluctuations? 6. What is the probable cause of these changes in magnitude? What seems to direct us to this conclusion?

SECTION LXXV.

Relations of Multiple Stars.

1. STARS are frequently united optically as well as physically, notwithstanding the great distances which separate many of them; and the number of both kinds which have been discovered amounts to between five and six thousand. The law of gravitation—the great parental law of the universe—prevails wherever matter exists, and holds all worlds and firmaments and schemes and systems subservient to the will of their Creator. Heavenly bodies are not only grouped together in consequence of their apparent juxtaposition, but they are actually held together by this universal force. We see it operating in every part of the universe.

2. Planets, satellites, and comets are all held in their orbits by this law; neither are the stars insensible to its sway, though apparently isolated, or companions of each other. Many of them are united in pairs, and double and triple pairs, by its omnipotent control, and constitute systems of themselves, which are truly wonderful in their arrangement.

SECTION LXXVI.

Stars Optically United, &c.

1. STARS are sometimes united optically, when they have no immediate physical connection. In the former case they appear near together, not because they are actually so, but in consequence of their being nearly on

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QUESTIONS.—1. In what two ways are stars apparently united? How many thousand have been discovered? Are the stars subject to the law of gravitation? 2. Are the planets, satellites, and comets? Are some of the stars united by it in pairs and systems?

SEC. LXXVI.—1. What do you understand by an optical union of stars?

the same line of vision. As may be seen by referring to Fig. 45, No. 1, they appear to the naked eye as one star, in consequence of their light travelling in the same direction and commingling before it reaches the eye of

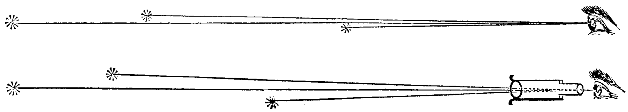

Fig. 45.

the observer; but when viewed by the telescope they are resolved into a number of individual stars, varying often in size and color, as may be seen by referring to Fig. 45, No. 2.

2. It is known by actual experiment that the further we recede from objects the nearer they appear to approach each other, and the further we are distant from the stars their connection appears more intimate, till a number of them separated by almost inconceivable distances, though nearly in the same line of vision, present the appearance of a single body. About five thousand of these multiple stars have been discovered in both hemispheres which have only an optical connection, whilst there are only about six hundred similar in appearance, the component parts of which are known to hold to each other a far more intimate relation.

QUESTIONS.—How do stars appear to the naked eye when united in this way? How when observed by the telescope? 2. Do bodies appear to approach each other the farther they are removed from us? Is this true in relation to the stars? How many thousand stars have been discovered to have an optical union?

SECTION LXXVII.

Stars Physically United, &c.

1. STARS physically double, like those which we have described, resemble single stars, and they would not be known as any thing else, were it not for the descrying power of the telescope. It reveals their plurality by causing them to appear to separate into parts, and testifies to the inflexible power of those dynamical laws by which they are all controlled. Under its almost omniscient gaze, stars single in appearance are resolved sometimes into various parts which have a mutual motion around each other.

2. These component parts, taken together, are denominated systems, varying in name according to the number that compose them. The binary systems embrace two stars, and are by far the most numerous. The ternary systems embrace three stars; and only one hundred and thirteen of these are known to exist. The quaternary embrace four stars; and only nine of them have been discovered. There are two quintuple systems, and only one sextuple and one octuple system, as yet, discovered.

3. As already noticed, stars apparently single are resolved into these various systems by the use of the telescope; and even some of the component parts of these systems might be separated still further, if we had better facilities for observing them. A view of all of these systems is represented by Fig. 46.

4. Letter A represents a binary system. Only a single star is first observed; but when viewed by the

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QUESTIONS.—1. What do you understand by a physical union of stars? How do they appear to the naked eye? How when examined with the telescope? 2. When the component parts are taken together, what are they called? A system composed of two stars is called what? What if composed of three stars? What if composed of four? What if composed of five? What if composed of six? What if composed of eight? 3, 4. Has each of these systems a centre of gravity?

telescope it separates into two, which parts are known sometimes to have a mutual revolution around each other. These parts vary sometimes in color, and they have a centre of gravity of their own. This centre of gravity is a point in space distant from each according to their respective masses; and the curves which they

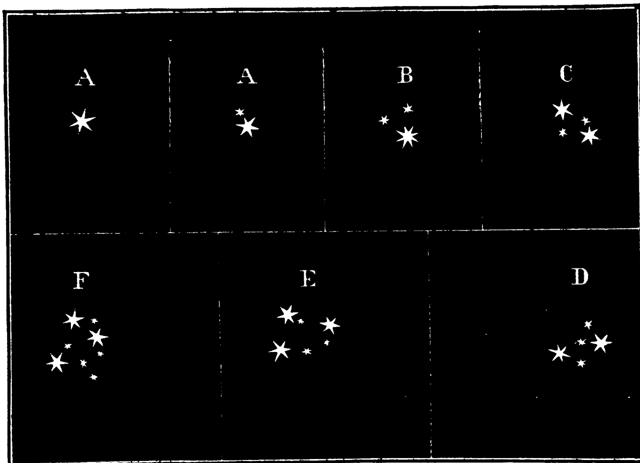

Fig. 46.

describe in their periodic revolutions will bear to each other a similar proportion. If the mass of one is comparatively large, the curve that it will describe will be proportionally less than the curve which is described by its less companion.

5. The periods of their revolutions vary from thirty to a thousand years, as is evident from the fact that some of them have actually completed their periods around each other, according to calculation, since their orbital motions were discovered. The same is also

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QUESTIONS.—May it be a point in space, or one of the stars? 5. What are the lengths of some of their periods? Are the other systems noticed in this section similar to the binary system?

true of the triple, quadruple, quintuple, sextuple, and octuple systems, which are represented by the following letters in Fig. 46, B, C, D, E, F.

6. In the first instance each of these objects presents the appearance of a single star, and by the use of the telescope one separates into two parts, another into three, another into four, another into five, another into six, and another into eight stars, all of which component parts of each system have an intimate physical relation. They separate more especially into pairs, indicating that the parts of each pair have a closer connection than the pairs themselves. Each pair sometimes has its centre of gravity, and one member revolves around another; while all of the pairs revolve around a centre of gravity common to the whole system.

7. The centre of gravity of such a system would be a point in space, unless one of the bodies in the system should be very large when compared with the mass of all the rest; and then they would circulate around it, as the planets do around the sun. For the stability and perpetuity of these systems, it matters not under which of these conditions they are placed, as they are all subject to the force of one universal law, whose prerogative it is to reign over every thing material.

SECTION LXXVIII.

Clusters of Stars.

1. Besides the objects which we have attempted to describe, numerous clusters, composed of hundreds of

Questions.—6. How do they appear to the naked eye? How do they appear to separate when viewed by the telescope? Has each pair a centre of gravity? Has the whole system also a centre of gravity? Are they all in motion around these centres? 7. If the centre of gravity of such a system was a very massive body, comparatively, how would the others revolve? Are all of these systems subject to physical laws with which we are in a measure familiar?
Sec. LXXVIII.—1. What is a cluster of stars?

glowing worlds, have been brought to view by the aid of optical instruments even of moderately penetrating powers. A group in the constellation Taurus, called the Pleiades, is one of them. Six or seven stars in it are visible to the naked eye, and about two hundred more may be seen with the aid of the telescope, apparently wedged in and projected on one another, as if there was no other space for them to occupy.

2. In the constellation called Coma Berenicis, there is another such group, though not so densely crowded together, and composed of much larger stars. Also, in the constellation Cancer, there is a cluster of very small stars, called Præsepe, which is sufficiently luminous to be seen at night in the absence of the moon, and may be resolved into separate stars, even with an ordinary spy-glass. Another such group is also found in the sword-handle of Perseus, composed of smaller stars, from which we would infer that it is much farther from us.

3. The general outline of these clusters is oval or globular, and they all appear to be more thickly populated or grow denser towards their centres. Nearly all of them are composed of stars of different magnitudes, and frequently of different colors, notwithstanding a few of them are uniform in these respects. From the two specimens represented in Fig. 47, some knowledge may be obtained of their general appearance, and we be led to inquire what wonderful dynamical arrangements can prevail in these stupendous sidereal systems, whereby order and harmony are maintained. Surely their component parts must fly with great velocity, and forces inconceivable must be exerted on each other to perpetuate their stability and existence.

QUESTIONS.—Are they numerous in the heavens? What one is that in Taurus? How does it appear when viewed with the telescope? 2. What other constellations have clusters in them? 3. What is the general form of these clusters? Are the stars in them frequently of different colors?

4. If they all are suns, as we have evidence to believe they are, and each having an annual motion around its

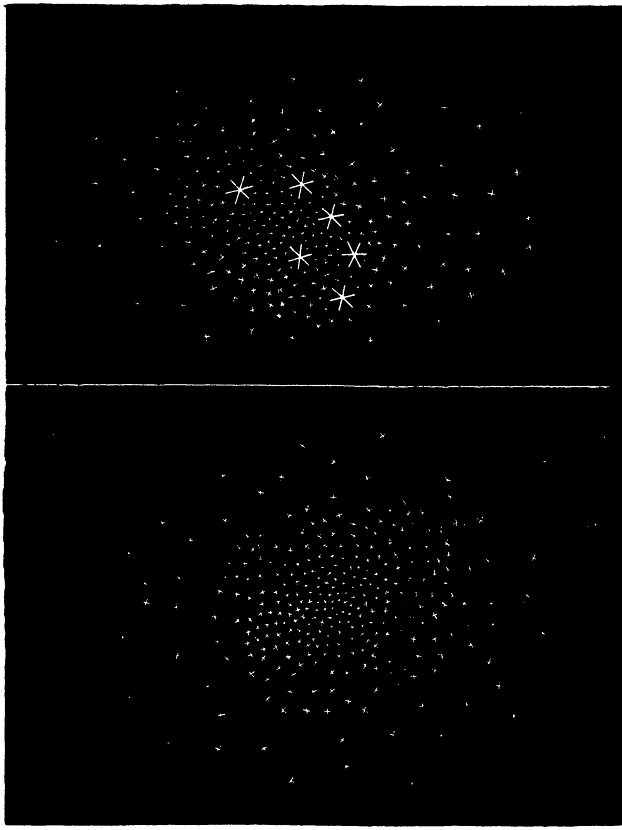

Fig. 47.

neighbor, and surrounded by circling planets, inhabited

QUESTIONS.—4. Are the bodies that compose these clusters self-luminous? Are they all in motion? May they have planets and satellites revolving around them?

probably with rational beings like our own, what must be the picture presented daily to their view! A red sun gilds the chambers of the east, a white one lights up the morning, soon a blue one spreads out its mild and mellow light, next a green one rises up to view, and, to variegate still more the color of the day, a yellow one blends its radiant beams in the chromatic picture, the equal of which the limner's pencil never painted, nor of which even Raphael had ever a conception.

SECTION LXXIX.

Nebulae.

1. ADVANCING farther into the unknown realms of the universe, we arrive at other cosmical objects, far more mysterious in their natures, and far more difficult to investigate. They are the nebulæ, or those patches of hazy light which are scattered, without any apparent regularity, in various parts of the heavens. They may be observed in whatever way the telescope may be directed; and they vary in form and brightness almost as much as the stars are known to vary in magnitude.

2. About four thousand of them have been discovered since they first attracted the attention of those devoted to the science of astronomy and engaged in exploring the heavens. Out of these four thousand, the greater number of which are in the northern hemisphere, nearly four hundred have been resolved, by the aid of the telescope, into clusters of stars; and no doubt many more of them might be resolved by increasing the facilities for observing them.

QUESTIONS.—If they have, what variations would occur in the light that constitutes their day?

SEC. LXXIX.—1. What are the nebulæ? Are they irregularly distributed over the heavens? 2. How many of them have been discovered? Are they more numerous in the northern or southern hemisphere? How many have been resolved into stars?

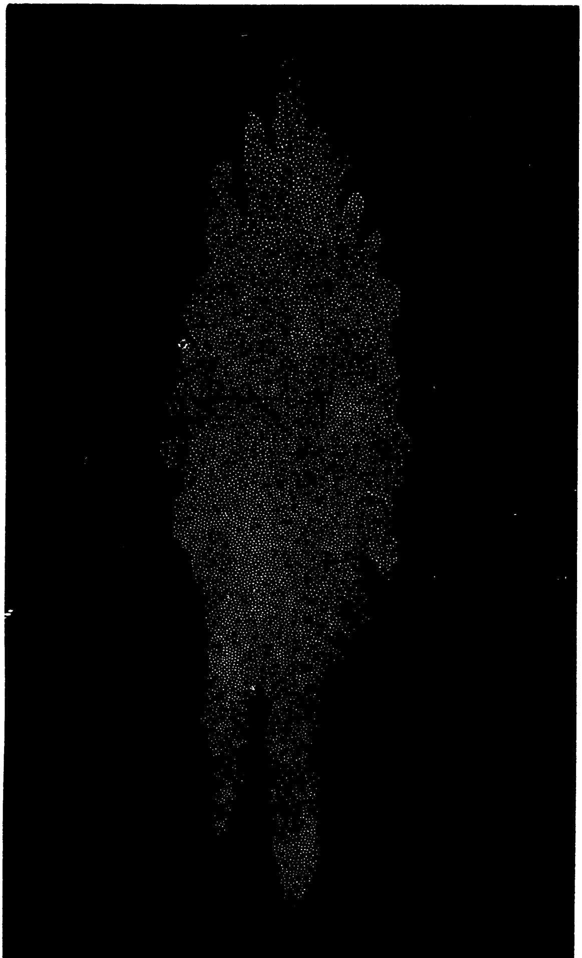

Fig. 48.

3. From the appearance of some of them we might infer that they are within the limits of our stellar system, and from the appearance of others we might as readily infer that they are at an inconceivable distance beyond it. No sufficient data has been discovered whereby we may determine this uncertain question, much less be able to discover the nature of their physical constitution.

4. Some of these nebulæ have been regarded, by men of great scientific ability who were favorable to the theory of a progressive formation and development of stars or worlds, to be self-luminous matter, undergoing a constant but almost imperceptible condensation. Others, of equal ability, are of the opinion that they are all great astral systems, buried so deep in space that nothing of them is visible, even with the aid of the most powerful glasses, except the faint glimmerings of their almost exhausted light.

5. In justification of the conclusions of the former, they contend that some of the nebulæ are growing less, losing the irregularity of their outlines, and becoming more globular in form. Also, they refer to the fact that there is celestial star-dust, or vaporous material substances, which are manifested by the zodiacal light and meteoric showers and comets within the planetary system, and why may not material elements analogous in their nature exist in various parts of the sidereal universe? Why may not these gaseous, nebulous masses exist in space like other heavenly bodies, and why may they not condense, through time, by their own molecular attraction, into worlds, and finally shine out like stars in the celestial firmament?

6. On the other hand, it is affirmed that scientific discoveries direct us to far more rational and accredited

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QUESTIONS.—3. What is said of the places they occupy? 4. What is the opinion of some astronomers concerning them? What of others? 5. What evidence is adduced by the former in favor of their opinions? 6. What by the latter?

results. With the optical facilities which we now possess, we are enabled not only to descry the nebulæ, but in many instances to penetrate beyond their filmy dimness that first attracts our notice, and fathom their depths and behold their glory. Many of these objects may be seen with instruments of moderate powers; and by constantly increasing their powers they manifest themselves more distinctly, till thousands of stars, of almost every class and color, burst forth into view, apparently in such proximity as to appear like diamond points joined together at insensible distances.

7. Some of the nebulæ offer such phenomena when they are made the objects of special investigation, whilst others have resisted every effort which has been made to resolve them. The more closely they have been examined by a succession of instruments of increased penetrating powers, they exhibit more and more the appearance of what, in all probability, the great majority of them are,—clusters of stars.

SECTION LXXX.

The Milky Way.

1. THE Milky Way has to the naked eye a nebulous appearance (see Fig. 48); but if a telescope of high power is directed towards it on a cloudless night, the nebulosity disappears, and thousands of very small stars, otherwise invisible, will, even in a few moments, be presented to view.

2. In this dim luminous zone one cluster of stars is crowded upon another so compactly that their parts appear to constitute as it were a great highway around

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QUESTIONS.—Which theory accords best with what is known? 7. Have some of the nebulæ resisted every effort to resolve them?

SEC. LXXX.—1. How does the Milky Way appear when viewed by the telescope? 2. Are the stars that compose it very numerous and apparently near together?

the heavens, paved with stars. These clusters are buried deep in space; and were it not for the artificial multiplication of the powers of vision, their existence would never have been indicated by that whitish hazy arch of light which we are permitted to observe.

3. The galaxy which they form, together with every other heavenly object similar in appearance in point of light, would have remained a hidden mystery, and those innumerable solar universes, far beyond the limits of our own, would have never revealed to us their existence. Not only would we be destitute of a knowledge of them, but also of all the peculiarities whereby they may be distinguished. Some of them are exceedingly irregular in their forms, and present outlines very indefinite and confused, like the Magellanic Clouds, as they are called, which are situated in the southern hemisphere.

SECTION LXXXI.

Magellan Clouds.

1. The two Magellan Clouds, or, more properly, the two patches of light which are known by that name, are situated in the southern hemisphere, and cover an area of about fifty degrees. These objects differ in size, are oval in their general form, and are visible, when above the horizon, to the naked eye. The smallest is the most brilliant, and in appearance both of them resemble the Milky Way. Some astronomers consider these objects as off-shoots or branches of the galaxy, and it is possible that they are: still, we may regard them as constituting a class differing somewhat from it in con-

Questions.—3. Are we indebted to the telescope for all of these discoveries?

Sec. LXXXI.—1. Where are the Magellan Clouds situated? How much of the heavens do they occupy? What is the form of these objects? Are they visible to the naked eye? Which is the most brilliant? What do they resemble? In what respect do they differ from it?

sequence of the inherent diversity of the objects that compose them, their irregularity of form and indefiniteness of outline.

2. When either of these clouds is examined through telescopes of great power, they disclose to the observer single stars, clusters of stars, and nebulæ. In general the clusters appear globular in form, and the stars that compose them, in certain instances, appear crowded upon each other towards their centres. The nebulæ that have been discovered in these clouds are of nearly every variety of formation found elsewhere in the heavens, and some are of unusual forms, which are nowhere else discoverable in the universe. Few of these unsymmetrical figures resemble each other; neither are they uniformly distributed in the celestial regions which they occupy.

3. About three hundred and twenty clusters and nebulæ have been discovered in the larger cloud, and about forty of both kinds have been observed in the smaller one. If we regard either of these clouds as single bodies, they are less rich in stars and less condensed towards the interior than any known class of stellar clusters or nebulæ, except those known as the nebulæ proper.

SECTION LXXXII.

Nebulæ Proper.

1. Of this class there is a great variety. Some of them appear to be formed of little flocky or fleecy scrolls of matter, slightly wrapped together, like wisps of cloud, which are as it were casually distributed at no

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Questions.—2. Of what are these objects composed? What forms have the clusters? What is said of the nebulæ? 3. How many clusters and nebulæ are in the larger one? How many in the smaller? What is said of these clouds as single bodies?

Sec. LXXXII.—1. What is the appearance of some of the nebulæ proper?

great distance from each other. Others appear more uniform in their character, and have outlines which are definite and regular. They manifest no signs of resolvability, neither do they indicate that they are any thing except self-luminous phosphorescent patches of gaseous

Fig. 49.

vapor suspended against the black groundwork of the heavens. (See Fig. 49.)

2. In like manner is it with many of those that present a more definite and substantial appearance. Notwithstanding some of them are elliptical, and increase by insensible gradations of brightness up towards the centre, yet they do not appear as if they were clusters

QUESTIONS.—What of others? Can they be resolved? What do they appear to be? 2. What is said of those that are somewhat elliptical in form?

of stars, but only nebulæ in a high state of condensation. So also do those that are spindle-shaped resist every effort that has been made to resolve them into stars.

3. Some astronomers suppose that these objects are composed alone of self-luminous, nebulous matter; whilst others think it probable that their form and appearance result from the oblique direction in which a ring composed of clusters of stars sunk deep in space may be seen, as such objects are known to exist.

SECTION LXXXIII.

Annular Nebulae.

1. ONLY nine of these nebulæ have been discovered in the heavens, and every effort which was made till recently proved ineffectual in revealing their nature and character. Sir William Herschel had a knowledge of their existence, and some of them have received special attention by Lord John Rosse, with the aid of his great reflector.

2. The most celebrated one in the northern hemisphere is somewhat elliptical in form, and in a number of places around the ring it has been resolved into luminous points resembling stars. (See Fig. 50.) With an instrument of high power its outer margin is rendered irregular by the development of nebulous appendages; and the interior of the ring is slightly illuminated by a faint, hazy light, gradually decreasing towards the centre.

3. Others of this class are circular, and are well

QUESTIONS.—3. Are all of these objects self-luminous?

SEC. LXXXIII.—1. How many annular nebulæ have been discovered? What astronomers examined them? 2. Where is the most celebrated one located? What is its form? Have portions of it been resolved? What is said of its outer and inner margins? 3. What is said of other nebulæ of this class?

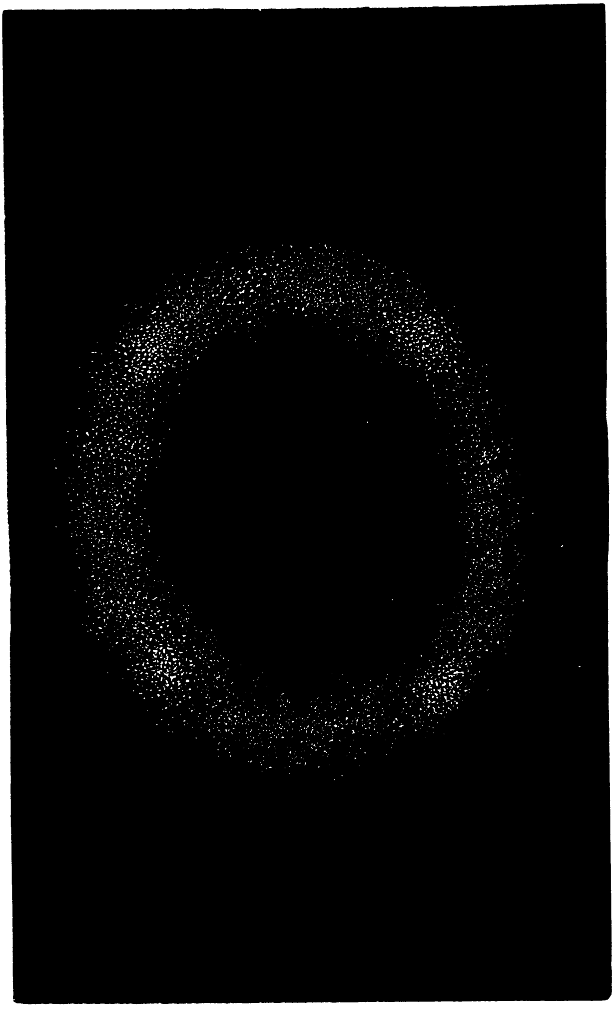

Fig. 60.

defined both without and within. They are in a great measure destitute of nebulous offshoots around their contours, and resemble a ring flattened in the direction of its plane, having no stars or nebulosity in the interior. They manifest no signs of resolvability, probably not because they are entirely nebulous, but because the annular congeries of stars of which they may be composed, contain stellar points so minute, by being so far away, as not to afford singly sufficient light to make an impression on the retina of the eye.

SECTION LXXXIV.

Stellar Nebulæ, and Nebulous Stars.

1. BESIDES the annular nebulæ, which we have just described, there are in the heavens objects equally if not more mysterious, known as stellar nebulæ, and nebulous stars. (See Fig. 51.) These objects differ somewhat in their outlines and general appearance. Sometimes the nebulous fluid is apparently drifted to one side of the star. Again it appears in globular form, gradually condensing from the circumference to the centre. In some the condensation is more sudden near the centre, presenting the appearance of a dull and blotted star.

2. In others there may be found the singularly beautiful and striking phenomenon of a sharp and brilliant star surrounded by a perfectly circular disc or atmosphere of faint light, in some cases dying away on all sides by insensible gradations, and in others terminating almost suddenly.

3. These wonderful objects naturally lead the mind

QUESTIONS.—Have they been resolved into stars? What is the probable reason why they have not been?

SEC. LXXIV.— 1. What objects are noticed in this section? What is said of some of these objects? 2. What of others? 3. Are these objects definitely understood?

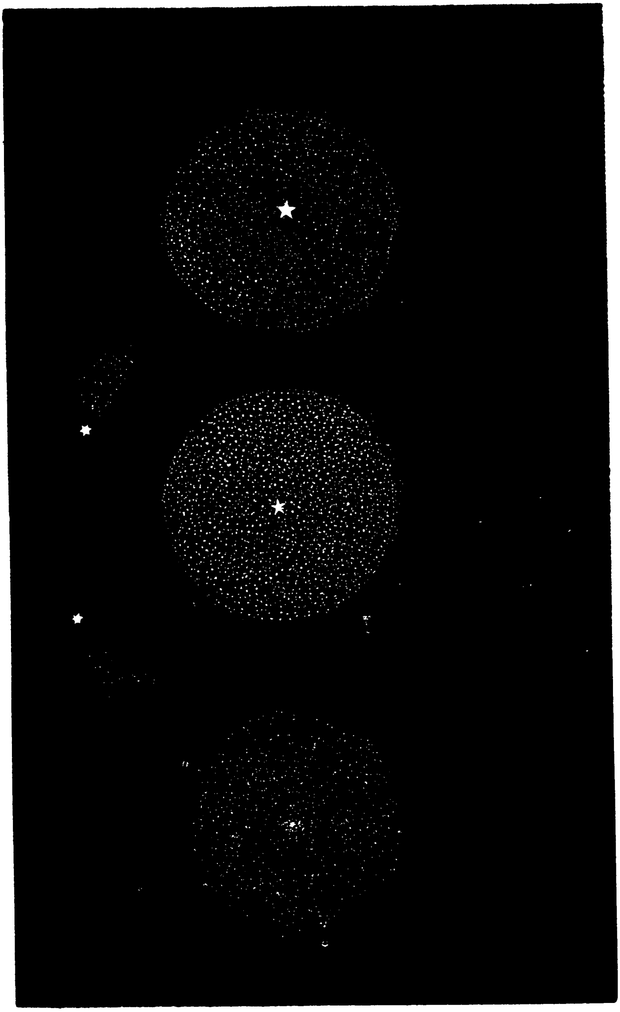

Fig. 51.

to inquiry and speculation. Were they originally primordial nebulous matter, and are they gradually condensing, and thereby arriving more and more at the perfection of stars or suns? Are their atmospheres self-luminous, or illuminated by the central body? Are they at an equal distance from us with other stars, and will they ever lose their nebulosity? These questions challenge the judgment; and with regard to being able to solve them, science has hitherto been silent.

SECTION LXXXV.

Planetary Nebulæ.

1. In like manner is it also with those objects in the heavens known as the planetary nebulæ. They present the most striking resemblance to planetary discs; and, whilst the greater number of them appear perfectly globular and sharply defined, yet there are others indistinct and vaporous at their margins.

2. They are of various colors, being usually uniform in their light, though in certain instances it is slightly curdled or mottled. From experiments which have been made on light emitted from a disc and that emitted from a self-luminous point, it is not improbable that they are very remote nebulous stars, in which the difference between the central body and the surrounding nebulous covering cannot be detected by the telescope.

3. A few of these objects have been partially resolved, so that in some, one star appears in the centre, and in others, two near together, with a ring of hazy light, emitted, it may be, by a great annular cluster of suns concealed in the infinite depths of space. (See Fig. 52.)

Questions.—Do we know much concerning their physical constitutions?

Sec. LXXXV.—1. What are the planetary nebulæ? What are their forms? 2. Are they all of one color? What are these bodies? 3. Do stars appear in the centre of any of them?

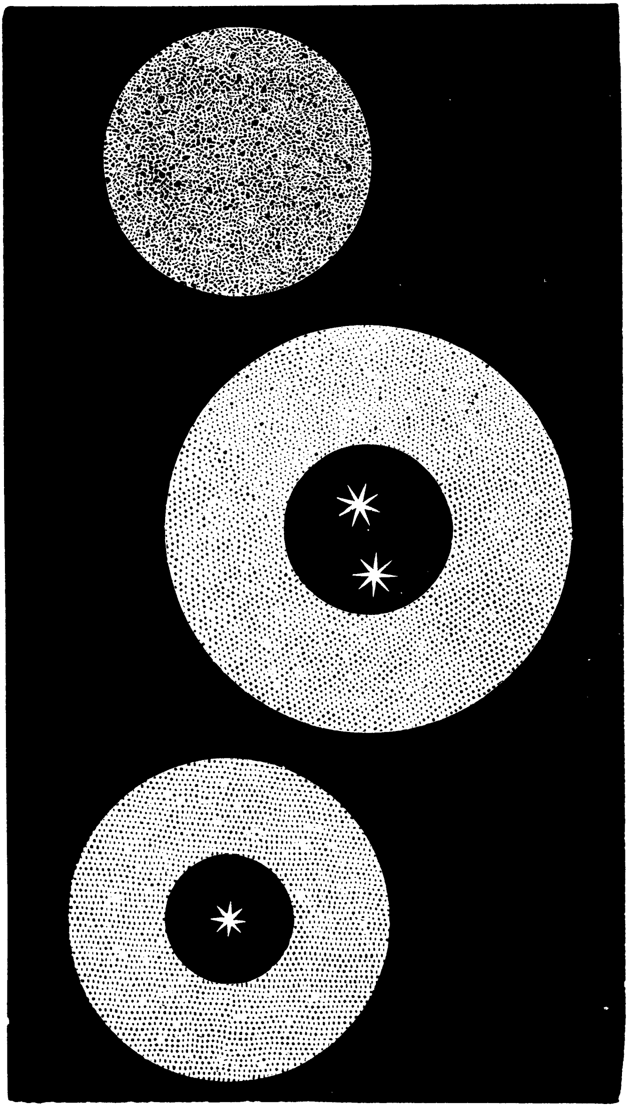

Fig. 52.

But, whatever may be their nature and the nature of the nebulous stars, they must be of enormous magnitude; and, granting that they are at an equal distance from us with the fixed stars, their real dimensions must be such as would fill the whole orbit of one of the outermost planets of the solar system. Such are some of the wonders that are scattered over the boundless field of space; yet there are other objects more wonderful.

SECTION LXXXVI.

Globular Nebulæ or Clusters.

1. THERE are a great number of globular nebulæ, promiscuously distributed in the heavens, which, when examined with instruments of great power, are perceived to consist generally of stars crowded together so as to have almost a definite outline and to run up almost to a blaze of light in the centre. Many of them present a figure exactly round, and thereby convey the idea of a perfectly spherical space filled full of stars.

2. Each appears insulated in the heavens, and to constitute in itself a family or society apart from the rest and subject only to its own internal laws. Others of them are not so regular in their outlines, in consequence of the paucity of stars in the outer parts, and, instead of exhibiting an ordinary stellar light, they are filled around their centres with rose-colored light, exhibiting an imposing contrast with the light of the exterior stars by which they are surrounded.

QUESTIONS.—Are these objects very large? Admitting that they are as distant as the fixed stars, what would be the diameter of some of them?

SEC. LXXXVI.—1. Of what are the globular nebulæ generally composed? How do they appear near their centres? 2. Are they apparently insulated in the heavens? Are their component parts subject to physical laws? Are these globular nebulæ ever irregular in their outlines? What is the color of some of them at their centres?

3. The stars in these clusters are very numerous, and are not to be reckoned by hundreds, but by thousands, apparently wedged in and projected on one another, so that the eye becomes enchanted by observing them, and the mind becomes bewildered in their contemplation. (See Fig. 53.) These clusters vary in size; and from

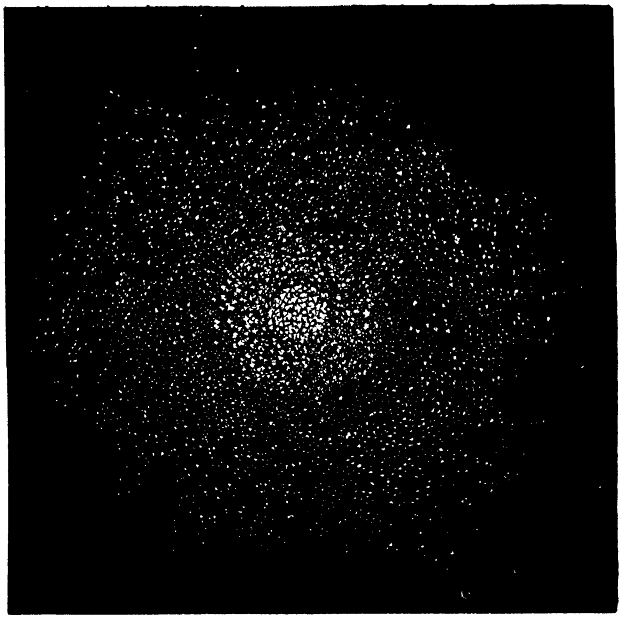

Fig. 53.

their forms it may be legitimately inferred that they are controlled in all their parts by the same laws which control all systems which pervade the universal heavens. The order and harmony that prevail in them assure us

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QUESTIONS.—3. Are they composed of many stars? Do they appear crowded on one another? Do these clusters vary in size? Are the existence and motions of the component parts of these systems the result of chance?

of the fact that their arrangement is not the result of chance, but that they are constantly made to feel the power of Him who has marshalled out the stars and called them by their names.

4. The law of gravitation is wherever matter exists, and has manifested itself not only in the peculiar formation of worlds, but also in the formation and perpetuity of those celestial schemes and systems, a perfect knowledge of which is possessed only by Him who is the Maker of them all.

SECTION LXXXVII.

Spiral Nebulae.

1. THE spiral nebulæ are probably the most remarkable objects in the heavens, both on account of their singular configurations and also the transformative effects produced on them by the telescope. Under its gaze some of them appear to change into heliacal twisted coils, or self-luminous spirals, whose convolutions appear unequal both in their centres and outwards, and are prolonged at either extremity into dense, globular knots. (See Fig. 54.) Others also pass through many phases when placed under the increased power of optical instruments, until when in their last stages of development they resemble a crown of luminous hair.

2. These objects are few in number; and the inquiry now, no doubt, suggests itself, What can they be? Are they systems of stars so far away and so closely crowded together as to appear like a single body? or are some of them double systems of suns, held in dynamical equilibrium by other cosmical systems, equal if not superior to themselves? Do their component parts

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QUESTIONS.—4. What law has manifested itself in their formation and government?

SEC. LXXXVII.—1. Describe the spiral nebulæ. 2. Are the spiral nebulæ numerous? Are they systems of stars or suns?

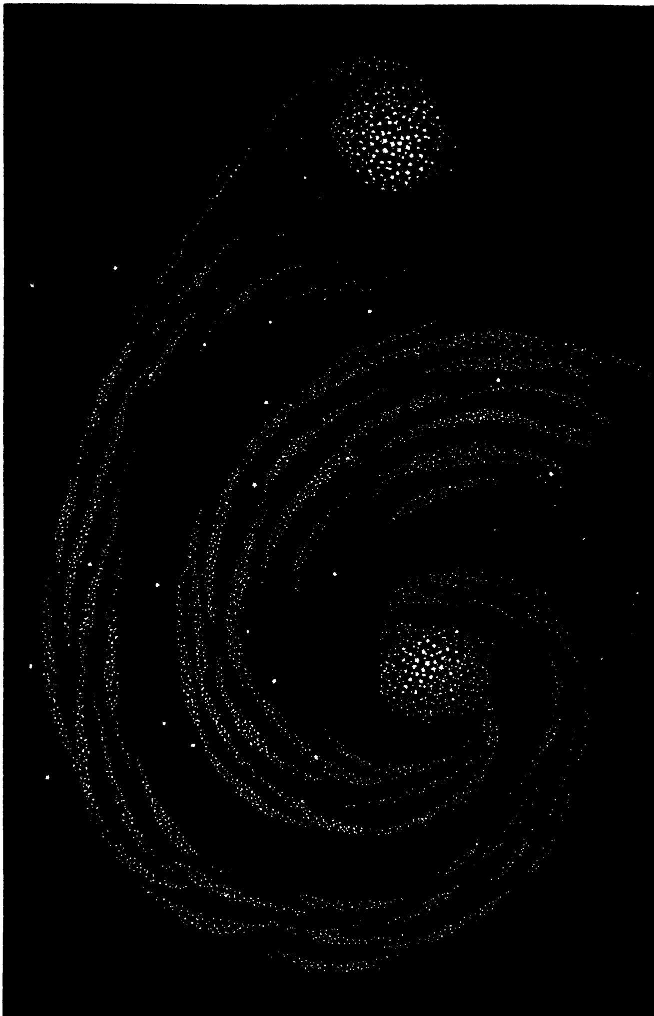

Fig. 54.

obey equally the centripetal and centrifugal forces, or are they in a constant state of collapse? Does their light represent their true form, or is it modified, in this respect, by any unknown influence?

3. In view of such unsolved problems as these, are we not ready, with the inspired penman, to exclaim, "Great and marvellous are thy works, Lord God Almighty," and does not a sense of our limited knowledge and of thine infinite greatness and the greatness of thy works constrain us to add, Truly, not only Thyself, but they also, are past finding out?

SECTION LXXXVIII.

Structure and Harmony of the Universe.

1. HAVING now presented very briefly, and in a measure separately and consecutively, some of the most prominent features and phenomena of the sun, planets, satellites, comets, nebulæ, and fixed stars, let us take a glance at them all as they loom up in beauty and grandeur before the intellectual vision. Go, in imagination, to yonder sun which is the author of light and life to our earth, and contemplate his might and his magnitude. He is hundreds of times greater than the aggregate of all his subordinates that play annually around him, and, according to an unerring providence, he controls them with a power absolute as despotism itself. No planet wanders out of its appointed way that he does not reclaim. No satellite deviates from its appointed course that he does not correct. No waywardness in the wandering comet is manifested that he does not restrain.

QUESTIONS.—Are they subject to physical laws with which we are familiar? Are they self-luminous? 3. What should our limited knowledge and the greatness of nature's works teach us?

SEC. LXXXVIII.—1. On what does this section treat? Does the sun control the planets and other bodies that revolve around him?

Implicit obedience is rendered by his subjects, infinitely more than unto a monarch on a throne.

2. But is the sun, with all his might, and grandeur, and glory, the great masterpiece of this boundless empire which we behold around us? Is he the only physical potentate that bears rule in the heavens? or is he himself not a subject? yea, a subject! There is a higher and mightier force than what he exerts, probably in the Pleiades, to which he with all his glorious cortege renders unremitted homage. With his retinue of dependent worlds he is hastening on with lightning speed to make his annual journey of more than eighteen millions of our years around the centre of this "island universe" of suns, of which this planetary system of ours is only an infinitesimal part.

3. The stars known by the name of fixed, and it may be all centres of subordinate systems, are paying obeisance also to this central force. It controls their motions according to their distances and their masses, and as a king of kings it sways universal empire over thousands of systems that roll majestically over the illimitable field of space.

4. But is this mighty central force, even, in this stellar universe of ours, the universal governor of all? Others may exist differing in office almost as much as finite differs from infinite. They may ascend by gradations in their functions, increasing in power and control in proportion to the increase of the number and magnitude of the suns and schemes and systems and firmaments that are their subjects. They may tend upwards in office and effect towards the eternal throne itself, till all created island universes, with all of their constituent parts, shall in their respective cycles circumscribe the

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QUESTIONS.—2. Is the sun the centre of the universe? Does the sun revolve around a centre? Where is that centre? How long is he making one revolution? 3. Do the stars also revolve around this centre? Do whole stellar systems revolve around this centre? 4. May there be other centres of motion superior to the sun, or that in the Pleiades?

highest; yet above them all there is an independent and immutable centre, around which they all move in harmony, an omnipotent Sun, from whom they all received their existence, an eternal Sun, to whom they all belong, and an everlasting central Sun, to whom they will forever be subordinate,—even the Sun of righteousness.

QUESTIONS.—Is there any living centre to which all others are subordinate? Who is He?

PART SECOND.

CIRCLES OF THE SPHERES.

Axis of the Heavens is the axis of the earth produced north and south into the starry heavens.

Poles of the Heavens are the extremities of the axis.

Equinoctial is the great circle formed in the starry heavens by extending the plane of the earth's equator.

Vertical Circles are great circles drawn through the zenith and nadir, the poles of the horizon, cutting it at right angles.

Prime Vertical is the great circle that passes through the east and west points of the horizon.

Ecliptic, the annual pathway of the earth, or apparent pathway of the sun which he seems to describe among the stars.

Equinoxes, two points where the equinoctial and ecliptic cross each other.

Obliquity of the Ecliptic, the angle formed by the ecliptic and equinoctial.

Poles of the Ecliptic, the extremities of the axis of the ecliptic, each twenty-three and one-half degrees distant from the poles of the heavens.

Parallels of Latitude are small circles north and south of the equator and parallel to it.

Parallels of Declination are the circles of latitude extended into the starry heavens parallel to the equinoctial.

Solstices are points in the ecliptic that on the celestial sphere touch the tropics of Cancer and Capricorn, and mark the limits to which the sun appears to decline north and south.

Polar Circles are small circles, each of which embraces one of the poles and is twenty-three and one-half degrees distant from it.

Meridians are great circles drawn through the poles, cutting the equator and equinoctial at right angles.

Colures, two great circles, one of which passes through the solstices and the other through the equinoxes, dividing the ecliptic into four equal parts, which mark the seasons.

Terrestrial Latitude is distance north or south of the equator, measured on a meridian.

Terrestrial Longitude is distance measured on the equator either east or west from a given meridian.

Celestial Latitude is distance north and south of the ecliptic, measured in the direction of its poles.

Celestial Longitude is distance east from the first point of the sign Aries, measured on the ecliptic.

Declination is the distance of a heavenly body either north or south of the equinoctial, measured on a meridian.

Right Ascension is the distance of a heavenly body east from the first point of the sign Aries, measured on the equinoctial.

THE ELEMENTS OF A PLANET WHICH ARE NECESSARY TO BE KNOWN TO DETERMINE ITS POSITION IN THE HEAVENS.

1. Its mean distance from the sun.
2. The periodic time of the planet.
3. The mean longitude of the planet at any particular time.
4. The longitude of the perihelion.
5. The longitude of the nodes.
6. The inclination of the plane of the orbit to that of the ecliptic.
7. The eccentricity of the orbit.

THE ELEMENTS THAT ARE NECESSARY TO BE IDENTICAL TO PROVE THE RECURRENCE OF A COMET.

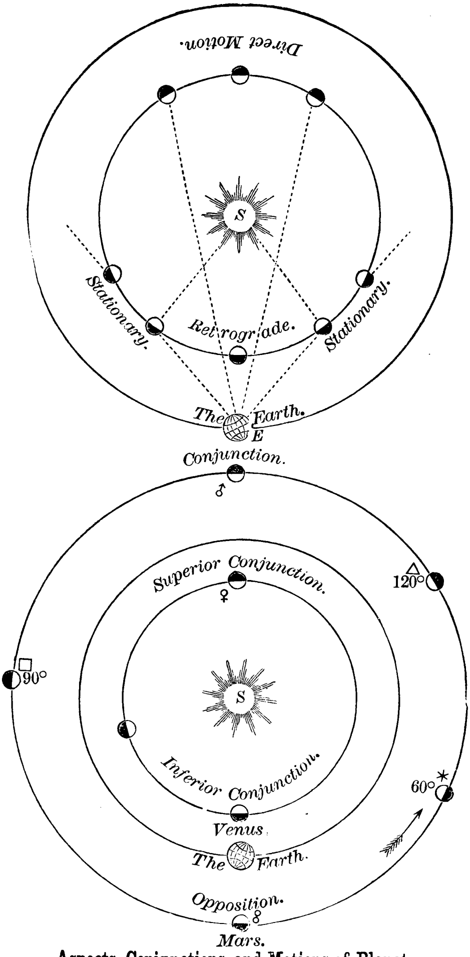
1. The inclination of the orbit.
2. The time of perihelion passage.
3. The perihelion distance.
4. The longitude of the perihelion.
5. The longitude of the node.

PLANETS AND CHARACTERS.

Sun - - -	🌞 or ☉	Asteroids - - -	○
Moon - -	🌕 ○ ◐ ◑	Jupiter - - -	♃
Mercury - - -	☿	Saturn - - - -	♄
Venus - - - -	♀	Uranus - - -	♅
Earth - - - -	⊕	Neptune - - -	♈
Mars - - - -	♂		

ASPECTS OF THE PLANETS.

Conjunction - -	☌	Opposition - - -	☍
Trine - - - -	△	Ascending Node -	☊
Quartile - - -	□	Descending Node - -	☋
Sextile - - - -	⚹		



Aspects, Conjunctions, and Motions of Planets.

SECTION LXXXIX.

The Visible or Sensible Horizon.

1. IF we were standing on a level plain, or on a vessel on the ocean, in whatever direction our eyes may be turned over the surface of either, the sky will appear

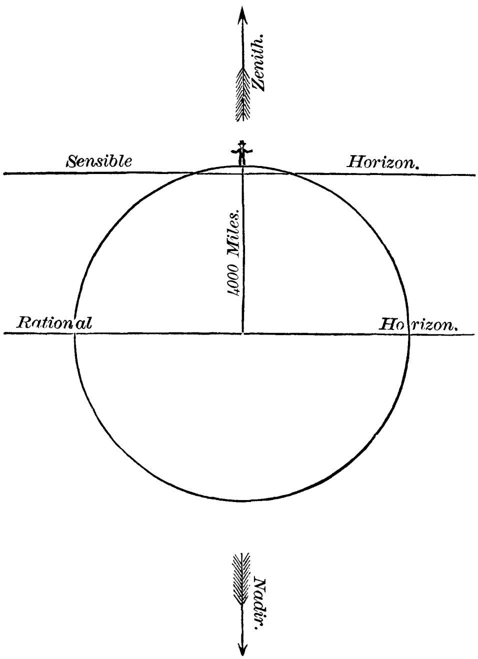


Fig. 55.

to come in contact with it. This apparent union of the sky with the earth or ocean appears circular in form,

QUESTIONS.—What is the visible or sensible horizon? Is it where it seems to be? Why?

and is called the visible or sensible horizon. This circle is not where it appears to be; neither does its plane pass through that point on the earth's surface where the spectator stands, as might be anticipated. (See Fig. 55.) In consequence of the convexity of the earth's surface, it is as much below the feet of the spectator as the earth's curvature is deflected from a horizontal line at the distance where the circle or horizon appears to be. This deflection, when accurately computed, amounts to about eight inches for the first mile, thirty-two for the second, and seventy-two for the third; but in ordinary computations no account is taken of it.

2. The horizon which is apparent to one person is not the horizon that is apparent to another, unless they should be both at one point; neither is it fixed in relation to any one, but is constantly changing as the observer changes his place. If he should stand on the equator, half of it would be in the northern hemisphere and half of it would be in the southern; and were he to move the distance of half its diameter, then it would lie wholly in one hemisphere. Were he to take his position on either pole, it would be equally distant from this point in every direction, if there were no irregularities on the earth's surface to obstruct the view. As a person moves from one place to another, so does the horizon. With every change in position there is a corresponding change in the horizon, wherever it may be on the surface of the earth.

QUESTIONS.—Is the horizon that is apparent to one person apparent to another, if they do not occupy the same position? Does the horizon change as the observer changes his position? If he should stand on the equator, how much of his horizon would be in each hemisphere?

SECTION XC.

The Rational Horizon.

1. THE limit of the rational horizon is an imaginary line extending clear round the earth, ninety degrees in every direction from any given point on its surface. The plane of this circle divides the earth into two equal parts, and is always parallel to the plane of the sensible horizon. (See Fig. 55.) If it was extended in every direction, it would divide the heavens also into two equal parts, or hemispheres, the one apparently above and the other apparently below. Like the plane of the sensible horizon, it changes with it, as they are always parallel to each other. Both of these horizons may be regarded astronomically as accompanying every person, no matter where he may be or what changes of position he may make. Their planes, if viewed from a distance equal to that of the fixed stars, though four thousand miles (or the half-diameter of the earth) apart, would appear to coalesce in the concave sphere of the heavens. Now, as they become apparently one by extending them, they may be regarded as producing one circular line clear round the heavens, cutting them always into two equal parts, or hemispheres. The limits of these parts, or hemispheres, will always change with a change of the position of the planes; and as there is no limit to their variations, there can be no conceivable place in the heavens where they may not extend.

QUESTIONS.—What is the rational horizon? How does the plane of this circle divide the earth? Is this plane always parallel to the plane of the sensible horizon? Are both of these horizons common to every person? How far are their planes apart? Would they seem to coalesce and be one plane if viewed from a distance equal to that of the fixed stars? Since they seem to coalesce in the concave sphere, how do they divide the heavens? Is this dividing plane fixed, or variable?

SECTION XCI.

Zenith and Nadir.

1. THE point in the heavens towards which a line extends upwards directly overhead, and at right angles to the planes of the sensible and rational horizons, is the zenith. (See Fig. 55.) The nadir is a point in the heavens directly in the opposite direction; that is, if the line that points upwards towards the zenith was extended down through the earth and continued towards the heavens on the opposite side of the earth, it would point towards the nadir. These points are the poles of the planes of both horizons, as they are apparently one when viewed at a great distance, and are always ninety degrees distant from the imaginary circle which is produced by the extension of these planes into the heavens. They have no permanent position, but constantly vary with the horizons and their planes, still maintaining a uniform relation to both.

SECTION XCII.

Arrangement of the Planets and the Planes of their Orbits.

1. THE sun is the central orb of the planetary system, and may be regarded, in relation to the bodies that revolve around him, as comparatively motionless. He serves various purposes of supplying them with light and heat, and by his attractive force he perpetuates their equilibrium and harmony in fulfilling the ends for

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QUESTIONS.—1. What is the zenith? What the nadir? What are these points the poles of? Are these points fixed, or variable? What causes them to vary? From what circles do they maintain a uniform distance?

SEC. XCII.—1. What is said of the relative motion of the sun? What is said of some of his offices? How are the planets situated in relation to each other?

which they were designed. The planets perform their journeys around him in orbits exterior to each other, the planes of which do not coincide, but are at different angles to each other. (See Fig. 56.)

2. If the plane of the earth's orbit is regarded as a stationary surface, from which the planes of the orbits of all the rest are measured, they are as follows. The plane of the orbit of Mercury, the planet nearest the sun, is at an angle with it of (7° 0′ 9″) seven degrees and nine seconds. The plane of the orbit of Venus, the second planet from the sun, is at an angle with it of (3° 23′ 33″) three degrees, twenty-three minutes, thirty-three seconds. The plane of the orbit of Mars, the fourth planet from the sun, and the first outside of the earth, is at an angle with it of (1° 54′ 4″) one degree, fifty-four minutes, and four seconds. The plane of the orbit of Jupiter, the fifth primary planet from the sun, is at an angle with it of (1° 13′ 47″) one degree, thirteen minutes, and forty-seven seconds. The plane of the orbit of Saturn, the sixth primary planet from the sun, is at an angle with it of (2° 29′ 35″) two degrees, twenty-nine minutes, and thirty-five seconds. The plane of the orbit of Uranus, the seventh primary planet from the sun, is at an angle with it of (46′ 27″) forty-six minutes and twenty-seven seconds. And the plane of the orbit of Neptune, the outermost planet of the whole system, is at an angle with it of (1° 46′) one degree and forty-six minutes.

3. It is apparent that the planes of the orbits of all these planets do not deviate far from the plane of the orbit of the earth: consequently, when we wish to observe any of them, they will always be found not far

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QUESTIONS.—Do the planes of their orbits coincide? 2. At what angle is the plane of the orbit of Mercury with that of the orbit of the earth? The plane of Venus' with that of the earth's? The plane of Mars' with that of the earth's? The plane of Jupiter's with that of the earth's? The plane of Saturn's with that of the earth's? The plane of Uranus' with that of the earth's? The plane of Neptune's with that of the earth's?

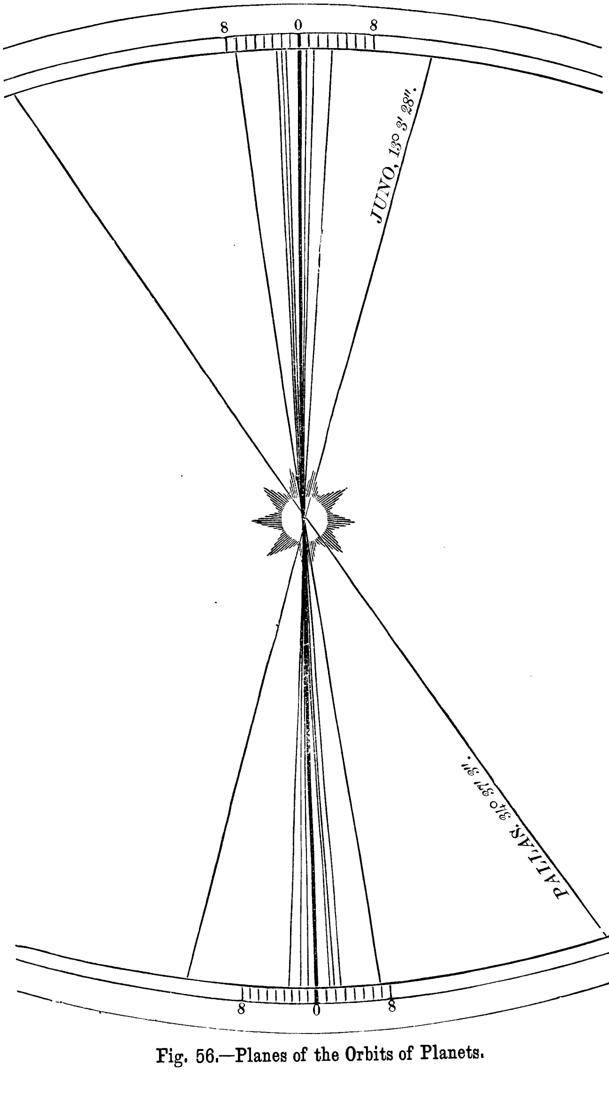

Fig. 56.—Planes of the Orbits of Planets.

either north or south of each other. All of them are within less than eight degrees of the plane of the ecliptic; and the very small angles which they have with each other may have resulted from one common cause in the formation of the planetary system.

SECTION XCIII.

Planes of the Orbits of the Asteroids and Comets.

1. NOTWITHSTANDING the planes of the orbits of the primary planets are not far from being coincident with each other, yet the planes of the orbits of other bodies belonging to the solar system are very far from it. The planes of the orbits of some of the asteroids, or ultra-zodiacal planets, as they are sometimes called, are at a very large angle with the plane of the ecliptic. All of these planetoids, or small planets, have their orbits at a greater distance from the sun than that of Mars, and less than that of Jupiter, though some of their planes are far from being coincident with that of either of them. The plane of the asteroid Juno forms an angle of more than thirteen degrees with that of the ecliptic; and the asteroid Pallas forms one with the same of more than thirty-four degrees. (See Fig. 56.) These large angles formed by these planes are not the rule, but the exception, as the general direction of the great majority of the planes of all the planets, whether small or large, is east and west.

2. Though this rule is general when applied to the planes of all of the heavier bodies that travel around the sun, yet it is not applicable to the planes of the

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QUESTIONS.—1. What is said of the planes of the orbits of some of the asteroids? Between the orbits of what two planets are the orbits of the asteroids? At what angle is the plane of Juno's orbit with that of the ecliptic? That of Pallas with that of the ecliptic? Are these large angles the rule, or exception? What is their general direction? 2. What is said of the planes of the orbits of comets?

orbits of comets when they come to be considered. They appear to extend in every direction, as if they were not subject to any definite law. Comets are found to come from the north and the south, the east and the west, and pass around the sun, sometimes to repeat their journeys, and at others to move off into the infinite depths of space, probably yielding to the greater influence of some other body or system to which they may hasten their flight.

SECTION XCIV.

The Three Great Laws discovered by Kepler.

1. THE planets travel in elliptical orbits around the sun, and the sun occupies a focus common to all of them.

2. The radius-vector passes over equal areas in equal periods of time.

3. The squares of the periodic times of the planets are proportional to the cubes of their mean distances from the sun.

Anterior to the promulgation of the Copernican theory of planetary motion, the circle, and the circle only, was regarded as the pathway of all the planets which were discovered to have motion. Ptolemy, who was an astronomer of Alexandria, one hundred and fifty years after the Christian era, held to this theory, as all his predecessors and successors did, till Kepler, about two hundred and fifty years ago, dispelled the error and shed a new light on the pathway of astronomical science.

2. Discrepancies were observed by him between the tables of antiquity, indicating where the planets should be found at certain times, and the places where he actually found them; and to reconcile them on the principle

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QUESTIONS.—1. What is the first law of Kepler? What the second? What the third? What form did ancient astronomers ascribe to the orbits of planets? 2. What led in part to the discovery of their true form?

of circular motion proved impossible. Undaunted by many abortive attempts to determine the true curve of the orbits, he abandoned the circle, and substituted in its place, for experiment, the ellipse. Locating the sun in the centre, as he had done when testing the circle, and observing the motion of the planet, it still did not conform to the conjectured curve. Considering next the sun in one of the foci, as this kind of a curve has always two focal points, and then observing the course of the planet, it was found to travel in an elliptical orbit, by its alternate rapid and less rapid motion, and satisfy perfectly the computations made in regard to where it should be found.

3. But this discovery did not rest alone for its validity on the inequality of motion, which of necessity resulted from the unequal distances that different points of the orbit are from the sun. The telescope, that far-searching eye which scans the workmanship of the Most High, corroborated with wonderful exactness the truth of this highly interesting achievement. This was done by taking observations of the sun at different seasons of the year. It is a fixed principle that if we observe an object near to us it will appear larger than when observed at a distance. Let us now apply this to the case under consideration. If the exact dimensions of the sun are taken when the earth is in the perihelion point of her orbit, he appears larger than he will six months hence, when the earth is in her aphelion; and he will appear to grow constantly less or larger as the earth travels to and from each of these points. This apparent increase and diminution of size indicate that at the points from which he has been observed he has been at unequal distances from the earth, fully verifying the fact that the orbit of the earth is not circular, but elliptical in form. (See Fig. 57.)

QUESTIONS.—How did Kepler proceed in this investigation? 3. Was the telescope used afterwards in confirming the truth of this discovery? In what way? Did the sun always appear of the same size? What did that prove?

4. Though science could now boast of another achievement, its author did not rest satisfied with what he had already attained. Kepler discovered also that

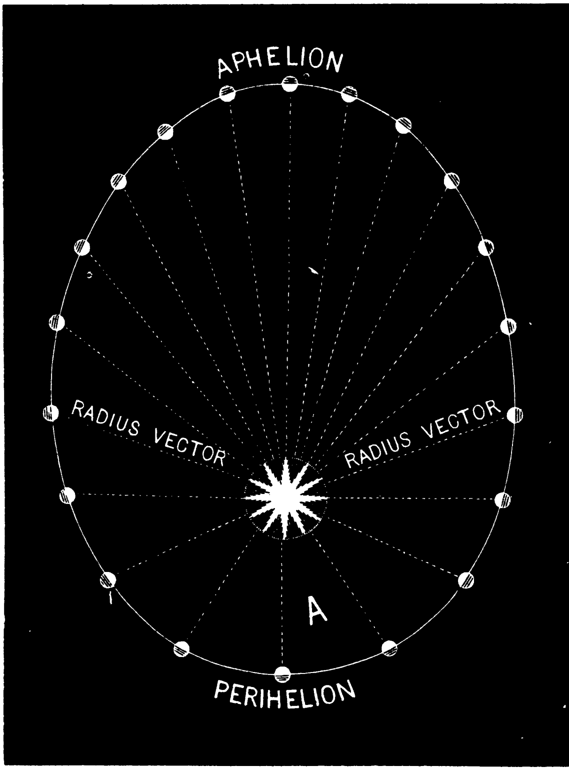

Fig. 57.

the radius-vector—an imaginary line drawn from the centre of the sun to the earth—would be carried by the earth in her annual motion over equal areas in equal

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QUESTIONS.—4. What is the radius-vector? Does it pass over equal areas in equal periods of time?

periods of time; that is, if the earth would travel a certain distance in a certain time, the radius-vector would pass over as much of the plane of the earth's orbit as it would in the same length of time wherever the earth may be in her orbit. Though the area of the triangle A, Fig. 57, is wider than any one on the opposite side of the sun, yet it is shorter; and they all contain an equal amount of the plane which is embraced within the whole of the orbit.

5. This also was another achievement worthy of its author; but, to crown the whole with a climax which has rendered his memory immortal, Kepler discovered another law, whereby, if the periods of the planets are known, their distances from the sun can at once be determined; for the squares of their periodic times are proportioned to the cubes of their mean distances from the sun; that is, if the period of the earth is three hundred and sixty-five days, by squaring it, and saying, As this number is to the cube of the earth's distance from the sun, so is the square of the period of any other planet to the cube of its distance from him. These revelations, with those of Galileo and Copernicus, shook every former system of astronomy from their old foundations, and bared their vagaries and errors to the light, which was then beginning to shine in the midst of darkness. Notwithstanding they had innumerable supporters and admirers, their devotees were silenced by the irresistible light of truth, and the intellectual world, which they had enslaved so long, awoke to the contemplation of the harmony of nature.

QUESTIONS.—5. If the periods of the planets are known, how can their distances be determined by Kepler's third law? What effect, in general, had the discovery of these laws and the discoveries of Galileo?

SECTION XCV.

Orbits of the Planets.

1. THE orbit of a planet is the pathway in which it travels around the sun. Circular figures were supposed by the astronomers of antiquity to represent the orbits of all the primary planets that were known. That of the earth also, when it was discovered to be one of them, was regarded the same, till Kepler, a German astronomer, in the beginning of the seventeenth century, as we had occasion to notice, revealed the fact that it is an ellipse. The ellipse, though a plane figure, is more complicated in its properties than those of the circle. It has a centre and two focal points, and these focal points vary in distance from the centre in proportion as the figure is more or less elliptical. The distance from the centre to either focal point is called its eccentricity; and the sum of any two lines that are drawn from each focus to various points in the curve of the same ellipse is always equal. The sun is always located in relation to the earth, and all of the other planets, not in the centre of their orbits, which are ellipses, but in one of the focal points; and, consequently, their distances from him change every moment as they revolve around him. (See Fig. 57.)

2. The orbits of all the planets differ in their ellipticity more or less, and none of them are fixed; but they are constantly varying by the influences of other bodies on the bodies that produce them. These variations are sometimes constant for thousands of years in one direction, till some of them attain almost the circular form, and then they return through as many years to

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QUESTIONS.—1. What is the orbit of a planet? What is its form? Is the ellipse more complicated in its properties than the circle? Describe an ellipse. Is the sun located in the centre? Where then? 2. Do the orbits of all the planets differ in ellipticity? Are they all fixed, or are they constantly varying? Are their variations in one direction of long duration?

their greatest ellipticity, only to repeat the same variations. If the earth and the system to which it belongs are perpetuated as they are at present, in forty-five thousand years the orbit of the earth would become circular. But ere this should occur, the compensatory influence which the Divine Governor of all things has provided in the construction and arrangement of all His works will operate on the earth in an opposite direction, to restore the wonted equilibrium of our system. Though a small preponderance of the mutual attractive influence of a system of worlds may be long exerted on one body in the same direction, still it has its limits, and the object of its control is caused to return in the same period through a series of similar phases.

3. The orbit of Mercury is very elliptical, and that of Venus is nearly a circle, while that of the earth is not so much on either extreme. These facts may be ascertained by their angular velocities, and by the use of the telescope. It is a principle in optics that the apparent magnitude of a body is in proportion to its distance; that is, when it is at a certain distance it will appear of a certain size, and when five times nearer it will appear five times larger, and when ten times farther away ten times smaller, and so on. By taking observations of the sun, in the various seasons of the year, when the earth is in different points of its orbit, he will not appear of the same size. For six months in the year he appears to grow larger, and then to diminish in magnitude for the same length of time, only to repeat the same variations. About the middle of summer he appears less than at any other time, and about the middle of winter he appears larger, as he is then nearer to the

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QUESTIONS.—Do they ever become nearly circular? How long would it require that the orbit of the earth might become a circle? What is said of the compensatory influences of nature? 3. What is said of the orbits of Mercury, Venus, and the Earth? How were these facts discovered? What principle in optics is noticed here, and how is it applied in determining the form of the earth's orbit? As the sun is nearer to us in winter, why is it not warmer than summer?

earth, and were it not that his rays fall at that time in a very oblique direction on the zones north of the equator, the temperature would be actually warmer than in the middle of summer.

4. This apparent increase and diminution of size indicate that at these periods in which he has been viewed, he has been at unequal distances from the earth. (See Fig. 57.) If the earth's orbit was circular, he would always appear of the same size, being always the same distance away; and if the orbit was of any other form than that of an ellipse, he would not at these different periods present these successive variations of magnitude. In a manner almost similar the elements of the orbits of all the planets have been discovered. By observing them at different times during their annual periods, and by marking their changes in motion and magnitude, data are afforded whereby the ellipticity of their figures is determined.

SECTION XCVI.

Characteristic Points of the Orbits.

1. ASTRONOMICALLY considered, there are six points which are common to the orbits of all the planets whose axes are inclined to the planes of their orbits,—the perihelion and aphelion, the winter solstice and the summer solstice, the vernal equinox and the autumnal equinox. In consequence of the sun being always in one of the focal points of the orbits of the planets, each one is nearer to him at one time than at another. When they are at that point nearest to him, they are in their perihelion, and when at their greatest distance from him,

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QUESTIONS.—Does the sun appear to change in size when viewed at different seasons of the year? What does that prove? What is said in relation to finding the forms of the orbits of the other planets?

SECTION XCVI.—1. How many prominent points are common to the orbit of each planet? What are they? What is the aphelion? What the perihelion?

they are in their aphelion. (See Fig. 57.) These latter terms, when used in relation to the earth, are also called perigee and apogee; and both of them are sometimes known by the name of apsides, and the imaginary line that joins them is called the line of the apsides.

2. The apsides are not fixed points in absolute space, but are constantly moving from west to east; that is, the earth makes one entire revolution round the sun, and about twelve seconds of distance over, in passing from perihelion to perihelion again. These twelve seconds, converted into time and added to 365 days, 6 hours, 9 minutes, and 10.7 seconds, the length of a sidereal year, make what is called the anomalistic year; and in about 115,000 of them the line of the apsides, or the orbit itself, will make one complete revolution, the sun being the centre on which it moves.

SECTION XCVII.

Equinoxes and Solstices.

1. THE plane of the equator of the earth on the twentieth of March, when the days and nights are equal, passes directly through the centre of the sun. For three successive months from this time the sun appears to be moving slowly northward, till he arrives at a point at which he appears to stand still, when the days are at their greatest length. During the next period of about three months, he appears to move slowly southward, till on the twenty-third of September the plane of the earth's equator again passes through the centre of the

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QUESTIONS.—What other terms are synonymous with these? 2. Are the apsides fixed points in space? In what direction are they moving? What distance do they move annually? What constitutes an anomalistic year? How long does it take the line of the apsides to revolve once?

SEC. XCVIII.—1. Does the sun appear to move north and south? How many months in succession does he seem to move north? How many south?

sun, when the days and nights are again equal. For a period of three months more he appears to move in the same direction, till he again appears to stand still, when the days are at their shortest. During the period of the next three months he appears to move northward, till he arrives at the point which he left.

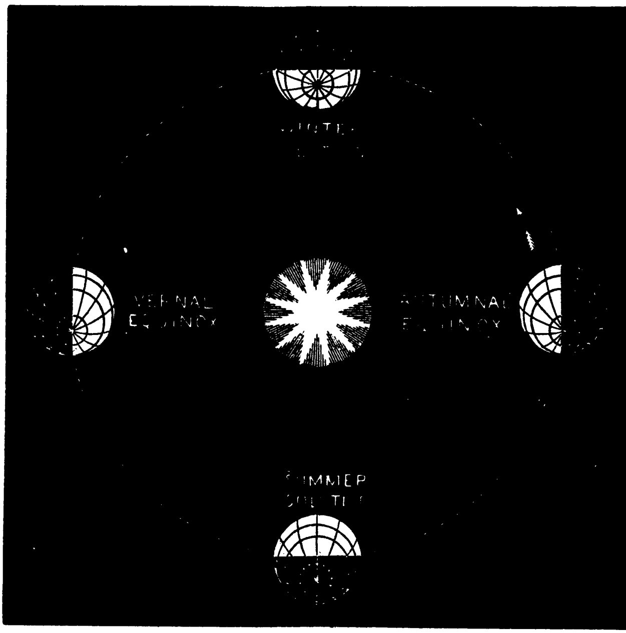

Fig. 58.

2. The point from which the earth left on the twentieth of March is the vernal equinox, because the days and nights are then equal. (See Fig. 58.) The point at which she arrived on the twenty-first of June

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QUESTIONS.—2. Where is he in relation to the earth on the 20th of March? Where on the 21st of June?

is called the summer solstice, because the sun appears there for a time to stand still. The point at which she arrived on the twenty-third of September is called the autumnal equinox, because the days and nights are again equal. The point at which she attained on the twenty-third of December is called the winter solstice, because the sun appears again for a time to stand still. (See note below.)

2. All these points belong to the orbit of the earth, and the apparent north and south motion of the sun does not result from any real motion of the sun north and south, but from the earth's annual motion and from the inclination of the earth's axis to the plane of its orbit. Its axis is inclined to the plane of the ecliptic about twenty-three and one-half degrees, and, it being always parallel to itself, the earth turns her polar regions alternately in her annual revolution towards the sun, which makes him appear to have a motion north and south. As she passes from the winter solstice, the sun appears to rise higher and higher in the heavens, till when at the summer solstice he is said to be at his greatest northern declination. And as she passes from the summer solstice, he appears to sink lower and lower in the heavens, till when at the winter solstice he is said to be at his greatest southern declination.

NOTE.—The reader will observe that the equinoxes and solstices are not named in this work, as they are generally, from the apparent position of the sun in the ecliptic at different seasons of the year, but from the position of the earth in her orbit at different periods.

QUESTIONS.—Where on the 23d of September? Where on the 23d of December? 3. Do these points belong to the orbit of the earth? From what do they result? What is the inclination of the earth's axis to the plane of the ecliptic? Is the earth's axis always parallel to itself? During what portion of the year does the sun appear to rise, or move north? During what portion does he appear to sink, or move south?

SECTION XCVIII.

Precession of the Equinoxes.

1. BOTH the equinoctial and solstitial points revolve around the orbit of the earth like the apsides, but in an opposite direction from those of the apsides. They move westward about fifty seconds of space each year, which at that rate would require nearly twenty-six thousand years to make one complete revolution. As the solstitial points always retain their relative distances from the equinoxes, being always dependent upon them, it will be only necessary to consider the cause that produces a change of the latter, to have a knowledge of the motion of the former.

2. The equinoxes are always at those points where the celestial equator crosses the ecliptic, and the angle formed by these lines is always equal to the inclination of the earth's axis to the plane of its orbit. These points are formed every year about fifty seconds farther west of where they were the previous year, for the reason that the earth in its annual revolutions arrives a little earlier at that point in its orbit where the days and nights become equal. (See the Fig. in this section.) If the earth was a perfect sphere, these points would be comparatively stationary, as the attraction of the sun and moon upon the earth would always be in perfect equilibrium.

3. But the earth is an oblate spheroid, flattened at the poles and swollen at the equator, on account of which the equilibrium in their mutual attraction is destroyed. As the greater amount of matter is at the

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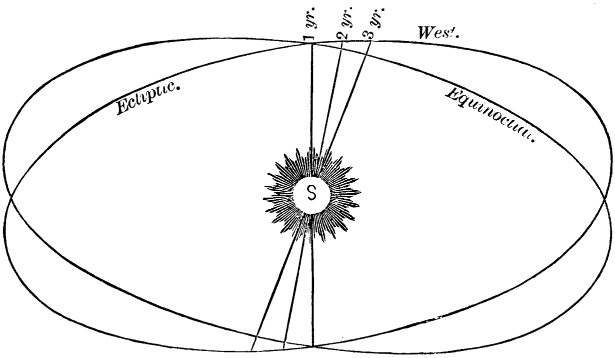
QUESTIONS.—1. Do the equinoctial and solstitial points move around the orbit of the earth? Do they move in the same direction as the apsides? What distance do they move annually? How long would it take them to make one revolution? 2. Where are the equinoxes in relation to the equinoctial and ecliptic? How much do they move westward every year? 3. What causes the precession of the equinoxes?

equator, it is there attracted with a greater force in an oblique direction, when the earth is not at her equinoxes, by both the sun and moon, which causes the equator to slide as it were westward on the ecliptic a little every day. This westward motion is not so much as might



Precession of Equinoxes.

at first be anticipated, owing to the fact that the planets counteract in a measure the action of both sun and moon on the earth, and makes the daily motion of the equinoxes less than it would otherwise be.

SECTION XCIX.

Nutation.

1. If the attraction of the sun and moon on the excess of matter around the equator of the earth was always the same, the pole of the equator would describe the circumference of a circle around the pole of the ecliptic. But such is not the case. Their influences

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Questions.—What counteracts the precession a little?

Sec. XCIX.—1. Is the attraction of the sun and moon ir an oblique direction on the excess of matter at the equator of the arth always the same?

are always varying as the earth and the moon change their positions in relation to each other and the sun. When the earth is at her equinoxes, the sun's action is nearly direct, and is not perceptible in this relation. But as she travels towards her solstice, his influence increases; and as she travels away from it, his influence diminishes. In like manner is it with the moon, though the periods are of more than eighteen times the length of those of the sun, as it requires her so much longer to resume her original orbit.

2. These changes in position produce corresponding changes in influence, and these changes of influence produce corresponding results. Instead of the pole of the equator describing the circumference of a circle as it revolves with the precession of the equinoxes, it describes a waved line, through the unequal attraction which is exerted periodically on the ring of matter that is in excess around the equator of the earth. (See Fig. 59.) This peculiar motion of the pole of the equator is called nutation, as it deviates alternately in either direction from the circumference of a circle in making its passage around the pole of the ecliptic.

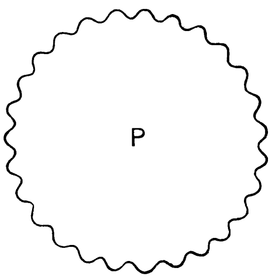


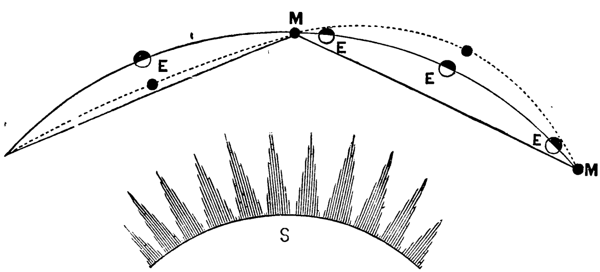
Fig. 59.

QUESTIONS.—What causes it to vary? What are their positions when it is not perceptible? What when it is most? 2. Are these influences periodical? Would their results be the same? What are the results in relation to the pole of the equator? What is this peculiar motion of the pole of the equator called?

SECTION C.

Lunar Orbit and Eclipses.

1. THE moon, which is a satellite of the earth, is carried along by her in her annual motion, as a constant companion, moving sometimes in her own orbit at the rate of twenty-three hundred miles per hour. She, like the earth, travels in an elliptical orbit, the concave side of which is always turned towards the sun. (See the first figure in this section.) The earth, instead



of occupying the centre of the moon's orbit, is constantly in one of the foci, which of course is nearer to one part of it than another. The nearest point of the orbit to the earth is called the perigee, and the point at the greatest distance is called the apogee. The difference of the distance of the earth from these two points is about twenty-six thousand miles: consequently, the moon is that much nearer to us at one time than at another. Sometimes these points are called the apsides, and the imaginary line that extends from one to the other is called

QUESTIONS.—1. At what rate does the moon move in her own orbit? What is the form of her orbit? Is she nearer the earth at one time than at another? What is the nearest point of her orbit to the earth called? What the point at the greatest distance? What other name are they known by?

the line of the apsides. These points are constantly shifting from west to east, through every successive month, and in each successive period of eight years, three hundred and ten days, thirteen hours, forty-eight minutes, and fifty-three seconds, they make a complete revolution, when the line that unites them returns to the same position that it left.

2. Besides these two points where the moon is nearest and at the greatest distance from us, there are two other points in her orbit of equal interest and significance, which claim our attention, and are known as the moon's nodes. As the plane of the moon's orbit does not coincide with the plane of the earth's orbit, but is at an angle with it of about five degrees, there are of necessity two points where the orbits cross each other. These crossing-points are called the nodes, and the imaginary line that unites them is called the line of the nodes. This line, like the line of the apsides, shifts a little every month, but in an opposite direction, as it moves from east to west. In eighteen years, two hundred and eighteen days, twenty hours, twenty-two minutes, and forty-six seconds, it completes one entire revolution, so that both the nodes have passed clear round the lunar orbit till each of them occupies again the same position that it did at the beginning of this period.

3. Owing to this fact, and others already noticed, the nodes are constantly approaching and receding from the earth within certain limits, as the orbit of the moon is elliptical in form. This being the case, and a part of the orbit of the moon being on either side of the ecliptic (see Fig. 60), as a result there are three kinds of solar and two kinds of lunar eclipses,—the annular, total, and partial of the sun, and total and partial of the

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QUESTIONS.—Are they constantly changing? In what direction? How long does it take them to make one revolution? 2. What are the moon's nodes? What is the line of the nodes? In what direction do the nodes move? How long does it take them or the line of the nodes to revolve once? 3. What is said of the causes of eclipses? How many kinds of solar eclipses are there?

moon. In an annular eclipse the shade of the moon, which is conical in form, falls short of the earth, and the body of the moon covers the central portion of the sun, leaving a ring of light all around at his circumference. In a total eclipse the moon is nearer to the earth, and her shade, which is then longer than the distance from the earth to her, passes over us, so that the sun is entirely concealed from our view. In a partial

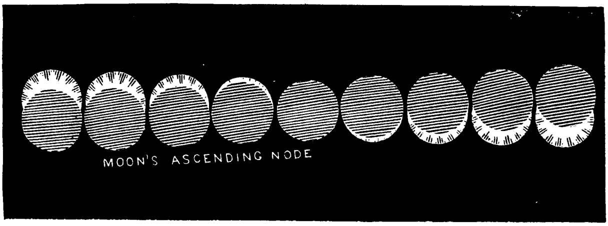

Fig. 60.

eclipse only one edge or limb of the sun is obscured, as the moon does not pass centrally over his disc.

4. In like manner is it with the total and partial eclipses of the moon. In a total eclipse the whole of the moon falls within the shade of the earth, and in a partial eclipse only a part of her disc enters the shade which is cast by the earth. Eclipses of both sun and moon can occur only when the moon is at or within about eighteen degrees of her nodes; for at no other time can the sun, earth, and moon be in either partial or perfect conjunction.

QUESTIONS.—How many kinds of lunar eclipses? Explain the solar eclipses. 4. Explain the lunar eclipses.

SECTION CI.

Method of Finding the Distance to the Moon, also to the Sun and from the Sun to the Planets.

1. CERTAIN mathematical elements are necessary to be known in order that we may find the distance to any inaccessible object. If it is required to find the height of a precipice without actually measuring it with a line, we stand a short distance from it, and take an observation of its top with an instrument that marks the number of degrees between the line of observation and a horizontal line, and then by measuring the distance to the base of it we have data sufficient to commence a correct mathematical calculation. A right-angled triangle is formed by the distan^ce to the base of the precipice, the line of observation, and the precipice itself, in which one line is found by measuring it, one angle is equal to (90°) ninety degrees, and the value in degrees of another is indicated by the instrument used for that purpose. These elements are sufficient to form a proportion from which we may obtain the distance to an inaccessible object.

2. In this way we may find how far it is to the moon. If we imagine a right-angled triangle formed by a line drawn from the centre of the earth to the centre of the moon's disc, and another from the surface of the earth to the same point, and both of them united by a third line, then we have a figure of which the length of one side, viz. the half-diameter of the earth, and value of one angle, are known, and the value of each of the other angles is easily found from the instrument that we use in such cases. (See Fig. 61.) These elements are all that are necessary to find the length of either of

QUESTIONS.—1. What is a right-angled triangle? How many of its elements are necessary to be known to find the remaining elements? Can the distance to inaccessible objects be measured by plane trigonometry? 2. Can we find the distance to the moor by this rule? In what way?

the other lines of the triangle, and either of them will satisfy the conditions of the question, as one of them measures the distance from the surface of the moon to

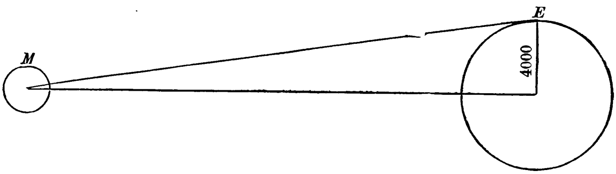

Fig. 61.

the centre of the earth, and the other measures the distance from the surface of the moon to the surface of the earth at the letter E, which is about 240,000 miles.

3. On the same principle we may find the distance to the sun. If two persons are stationed on the same meridian four thousand miles apart, and take observations of the sun at the same moment of time, he will not appear to each of them exactly in the same place in the heavens. By this apparent difference the value of each angle in the triangle is found, which is formed by the imaginary lines which extend to the sun, and the distance between the observers, which may be regarded as a line that unites them. From these elements which are obtained, the length of either of the lines which measure the distance to the sun may easily be found.

4. This distance once ascertained, the distance from the sun to any of the other planets is very readily computed, by Kepler's third law of planetary motion, since the periods of the planets may be known by simply observing the time it requires each of them to revolve around the sun from any particular star to the

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QUESTIONS.—3. Can we apply the same principle in finding the distance to the sun? How is it done? 4. How can we find the length of the periods of the planets? If the length of their periods is known, how can we find their distances from the sun by Kepler's third law when the distance of the earth from the sun is known?

same star again. Thus may the distance of each of them from the sun be obtained; for, according to this inflexible law, the square of the annual period of the earth, or that of any other planet, is to the cube of its distance from the sun, as the square of the period of any other planet is to the cube of its distance from him: hence, by extracting the cube root of the fourth term of the proportion, the desired distance is obtained.

SECTION CII.

Method of Finding the Magnitude of the Moon, Sun, and Planets.

1. In finding the magnitude of the moon, the same principles are involved which were employed in determining her distance from the earth. Her distance, as has been observed, was discovered by forming an imaginary triangle between the moon and the earth, the perpendicular line being the length of half of the diameter of the earth; but in finding her magnitude the order is reversed. By making the perpendicular the half-diameter of the moon, and by finding the length of it according to the principles of plane trigonometry, and then doubling it, we have found the length of her whole diameter, which is about twenty-one hundred miles. Now, by comparing this number with the number of miles in the diameter of the earth, it may be ascertained how many times larger the earth is than the moon; for, according to a fixed principle in the measurement of spheres, if the diameter of one is double that of another, the former will be eight times greater than the latter, and if the diameter of the one is ten times greater than that of the other, its magnitude will

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Questions.—1. What rule do we apply in finding the diameter of the moon? Which line of the imaginary triangle is the perpendicular in finding her diameter? When her diameter is found, how do we proceed to find her relative magnitude?

be a thousand times greater, and so on. By cubing the diameters of each, and dividing the less into the greater, the quotient will represent the size of the one compared with the size of the other.

2. Similar reasoning may also be employed in relation to the magnitude of the sun, and with similar results. As the three sides of a right-angled triangle are always proportional to each other, if the length of two of them is once found, the length of the third side can always be obtained. The length of two sides having been found in the imaginary triangle used in finding the distance to the sun, if the triangle is reversed, making his half-diameter the perpendicular line, its length is easily found, which if doubled will give his whole diameter, amounting to nearly nine hundred thousand miles. Now, from the length of his diameter we may conveniently arrive at his relative magnitude compared with that of the moon, or the earth, or that of any other spherical body whose diameter is known. By a principle already stated, the diameter of a sphere is always proportionate to its magnitude; and as the diameters of all spheres are always proportionate, so are all of their magnitudes. Hence, by comparing the diameter of the earth with that of the sun, we find that of the sun about one hundred times the greater; and by cubing both of them and dividing the greater by the less, the result will represent the relative size of the earth, which is about fourteen hundred thousand times less than the sun.

3. According to this method we may find the relative size of the moon compared with the sun. The sun's disc and the moon's disc appear nearly of equal size, and if they were at an equal distance from us and appear as they do they would be equal in magni-

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QUESTIONS.—2. Can we employ the same method in finding the diameter of the sun, and his relative magnitude? Explain how his relative magnitude is found. 3. How can we find the relative magnitude of the sun and moon when their diameters and distances are known?

tude; but as the sun is about four hundred times farther away, his diameter is about four hundred times greater: hence, by computing as before, the relative magnitudes of both are obtained. This principle is applicable in determining the relative magnitudes of all the planets, and of all other heavenly bodies whose distances are known and whose diameters can be measured.

SECTION CIII.

Seasons on the Earth.

1. In consequence of the obliquity of the plane of the ecliptic to the plane of the equator, and the earth's annual motion, the earth naturally divides itself into five zones,—one torrid, two temperate, and two frigid. These zones are of different widths, which result from the different places which the earth occupies in her orbit during the year in relation to the sun. When she is at the summer solstice, the sun then being at his greatest northern declination, his light is withdrawn twenty-three and one-half degrees from the south pole; and when she is at the winter solstice, and he at his greatest southern declination, his light is withdrawn from the north pole the same number of degrees.

2. It is apparent that the circle of the sun's illumination, which always embraces the half of the whole surface of the earth, changes about forty-seven degrees as the sun appears to go from north to south, and *vice versa.* This change is just as much as the apparent change of the sun, and amounts to just double the angle made by the plane of the equator and the ecliptic, and is the exact width of the torrid zone. *The Frigid Zones*

Questions.—What is said of determining the relative magnitude of other heavenly bodies?

Sec. CIII.—1. How many zones are there? What regulates the width of each? 2. What is the width of the torrid zone? How far does either frigid zone extend from either pole?

extend twenty-three and one-half degrees from either pole, which is the distance that the light of the sun extends beyond the poles, and is withdrawn from the poles, at different periods during the year.

3. The temperate zones embrace what is left from the other zones, and are limited by the tropic of Cancer and the tropic of Capricorn, and the distance that the sun's light is withdrawn at certain periods from either pole. All these zones have different seasons, which correspond to their respective locations on the surface of the earth; the more direct the rays of the sun fall on any part of the surface of the earth, the warmer it is; and the more oblique they fall on any part of it, the colder it is. Now, as the seasons depend upon the temperature, and the temperature upon the location of the zones, we will notice them in their order, commencing with those of the torrid zone. This zone is so situated that the rays of the sun are always direct to some portion of it, and, consequently, its temperature cannot at any time vary very much. When they are vertical on one side of it, its temperature diminishes a little on the other; and when the latter side is turned directly to the sun, the former also diminishes in temperature as much. These variations of temperature constitute or produce the seasons of this zone; and they are known as the wet and the dry.

4. In these apparent oscillations of the sun from north to south and south to north, from which result the seasons of the torrid zone, is found the cause also of the various seasons of the temperate zones. As the axis of the earth is always inclined in the same way, and always to the same amount in relation to the plane of the ecliptic, it is always parallel to itself; consequently, on the twentieth of March and on the twenty-third of September

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QUESTIONS.—3. What is the width of either temperate zone? Have the zones different seasons? How many seasons are in the torrid zone? What are they? What causes them? 4. Do the same causes produce the seasons of the temperate zone?

the earth is at her equinoxes, and the light of the sun extends to either pole. When she begins to leave her vernal equinox, her north pole rises slowly by the earth's

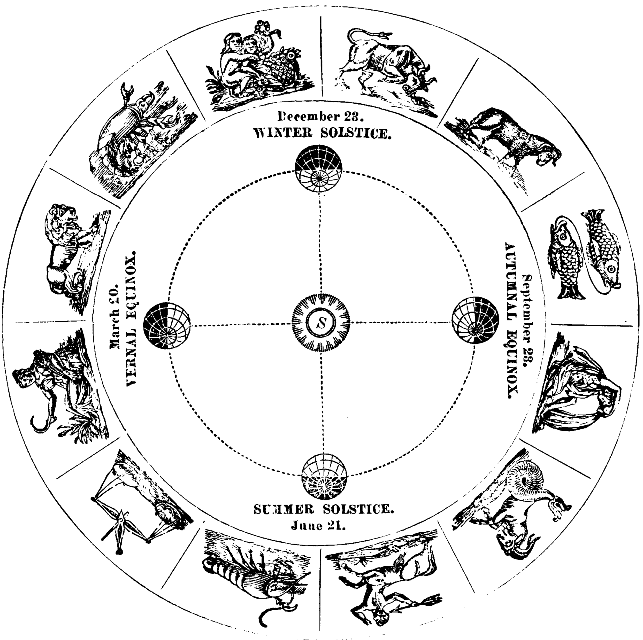

Fig. 62.

annual motion, and his rays become more and more direct. (See Fig. 62.) During this time the days in the northern hemisphere are increasing in length, and with this increase there is a corresponding increase of temperature, from which results the spring of the year. As the earth continues in its course, the northern hemisphere is still more exposed to the direct rays of the sun, till the days are at their greatest length, when summer

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QUESTION.—Explain them in their order.

arrives. (See Fig. 63.) The earth still advancing in her orbit, her northern hemisphere begins to decline from the sun, causing his rays to be less direct, and the days become shorter, from which results the season of Fall. Advancing on in its orbit, the northern hemisphere declines still more from the sun, shortening the days, and rendering his rays more oblique, till winter arrives as the result.

5. The same phases through which the earth has passed in relation to the sun produce the seasons of the north

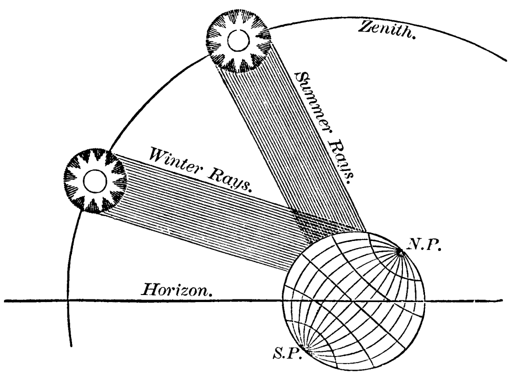

Fig. 63.

frigid zone. It has two seasons, summer and winter, the latter being very long, and the former very short. Owing to the great obliquity of the rays of the sun on this portion of the earth, and the great inequality in the length of day and night at different periods, its seasons are necessarily confined to half the number of those of the temperate zones. Instead of four periods, each of which is marked in the temperate zone by its uniformity of temperature, the frigid zone has two which mark its seasons in the same way.

QUESTIONS.—5. How many seasons has the north frigid zone? What are they? Explain them.

6. Similar to the seasons of the zones north of the equator, are those of the zones south of it, but with the order reversed. As the northern hemisphere rises one portion of the year towards the sun, producing spring and summer over its temperate zone, the southern hemisphere declines as much from him, producing fall and winter in its temperate zone. And as the southern hemisphere rises the other portion of the year towards the sun, it has its warm seasons, while we have fall and winter. Corresponding with these changes in the orbital motion of the earth, and the consequent directness and indirectness of the sun's rays, are the seasons of the frigid zones. Their summers occur during the warm seasons of their adjoining zones, and their winters occur during their cold seasons.

SECTION CIV.

Seasons of the Planets.

1. It is obvious that, as the character and extent of the zones and length of the seasons on the earth are determined by the inclination of its axis and the length of its year, so may the seasons of any of the planets be known, providing we have learned the position of its axis and length of its annual period. The annual period of Mercury is about eighty-eight days; but, in consequence of the difficulty of observing him, the inclination of his axis has not been determined; therefore we can form no knowledge of his seasons, if he has any.

QUESTIONS.—6. Are the seasons of the zones south of the equator similar to the seasons of those north, with the order reversed? Explain them. Are the sun's rays more direct in the summer than winter? Is it summer in either frigid zone when it is summer in the adjoining zone?

SEC. CIV.—1. What is necessary to be known in relation to the planets that we may have a knowledge of their seasons? What is the annual period of Mercury? Is the inclination of his axis to the plane of his orbit known?

It is not so with Venus; she is the most brilliant of all the planets, and her axis is inclined to the plane of her orbit seventy-five degrees, which is more than three times that of the earth, producing many peculiar results. Instead of having two seasons at her equator, like the earth, she has eight; and instead of having two near her poles, she has four. The inclination of her axis is so great that her tropics extend to within fifteen degrees of her poles, and her polar circles extend to within fifteen degrees of her equator. Her torrid and frigid zones overlap each other sixty degrees, and, consequently, she has no temperate zones.

2. The annual period of Venus being about two hundred and twenty-five days, the sun seems to pass during this time from his greatest northern declination to his greatest southern declination, and back again. When she is at one of her solstices, it is winter not only at the other tropic, but also at her equator. As she travels in her orbit from one solstice to the other in about one hundred and twelve days, or in the half of her year, spring sets in at her equator as she approaches her equinox, summer when she is at it, autumn as she leaves it, and winter when she arrives at her other solstice. Now, as she has only gone through the half of her orbit, the same number of seasons will occur in the same order as she returns to the same point that she left. Hence she has eight seasons at her equator, each of which is about twenty-eight days long; and from the extreme heat of summer to the extreme cold of winter is about double this period. At her tropics she has four seasons, each of which is about fifty-six days long, or the one-fourth of the time that she requires to make one revolution around the sun.

QUESTIONS.—How much is the axis of Venus inclined to the plane of her orbit? How many seasons has Venus at her equator? How many at her poles? How far are her tropics from her poles? How far are her polar circles from her equator? Has she temperate zones? 2. What is the length of her annual period? Give the length of her seasons at her equator and at her poles.

3. The inclination of the axis of Mars to the plane of his orbit is twenty-eight degrees and forty minutes, which is only a few degrees more than that of the earth. This being the case, he has five zones, each of which is marked according to the alternate elevation and depression of his poles in his annual motion. These elevations and depressions being a little greater than those of the earth, his torrid and frigid zones are increased in width, and his temperate zones are proportionately diminished. But, notwithstanding the width of his zones is not in perfect conformity with those of the earth, still his seasons are the same in number, but different in length. As his year consists of six hundred and eighty-seven days, each of his seasons must be nearly twice the length of the seasons of the earth.

4. In relation to Jupiter, the order of his zones is reversed. So slight is the inclination of his axis to the plane of his orbit, it being only three degrees and four minutes, his torrid zone is very narrow, and his frigid zones are very small. Now, as his zones are determined by this inclination, and as they in turn determine the limits of the seasons, it follows that there can be scarcely any perceptible change of season on the planet during one-half of his year. Since one of his poles is elevated and the other depressed only about three degrees as he travels from his equinoxes, his torrid zone cannot be more than about six degrees in width; consequently, its temperature must be constantly nearly the same.

5. Neither can the seasons of any parallel of his temperate zones vary very much, as the sun is nearly always vertical to his equator. So also are the corre-

QUESTIONS.—3. What is the inclination of the axis of Mars to the plane of his orbit? How many zones has he? Do the seasons of his zones correspond with the seasons of the zones of the earth in number? Do they in length? Why? 4. How much is the axis of Jupiter inclined to the plane of his orbit? What is the width of his torrid zone? Does it change much in temperature? 5. Does the temperature at each parallel continue nearly the same?

sponding parallels of his frigid zones in relation to climate, as neither of them is ever turned but very little towards the sun. Hence summer reigns perpetually at his equator, and as we leave it in either direction we have on every successive parallel of latitude a climate lower in temperature, as it gradually diminishes, going both north and south, till the poles are attained. At them it is perpetual winter; and as his year is equal to about twelve of ours, either pole has alternately six years day and six years night, whilst all the other zones have their days and nights nearly equal in length.

6. The polar inclination of Saturn is twenty-eight degrees and fifty minutes, being nearly the same as that of Mars, and about five degrees more than that of the earth. At this inclination he would have five zones, corresponding to those of the earth or Mars, from which would result seasons similar in character and length, if his annual periods were the same as either of theirs. But each of his years is equal to about thirty of ours; and as the length of his seasons depends upon the length of his year, each of his seasons in his temperate zones must be about seven and one-half years in length. Two seasons, probably the wet and the dry, each of which is about fifteen years in length, alternate with each other at Saturn's equator; and two of a similar length, summer and winter, alternate with each other at his poles.

7. Such are the natural seasons of this planet, yet they no doubt are modified by the anomalous appendages which constantly accompany him, known as his rings. Though they are separated from him and from each other thousands of miles, they revolve with him in

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QUESTIONS.—Does it grow colder gradually from his equator to his poles? Is it constant winter there? What is the length of daylight at his poles? What of night? 6. What is the inclination of Saturn's axis to the plane of his orbit? How many zones has he? Do his seasons correspond in number to those on the earth? Do they in length? Why? 7. Are Saturn's seasons affected by his rings?

the plane of his equator, and are crossed by the sun as he crosses the equinoctial of the planet. When the sun is in the plane of Saturn's equator, the shade of the rings falls within the same plane on his torrid zone; and as he inclines north it inclines south on the planet, till his greatest declination is attained. So also is it as he leaves the equinoctial in a southern direction. As he inclines south the shade inclines north, till he and it reach the opposite tropics, when they again begin to return.

8. Now, as Saturn's rings revolve with him on his axis, they have day and night as he has, but only on one side at a time, when the planet is not at either of his equinoxes. When the sun is on either side of them, that side next to him is enlightened till when at the tropics on either side, each side has its midsumner. For about fifteen years the sun is in either declination, which determines the length of night on either side of the rings, as well as the length of day and night at the poles. With these variations of light and shade on the planet and rings, together with the light and heat reflected by the latter, other results could not be anticipated than that his winters would be rendered colder and his summers warmer than they would otherwise be.

9. Outside of Saturn are Uranus and Neptune; and owing to the great distance that each of them is from the earth, it has not been ascertained whether they have even a daily motion, much less an inclination of their axes. If they have an axial inclination like that of Venus, three zones and eight seasons would belong to each of them, as they do to her; and if inclined like the

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Questions.—In what way? 8. What is said of the days and nights of Saturn's rings? When have the rings on either side their midsummer? Do the rings reflect light and heat? 9. Have the inclinations of Uranus' and Neptune's axes been discovered? Are they known to have daily motions? If their axes are inclined like that of Venus, how many seasons would each have at the equator? How many at their poles? If inclined like the axis of the earth, how many seasons would each have at the poles?

earth, or Mars, or Saturn, then each would have five zones, and five seasons which would correspond in number but not in length with our own. In length in their temperate zones they would be respectively about twenty-one and forty-one years. But if their axes have no inclination, or comparatively none, then their climates would be like those on Jupiter, diminishing gradually in temperature from their equators to their poles, where they would have perpetual winter.

SECTION CV.

Divisions of Time.

1. **Time** is a portion of infinite duration, and is divided both naturally and artificially into periods which differ in their length and are parts of each other. The day, the month, and the year may be regarded as the natural divisions, and those that are artificial are founded on them, and consist of the week, the hour, the minute, and the second. Sixty seconds make a minute, sixty minutes make an hour, twenty-four hours make a day, seven days make a week, and, with slight variations, which we will notice hereafter, four weeks make a month, and twelve months make a year.

2. *Sidereal day.*—Of all these periods, that one known as the sidereal day is the acknowledged unit measure of time, since it has not been known to vary one second for thousands of years. This day receives its name from the method by which it is determined, and consists of the exact time that it takes the earth to make one complete revolution on its axis. (See Fig. 64.) If a fixed

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Questions.—In the temperate zones? In the torrid zone? If their axes are inclined but little, what planet would they resemble in their climates?

Sec. CV.—1. What is time? How is it divided? Name the divisions. 2. What period is the unit measure of time? Does it ever vary? How is it determined?

star is observed with the transit instrument, which is a telescope of peculiar form, at any particular moment in the night, and then observed on the following night precisely at the same moment, according to a perfect sidereal time-keeper, it will be found that the earth will have completed one of her rotations in the definite

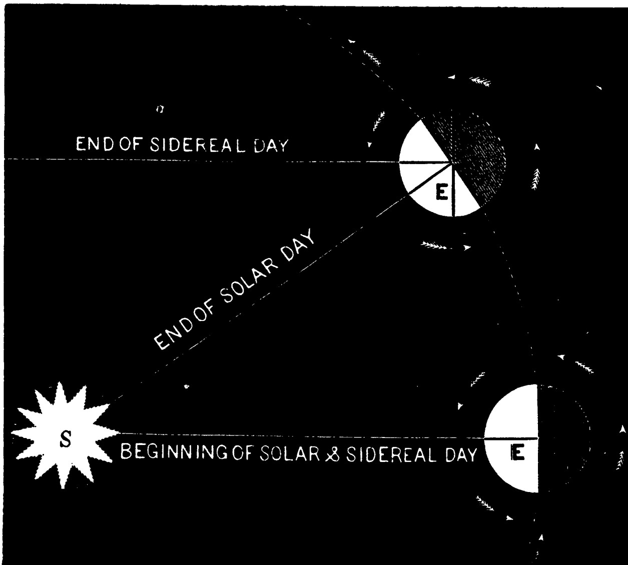

Fig. 64.

period of twenty-four sidereal hours. By repeating these observations even at long intervals, it has been distinctly ascertained that her daily periods are not only exactly the same, but that her motion is uniform during every hour of which they are composed.

QUESTIONS.—What is its length? Is the motion of the earth uniform on her axis?

3. Each of these sidereal hours is a little over nine seconds shorter than the common hour, which is marked by the clock commonly in use; and by deducting the sum of them for twenty-four hours from the period of twenty-four hours that compose the common day, it will leave the sidereal day only twenty-three hours, fifty-six minutes, four seconds and one-tenth long. Though this latter period is the natural standard and exact measuring unit of time, as it is the definite period in which the earth rotates once on its axis, still it is not the time to which we generally refer in the common affairs of life, except at long intervals, which we will notice hereafter.

4. The sidereal day commences when the vernal equinox is on the meridian, and is counted from zero to twenty-four hours. By four o'clock of sidereal time we mean that it is four hours since the vernal equinox crossed the meridian. Now, since twenty-four sidereal hours measure the whole circuit of the heavens, and this equinox being the point from which right ascension is reckoned, the time by the sidereal clock will always indicate the right ascension of such stars as are passing the meridian above the pole.

SECTION CVI.

Solar Day.

1. As the sidereal day is measured by the time intervening between the transit of a star across the meridian till the time that it crosses it again, so is the solar day measured by the time that intervenes from the sun's

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QUESTIONS.—3. Is the sidereal hour longer or shorter than the hour of mean time? What is its length? 4. When does the sidereal day commence? What is meant by four o'clock sidereal time? Does the time indicated by the sidereal clock indicate the right ascension of such stars as are above the pole?

SEC. CVI.—1. What is the measure of the solar day?

crossing it till he crosses it again; or, more properly, till the meridian is brought in conjunction with him by the rotation of the earth on its axis. (See Fig. 64.) In the former case the period, as has been noticed, from one transit to another is apparently unchangeable, owing to the great distance that we are removed from the stars; and in the latter it is constantly varying, on account of the comparative nearness of the sun to us, and the elliptical form of the orbit of the earth and inclination of the earth on its axis. If the earth's orbit would dwindle down to a mere point, without any magnitude at all, when viewed from the sun, as it does when viewed from the stars, then the sidereal and solar days would be exactly equal in length. But as her orbit is of large dimensions when observed from a body so near as the sun, and the earth has a very rapid motion in it, no meridian can be successively in conjunction with him in equal periods of time.

2. The earth, to bring a given meridian back in conjunction again, must always make a little more than one complete rotation, as she is constantly travelling in the same direction around the sun. And as the orbit of the earth is an ellipse, during certain portions of the year, the centripetal force of the sun unites to a certain degree with the centrifugal force of the earth, which increases her annual motion; and during other portions of the year his centripetal force, by reason of the earth changing its place, operates in the opposite direction, producing an opposite effect; therefore the sun is said to be slow at one time and fast at another, whereas it is the earth that is not uniform in her annual motion, from which also results an irregularity in the return of any given meridian. On account of

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QUESTIONS.—Is it variable? What causes its variations? What would render it invariable? 2. Does the earth make more than one complete rotation on her axis in a solar day? Does the earth travel faster in her orbit at one time than another? What causes it to do so?

this constant change of velocity of the earth in its orbit, there is a constant change in the periods of the meridian solar conjunctions, which causes the solar day never to be successively uniform in length. Though its average length is twenty-four hours, yet each, except four days in the year, is a few minutes more or a few minutes less, as indicated by the sun.

3. On the first of September, mean solar time and apparent solar time agree, as the rotary and orbital motions of the earth correspond. As the earth advances towards her perihelion, she changes in motion, till on the third of November the sun is sixteen minutes and seventeen seconds faster than mean time,—that is, the sun will cross the meridian that length of time before it is noon by the clock. Continuing on in her orbit, the difference between clock time, which is mean solar time, and apparent time, which is sun time, begins to grow less, till when the earth is near her perihelion, on the twenty-fifth of December, they again correspond. Advancing on towards her aphelion, with her varying changes of motion, on the sixteenth of April she arrives at a point where the meridian will come in conjunction with the sun again when it is noon by the clock. Advancing on from this place, she reaches a point where the sun does not arrive to the meridian till fourteen minutes and one-half after noon of mean solar time. Still pursuing her orbital motion, on the sixteenth of June mean and apparent time are again found to agree.

4. It will be observed that apparent time is fast and slow alternately with mean or clock time, fast from September till December, slow from December till April, fast from April till June, and slow from June till Sep-

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QUESTIONS.—Does this slow and fast motion affect the length of the solar day? In what way? 3. When do mean solar time and apparent solar time agree? How much do they differ on the third of November? Do they agree again on the twenty-fifth of December? When do they next agree? How much slower does the sun get than the clock? When do they next agree? 4. Explain when the sun is fast and slow.

tember. Since the orbit of the earth is elliptical, her annual motion is fast and slow alternately, which causes the alternate variations in apparent time, together with other results. The earth's average velocity from the vernal to the autumnal equinox is slower than her average velocity from the autumnal equinox back to the vernal equinox. On account of these variations of motion, together with the increase of distance of about eight degrees between the former equinoxes over the distance between the latter, the sun continues about eight days longer on the north side of the equator in the summer than he does on the south side in the winter.

SECTION CVII.

Equation of Time.

1. THE equation of time is the difference between apparent time and mean solar time on every day in the year except the first day of September, the twenty-fifth of December, the sixteenth of April, and the sixteenth of June, when they agree. From noon till noon by the clock, if it is always uniform in marking the hour, the time is always the same, and from noon till noon again by the sun it is constantly varying, through causes which have been already explained. These variations from the average length of a day, which is twenty-four hours, is the equation of time. It amounts to but little per day; but as it increases and diminishes alternately it exceeds at one time the length of a mean solar day about sixteen minutes, and at another it falls short of

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QUESTIONS.—Does the earth move faster or slower when the sun is north or south of the equator? Which is the longer, the summer or winter half-year? How many days?

SEC. CVII.—1. What is the equation of time? Is correct clock time uniform? Is sun time variable? What is the greatest difference between true clock time and sun time?

the same period about fourteen minutes. The equation of time when in advance of mean time subtracted from apparent time, and added when behind it, gives the length of the mean solar day.

2. In connection with this subject we may notice the variations which are constantly occurring in the length of the solar in relation to the sidereal day. Each sidereal day is twenty-three hours, fifty-six minutes, four and one-tenth seconds in length, as marked by the common time-keeper, whilst each solar day is about twenty-four hours: consequently, the difference is nearly four minutes. But this difference is seldom the same during the year. The same causes which operate to produce the equation of time operate in producing the difference of time between the length of each solar and sidereal day. The earth's orbit not being at all points equally distant from the sun, her motion is not uniform in it: consequently, the position of the plane of the meridian must vary a little at every rotation of the earth, and with it, of necessity, the length also of every solar day. The greatest difference in length between the solar and sidereal day is four minutes and twenty-six seconds; the least, three minutes and thirty-five seconds; and the average for each day in the year, three minutes and fifty-six seconds.

3. *Civil Day.*—The mean solar day is adopted as the civil day, according to which commercial business is transacted and the common affairs of life are regulated. It commences at midnight, and is divided into two periods of twelve hours each, the first period ending at noon, and the second at midnight.

4. *Astronomical Day.*—The apparent solar day, when

QUESTIONS.—How is solar time converted into mean time? 2. Does the sidereal day vary in its length? Does the solar day? What causes each solar day to vary a little? What is the greatest difference of time between the solar and sidereal day? What the least? What the average? 3. What is the civil day? What day is adopted as the civil day? When does it commence? When does it end? 4. What is the astronomical day?

used for scientific purposes, is called the astronomical day. It commences at noon, and ends at noon the next day.

SECTION CVIII.

Tropical, Civil, and Sidereal Years.

1. SOME of the most ancient nations discovered that if a rod was placed perpendicular on a level plane, its shadow would change in length a little every day,—at one time grow longer, and at another grow shorter, through alternate periods. Commencing to count when the shadow was shortest, its increase was marked every day till it arrived at its maximum length, when the sun was at the opposite tropic. Continuing the same observations as the shadow began to decline, its daily decrease was constantly noted, till it arrived again at its shortest. By counting the number of days in each of these periods, and adding them together, the whole number amounted to three hundred and sixty-five days, which appeared to be the length of the tropical year. According to this plan, an attempt was made to mark the annual periods; but, owing to the uncertainty of determining by this crude method exactly when the stylus or rod cast the shortest shadow, the true length of the year was not accurately obtained.

2. The sun when the earth is at her solstitial points appears to change very little either north or south for a number of days: hence very slight variations would occur in the length of the shadow of objects which would be cast at such times. These variations being almost imperceptible till the earth had proceeded some distance from her solstices, it could not be expected that

QUESTIONS.—When does it commence? When does it end?

SEC. CVIII.—1. What discovery was made by the ancients? How did they attempt to discover the length of the tropical year? Were they successful in discovering its exact length? 2. Why were they not?

the true length of the year could be ascertained at once in this way. Hence that result which might be anticipated soon occurs. The dates of the year, and the places where the earth should be at certain times which they were intended to indicate, were found to be constantly separating by periods of about six hours in every year. To remedy this discrepancy, six hours were added to every year, making it three hundred and sixty-five days and six hours long. Through the lapse of time this addition of six hours proved a little too much, and the same difficulty still existed as at first, but to a less degree. Renewed efforts were made to determine with greater accuracy the exact length of the tropical year, or, in other words, to determine how long the earth would be in arriving at the same position exactly in relation to the sun that she had previously occupied.

3. The Egyptian astronomers, before the Christian era, directed their attention especially to this subject, and were in a measure rewarded for their labor. Instead of making their observations when the sun was at the tropics, where the shadow of the rod changed least, they made them when the earth was at her equinoxes, where the shadow changed more rapidly in length. By this change of time in making observations they arrived at more accurate results. Four minutes and forty-eight seconds was subtracted from the length of the year, leaving it three hundred and sixty-five days, five hours, fifty-five minutes, and twelve seconds long. With this correction, which approximated closer to the truth than any hitherto made, it appeared to be, at least for a time, conceded that they had arrived at the desired result.

4. But with the lapse of time there were indications of a slight error in their computations, which led others

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QUESTIONS.—What resulted from the inaccuracy? How did they attempt to remedy it? Did six hours prove too much? Were there renewed efforts to correct it? 3. Who made them? How did they proceed? What change did they make in the length of the year? Were they exactly right? 4. When was the next correction made?

to examine this subject with the greatest scrutiny. For more than eighteen hundred years it occupied the attention of the astronomer, and with but little success, till in the beginning of the present century, by means of greater facilities and the refinements of science, another correction was made, which reduced the year a few minutes more, leaving it only three hundred and sixty-five days, five hours, forty-eight minutes, and forty-seven and eight-tenths seconds long. Whether this period is exactly correct or not, no one can tell; still it is near enough for all practical purposes, and is now the acknowledged length of a tropical year.

5. Notwithstanding this is the length of the natural year, and periods differing very little in length from this were regarded as such both before and after the beginning of the Christian era, yet the civil year, by common consent, generally contained an even number of days. To avoid computing the fractional part of a day in business transactions, which belong to the natural year, it has nearly always been omitted for a time, leaving only three hundred and sixty-five days in the civil year, and then the sum of a number of these fractions supplied at regular intervals, so that the civil and natural year might be made to agree.

6. The Egyptians appear to be the only exception to this rule in making their computations of time. Instead of adding together a number of the fractions of a day, which belong to each natural year, and then adding this sum to certain civil years at certain periods as might be required, they allowed the natural and civil years to separate more and more, till the fractions of each successive one added together amounted to a whole one. It required fourteen hundred and sixty years to accomplish this, during which time the seasons made a com-

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Questions.—What is the length of the tropical year according to our standards? 5. Does the civil year contain an even number of days? 6. How did the Egyptians reckon the civil and tropical year? How long did it require them to come together again and agree?

plete revolution, each taking the place of the other in regular succession in point of time, till they returned to the date at which they set out. This was a natural result arising from the difference of civil and natural time, and was adopted more to conform to religious notions than for secular purposes.

SECTION CIX.

The Calendar.

1. THE calendar which is now in general use in nearly all Christian nations was derived from the Romans. They made their civil year to consist of three hundred and sixty-five days. By reckoning time in this way, the astronomical or natural year soon ceased to correspond with the civil. The seasons began to change the time of their return, and the real position of the earth in its orbit deviated farther and farther from the position indicated by every date in the civil year. This discrepancy becoming eventually inconvenient, early in the Christian era it was found necessary to have it in some way corrected. Accordingly, Julius Cæsar, who was then emperor of Rome, ordered that ninety days should be added to the previous year, so that the civil dates and annular solar time might agree.

2. This being accomplished, a new era commenced, in attempting to keep the civil and solar time together. Instead of adding the difference of time when it had accumulated at long intervals, as had been done, one day was added to the month of February every fourth year, which gave rise to the name bissextile or leap year. But the same evil still existed as before, but only to a

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SEC. CIX.—1. Where had our calendar its origin? How many days did the Romans reckon in the civil year? Did natural and civil time keep together? Who attempted to make them agree early in the Christian era? In what way? 2. What other change was made to keep them together?

less degree, as a whole day in four years was too much by about forty-four minutes to restore their equality.

3. According to this arrangement time was observed till the slight error of a little over eleven minutes per year accumulated into days, which began again to manifest itself and arrest attention early in the fifteenth century. As time elapsed, the discrepancy still increased, till in fifteen hundred and eighty-two it amounted to nearly ten days. Hence it was found necessary to make another reform in the calendar, which was accomplished by Pope Gregory XIII. by omitting ten nominal days in October in this year, making the fifth the fifteenth. By this correction the vernal equinox, which was known to fall in the year three hundred and twenty-five, anno domini, on the twenty-first of March, by civil computation, was again restored to the same date, but only to go through similar changes without further reform.

4. The error of about eleven minutes between the length of the civil and solar years was not removed: consequently, as the cause of the discrepancy remained, the same results would follow as before. To prevent the return again of a large error, an additional reform was made by omitting one day in the last year of each successive century for three centuries, leaving the last year of every fourth century a leap-year. Hence the following rule:—

5. Every year whose number is not exactly divisible by four contains three hundred and sixty-five days. Every year whose number divides even by four, and not by one hundred, contains three hundred and sixty-six days. Every year whose number is divisible by one hundred, and not by four hundred, contains three hundred and sixty-five days; and every year whose number is divisi-

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QUESTIONS.—3. Did adding one day to February every fourth year accomplish it? Why? How many minutes too much annually? In what year did this slight annual error amount to ten days? Who reformed the calendar next? How did he make civil and solar time agree? 4. How did he attempt to keep them together? 5. Repeat the Gregorian rule.

ble by four hundred contains three hundred and sixty-six days.

6. To illustrate this rule, known as the Gregorian, the year eighteen hundred and thirty-six was a leap-year, because it was divisible by four without a remainder, and eighteen hundred and thirty-seven was not, because by dividing that number by four there would be one left. The same would be true if the division was extended to the numbers representing the years eighteen hundred and thirty-eight and nine; but eighteen hundred and forty would be another leap-year, because the number representing it can be divided even by four. The remainders after dividing the numbers representing the years by four, always indicate the number of years after leap-year. If the remainder is one, it is the first; if two, it is the second; and if three, it is the third.

7. Through the addition of these intercalary days, as they are termed, every fourth year, we only approximate to the truth; for in every hundred years it amounts to nearly three-fourths of a day too much. To approximate still nearer to the truth, we consider every four hundredth year a leap-year, omitting the first, second, and third hundredth from being leap-years, even if the numbers representing them are divisible by four without a remainder. By this method of harmonizing solar with civil time, through long periods, it involves an error of less than one day in forty-two hundred and thirty-seven years; and if this rule was extended by making the number that expresses each leap-year that can be divided by four thousand without a remainder, a common or civil year, the error would not be more than one day in one hundred thousand years.

8. This mode of reckoning time, soon after its pro-

QUESTIONS.—6. Illustrate this rule. 7. Illustrate still further when the periods are centuries. By the Gregorian rule are civil and solar time kept exactly together? What is the difference in forty-two hundred and thirty-seven years? What would be the difference in one hundred thousand years, if the rule was extended? 8. Is this mode of reckoning time in general use?

mulgation, went into use in nearly all Christian countries, but was not adopted by law in England and her colonies till in seventeen hundred and fifty-two, when it was found that the vernal equinox had fallen back eleven days towards the beginning of the year. To restore the equinoxes to the same days of the month in which they occurred in the year three hundred and twenty-five, the eleven days were stricken out of the month of September, by calling the third day the fourteenth: hence the names of Old Style and New Style.

9. Another change was also made at the same time by the British Parliament, in relation to the beginning of the year. The previous year commenced on the twenty-fifth of March, and was made to end on the last day of the succeeding December, leaving it only nine months long. For the first time, the year according to the reformed calendar commenced on the first of January, one thousand seven hundred and fifty-two. Russia still retains the old method of reckoning time; and the difference between her calendar and ours at present is about twelve days.

10. *Sidereal Year.*—The period denoted by this name receives its title from the method by which it is determined. If the earth is observed to be at any time directly between the sun and a fixed star, and a constant watch kept on these three bodies in relation to each other, they will be found to separate for a time, owing to the annual motion of the earth, and then to return to their former relation; that is, when the earth makes one complete revolution round the sun, it will return exactly to the same point between the sun and the star from which it left. To accomplish this it requires the earth three hundred and sixty-five days, six hours, nine

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QUESTIONS.—When did the English adopt it? How did they bring civil and solar time together? 9. What change did this make in beginning the year? What was the first year that commenced on the first of January? What nation retains the old method of reckoning time? 10. What is the sidereal year? What is the length of the sidereal year?

minutes, and nine seconds, which makes an excess of about twenty minutes over the length of the tropical year.

SECTION CX.

Calendar, Synodical, and Sidereal Months.

1. THE Julian calendar divided the year containing three hundred and sixty-five days into twelve months, each containing a fixed number of days, except February, which was increased by one day every fourth year, as we had occasion to notice. These divisions are arbitrary, as none of them represents exactly the twelfth part of a year, neither the exact length of a sidereal or synodical month. They originated, no doubt, in the fact that the moon does revolve around the earth in a period the length of which differs but little from any one of them, and also that the year may contain only twelve parts nearly of equal length, without any fractional part of a day or of one of themselves. This division of the year into twelve parts was observed by nearly all nations for many centuries, and still continues in use, and probably will, as it is adapted to the purpose for which it was designed.

2. *Synodical Month.*—The moon revolves around the earth, as the earth revolves around the sun; and as a consequence of the various forces under which she moves, her orbit is enlarged, and of necessity she travels farther in making a revolution around the earth than if the earth was at rest. The moon, under these conditions, to make one complete revolution around the earth,

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QUESTIONS.—1. Into how many months did the Julian calendar divide the year? Were these divisions arbitrary? What gave rise to these divisions? Were these divisions of the year observed by many nations? Are they still observed? 2. Has the moon to travel farther to make a revolution round the earth than she would if the earth were at rest? What is the time that she requires to revolve once?

requires twenty-seven days, seven hours, forty-three minutes, eleven and one-half seconds, and to return to conjunction again, requires twenty-nine days, twelve hours, forty-four minutes, and three seconds. The latter period is called a synodical month, and the moon during this period passes from one change to the next, or, in other words, this period intervenes between two consecutive conjunctions. This is the length of the natural lunar month; and it exceeds the moon's sidereal month two days, five hours, fifty-one and one-half seconds.

3. *Sidereal Month.*—Notwithstanding the moon appears to rise in the east and move westward, it is not her real motion, but only an apparent motion, produced by the daily motion of the earth on its axis. Like all of the planets, she revolves from west to east, and even, at times, with greater velocity than the earth. By noting her position at any time in relation to any of the fixed stars near which she appears to pass, it will be found that she recedes from them for a time, and then approaches nearer and nearer, till at last she arrives at the point at which she left. The time that intervenes from passing a certain position, as marked by a star, till she returns to the same position again, is called a sidereal month, and consists of twenty-seven days, seven hours, forty-three minutes, and eleven and one-half seconds, which is less by nearly two days and one-fourth than the length of a synodical month. This difference results from the annual motion of the earth in her orbit, and the comparative nearness of the sun when contrasted with the enormous distance that the stars are from us. If the earth were stationary, then the synodical and sidereal months would be exactly the same length, each being the length of the sidereal month.

QUESTIONS.—What is this period called? Does this period express the time that elapses from one change to another? What period does? 3. In what direction does the moon appear to move? In what direction does she move? What is a sidereal month? What is its length? How much does it differ from the synodical month? What produces this difference?

SECTION CXI.

Tides.

1. THE waters of the ocean rise and fall alternately twice in about twenty-four hours. For nearly six hours they continue to rise higher and higher, as if there was an actual increase of water to what the ocean already contains. Arriving at their maximum height, they are for a few moments apparently at rest, when they begin to recede, and continue to fall lower and lower, till they arrive at their original level. Being at rest again for a few moments, as they were at their highest, they continue to alternate in their rise and their fall as before. When the waters are at their greatest elevation, it is flood or high tide, and when at their greatest depression, it is low or ebb tide; and their rising and falling are called the flux and reflux of the tides.

2. Now, as the waters of the ocean rise twice in twenty-four hours, and fall twice, the interval between two successive high tides and low tides is about twelve hours. This being the case, of necessity there are two high tides at the same time, but they are on the opposite sides of the globe from each other. As the waters rise on one side of the earth they rise also on the other, from causes which we will now attempt to explain. Since the theory of gravitation was established by Newton, and its laws fully developed, it is conceded by all who have given tides their special attention, that it is the unequal attraction of the sun and moon on the waters of the ocean that produces their periodical rising and falling in alternate succession.

3. It has been clearly exemplified that the earth and the moon have a mutual attraction for each other, and

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QUESTIONS.—1. How often do the tides rise in every twenty-four hours? How often do they fall? What are the rising and falling of the tides called? 2. Do high tides occur at the same time on the opposite sides of the earth? What produces them? 3. What is said of the attraction of the earth and moon?

that the earth revolves once every day on her axis. If they were at rest, they would not remain so, but would begin immediately to approach each other, and would constantly increase in their velocities, till they would come together. But as all of the particles of each of these bodies are attracted with forces that are proportionate to their distances apart, some have a greater influence exerted on them than others. Those that compose the hemispheres of the earth and moon that face each other, are influenced more than those of the hemispheres that are opposite; and were it not that the solid particles of each are held together by a strong adhesive force which acts at insensible distances, they would move about among themselves like the particles of water.

4. Water yields to very slight influences; and as the ocean is indebted to gravitation for its general form, so are the tides at times indebted to lunar attraction for their rise. The earth attracts the waters and retains them on itself, and the attraction of the moon disturbs them, as their particles are at liberty to move freely among themselves. As has been already stated, the attractive force of the moon is always greater on the side of the earth next herself than on the opposite side: hence the waters nearest to her will tend to rise or heap up on that side; so also will they heap up at the same time on the opposite side of the earth, though apparently from a different cause. (See Fig. 65.)

5. On the opposite side of the earth from the moon there is less lunar attraction exerted on the waters of the ocean than anywhere else over the whole earth, as she is at a greater distance from them, the centre of the earth being in a straight line between them and her. Under these circumstances, the moon's attractive influence in

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QUESTIONS.—4. What gives the ocean its form? What causes it to vary? In what way does lunar attraction create high tide on the side of the earth next to her? 5. In what way is it created at the same time on the opposite side?

relation to the waters being directed practically towards that point of the earth's surface nearest herself, it is practically not so great on that part of the ocean in question, consequently the gravity of the waters that compose it is diminished. Now, as the waters of that part of the ocean have less gravity than the waters of those parts that are immediately around them, they are urged up or outwards from the earth, till high tide is the result. From the foregoing it is now evident that it is the excess of lunar attraction that produces high tide on that part of the ocean next to the moon, and that it is a deficiency in her attractive force that produces indirectly at the same time the same result on the opposite side of the earth.

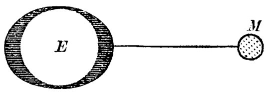

Fig. 65.

6. But these tidal waves are not the only effects which result from the unequal attraction of the moon on different parts of the ocean. There are at the same time corresponding depressions of its surface at a certain distance from each, which may be traced to a similar cause. (See Fig. 65.) As the attractive force of bodies is always exerted in straight lines, that of the moon unites in a measure at these points with that of the earth, and gives the waters that are there greater gravity, which causes them to sink below their general level. These depressions are called low tides; and as the action of the moon is always more oblique to the surface of the ocean at these points than anywhere else, it is evident that two of them will invariably take place on opposite sides of the earth at the same time.

7. If the earth and moon were at rest, the tides would be local, and there would be constant high tide at one place and constant low tide at another; but in consequence of their various motions the tides retain their relative distances and succeed each other in alternate

QUESTIONS.—6 What is said of the low tides? 7. Do the low tides occur at the same time on opposite sides of the earth?

succession. The earth is constantly revolving on her axis, which brings new portions of her surface successively round towards the moon, and the moon herself is constantly revolving around the earth, which changes her direct action from any particular part of the earth in every moment of time. With these changes there are corresponding changes in the tides. They occur about fifteen minutes later every day, owing to the fact that the moon does not reach the meridian of any given place as soon as she did the day previous, by about that length of time.

8. The tidal wave tends to keep under the moon; and as the surface of the earth revolves rapidly through space, the wave appears to have about the same motion, thereby returning to any given place in precisely the same length of time that it requires the moon to return again to any given meridian. In these coincidents, which have been manifested so frequently for centuries, we see both cause and effect; and as long as the earth and moon shall revolve, so long shall the tides have their ebb and flow. So also would this be true even if the moon should be removed and the sun allowed to remain in his place. He attracts the waters of the ocean with a force sufficient to form tides; and were it not that he is so far away from us, they would be much greater than those that are formed by the moon. His influence in relation to hers is about as one is to three, in producing the tidal wave.

9. If he were alone, his action on the ocean would be similar to that of the moon, making high tide occur at the same time on the opposite hemispheres, and low tide also midway between them. His attraction on the waters being less than that of the moon, and not so

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QUESTIONS.—How much later are they every twenty-four hours? 8. Is there a marked coincidence between the motion of the earth, moon, and tides? Is the attraction of the sun also concerned in forming the tides? What is his influence compared with that of the moon? 9. Has the sun a similar influence to that of the moon in forming the tides?

variable in relation to the places that it acts with its greatest force, his tides would not run so high, neither would the intervals between them be quite so long as those between the lunar tides, since the sun is only the length of a natural day in returning again to any given meridian. Hence the variations in relation to the height of the tides, and also the names by which they are known.

SECTION CXII.

Spring Tides.

1. For the purpose of making this subject easily understood, we have spoken of the lunar and solar tides separately, as if either of these bodies had no place in the heavens, while the other was exerting its influence on the waters of the ocean. Now we will consider them as they are, in regard to their tidal effects. At one time their action is united in raising the tides, and at another time their influences are in opposition to each other. When the moon is at her change, their forces are united and concentrated on one point of the ocean, as both of them are nearer one hemisphere than the other. Under these circumstances the solar and lunar tides are heaped on each other, causing the waters to attain a greater altitude than if their influences were not united in one common direction.

2. On the hemisphere next to the sun and moon, as we are now considering both on the same side of the earth, the excess of their direct action raises the waters to their greatest elevation, and the deficiency of

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Questions.—Are they as high and variable as those formed by the moon?

Sec. CXII.—1. Are the influences of the sun and moon ever united in forming the tides? Are they ever in opposition to each other? When are they united? What kind of tide do they form on the side of the earth next to them? 2. What kind on the opposite side is formed in the same way?

their attractive forces, together with the increased centrifugal force generated by her motion around the centre of gravity of the three bodies in question, elevate to the same height the tide at the same time on the op-

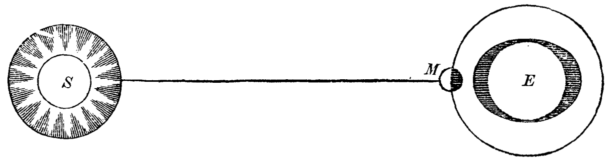

Fig. 66.

posite side. (See Fig. 66.) If the moon is on the opposite side of the earth from the sun, as she is at her full, the same kind of tide will also occur. For as we have shown that each body produces two tidal waves of equal height at the same time on opposite sides of the earth, thus do we discover again their influences united directly and indirectly in giving the tides their greatest elevation. The direct influence of the moon and indirect influence of the sun, united, produce one elevation, and at the same time the direct influence of the sun and indirect influence of the moon, united, pro-

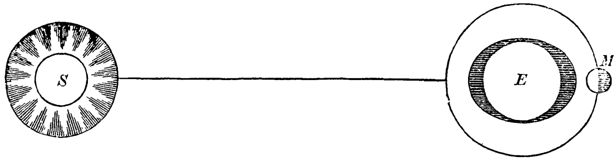

Fig. 67.

duce the other. (See Fig. 67.) These tides occur twice every month, and are called the spring tides, because they rise unusually high.

QUESTIONS.—Explain in what way. What kind of tides will be formed when the moon is on the opposite side of the earth from the sun? Explain how they are formed. How frequently do they occur?

SECTION CXIII.

Neap Tides.

1. As the earth and moon are constantly changing their positions in relation to the sun and each other, at one time the sun's and moon's influences are united and at another they are opposed to each other. When the sun, moon, and earth are in conjunction, as we had occasion to notice, the sun's and moon's action is united, directly and indirectly, in producing the spring tides; and when the moon is in quadrature, or ninety degrees from the sun, their action is at right angles to each other. (See Fig. 68.) When the action of the sun is at right

Fig. 68.

angles to that of the moon, the action of each is in a measure neutralized, and consequently the tides do not rise so high. Under these conditions, the waters tend to rise in the direction of each; and as the low tide is at a distance of ninety degrees from high tide, the high tide produced by the former occurs just where low tide is produced by the latter. Where the sun's influence tends to elevate the waters, the moon's influence tends to depress them; and where the moon's influence tends to elevate them, the sun's influence tends to depress them. Hence the slight perceptible effect manifested by neap tides, corresponding to the relative positions of

QUESTIONS.—What are neap tides? How are they formed? Explain these tides.

the bodies that produce them. These tides occur twice every month, and are called the neap tides, because they are unusually low.

SECTION CXIV.

Height of the Tides.

1. It has been ascertained that the entire tidal wave raised by the moon's influence is about five feet, and that raised by the sun's influence is about two feet; consequently, the average spring tide would be about seven feet, and the average neap tide about three feet, since each of them is the result of a compound influence, which has been explained. Were it not for local causes, neither of these tides would change very much from its average height; but, as each is constantly influenced by them, in some places one of them rises very high, and the other at other points is scarcely perceptible.

2. In the mouths of channels that open in the direction towards which they flow, they rise the highest, since at these places sometimes two tidal waves flowing from different quarters unite. This is the case in the Bay of Fundy, where the tide-waves of the South Atlantic Ocean meet the tide-waves of the Northern Ocean and raise the surface of the waters from sixty to seventy feet. In the Bristol Channel also, and in the Bay of Malo, the waters are compressed, and rise nearly as high. Where these peculiar land-formations are wanting, and the tidal wave is at liberty to move without interruption, this unusual height is never attained. On the shores of the South Sea islands it rises about

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Questions.—How frequently do they occur?

Sec. CXIV.—1. What is the average height of the spring tide? What of the neap tide? Do these tides vary very much? 2. Where do they rise the highest? Can you name some places where they rise very high? Where are they below an average?

two feet; and in other places its height is in proportion to the nature of the shores and direction of its flow.

3. Notwithstanding the general course of the tides is westward, yet they are frequently diverted by islands and headlands, so that they flow in different directions. These are local causes, which produce only local results; but there are other causes, which produce other variations, even in their general course, on account of which the highest point of the tidal wave is not always on the equator. If the sun and moon were always in the plane of the equator, then the tidal wave would always run highest on it, quite round the earth if not obstructed; but, owing to the fact that these bodies are at one time north of the equator and at another time south, the tides change north and south also with the causes that produce them.

4. When the moon is at her greatest northern declination, and above the horizon, the daily high tides are highest a certain number of degrees north of the equator, and lowest in the same place when she is below the horizon. South of the equator this order is exactly reversed, so that the daily high tide is highest at a certain number of degrees south of the equator when she is below the horizon, and lowest in the same place when she is above it.

5. Besides these changes of the tides north and south, they are subject to other variations, that are worthy of notice. As has been stated, they tend to keep under the bodies whose influences produce them; yet they are never found there. If there was no friction of the waters on the shore or bed of the ocean, or between their own particles, as the sun and moon would cross the meridian so would the tidal waves cross it at the same time. But, owing to the inertia of the waters, and

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QUESTIONS.—3. What is the general course of the tides? What causes them at times to flow in different directions? What causes the tides to change north and south? 4. Explain how these causes affect the tides. 5. What causes the tides to lag behind the influences that produce them?

causes already referred to, they do not arrive at it till after some two or three hours have elapsed. As they are not perfectly free to move, they do not obey at once the first impulse that they receive, and consequently they follow at unequal distances varying according to the retarding influences with which they have to contend.

6. Though the tidal waves in certain latitudes complete a revolution in about a day, and travel at the rate of nearly one thousand miles an hour, in other places they move very slow, and sometimes are entirely arrested by winds and currents that move in the opposite direction. When this is the case, it happens at times that the tidal wave is separated into two or three parts, which parts follow after each other at various intervals during several days.

7. Tides are never observed on small seas, or even on the largest lakes, as the extent of their waters is not sufficient for them to be formed. When the sun or moon is directly over a comparatively small body of water, the attraction on every part of it is very nearly equal, since the whole of its area is at nearly equal distances from either. A difference in the degree of attraction is necessary to disturb the waters; and, as this difference is very slight over a small area, it has no sensible effect in any particular place. Even in the Mediterranean, a sea of considerable extent, the tides are not much more than perceptible. They occur only where the surface of the waters is large enough to allow an unequal action to be exerted on their various parts, which necessarily disturbs some more than others, and gives to them their successive periodical flow.

QUESTIONS.—6. At what rate does the tide-wave sometimes travel? Is it at times entirely arrested? 7. Are tides on small seas or the largest lakes? Why? What is said of the tides in the Mediterranean?

SECTION CXV.

Parallax.

1. PARALLAX is the apparent displacement of a body when viewed from different points. If two persons were stationed a certain distance apart, and take observations at the same time of a particular object, its relations to those that surround it would not appear the same to both. To one observer it might appear in a line with a number of them, and to the other it would appear less or more separated from them. This would be true also were observations taken of the moon in the same way, if the observers were stationed a sufficient distance apart. She would not appear to be exactly in the same place in the heavens, owing to the fact that the visual line of each observer differed in direction.

2. If the observers were stationed at the same point, she would appear to both in the same place; and the further they would separate, the greater would be her apparent change to each on the celestial sphere. Hence the necessity of adopting some specific point that is fixed, from which her true place may always be determined. The point selected by astronomers is the centre of the earth; and were it possible for an observer to see her from that place, he would at all times see her occupy her true relative position in the starry heavens. But, as it is inaccessible, we are compelled to view her from the surface of the earth: consequently, she is seldom seen in her real, but only in her apparent place.

3. When she is in the zenith, she is seen in her real position; for then the line of vision and one extended

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QUESTIONS.—1. What is parallax? If two persons would take observations of the moon from different places on the earth, would she appear to both in the same place in the heavens? 2. What would cause her to deviate further? What point have astronomers fixed from which to determine her true place? Since this point is inaccessible, from where are we compelled to view her? 3. Where must she be that we may see her in her true place?

to her from the centre of the earth coincide. As she leaves this point, she appears more and more out of her true place, till she arrives at the horizon, where her parallax is greatest, as the angle formed by a horizontal straight line drawn to her from the centre of the earth and one drawn to the same point from its surface is greater than at any other place. (See Fig. 69.) By the

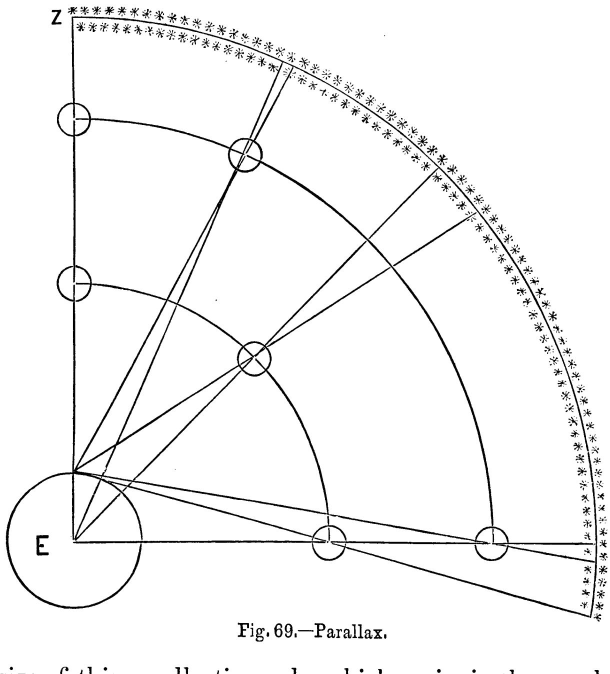

Fig. 69.—Parallax.

size of this parallactic angle, which varies in the number of degrees that it contains, at every point in which the moon may be between the horizon and the zenith, the amount of her displacement is determined. This is

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QUESTIONS.—Does she appear more and more out of her true place as she sinks towards the horizon?

also true in relation to all other heavenly bodies whose parallax can be measured. It is greatest when they are at the horizon, and it gradually diminishes as their altitude increases. At the zenith it is nothing.

4. In connection with this cause, change of distance also increases or diminishes the parallax of heavenly bodies. If they are near to us, it is greater than when they are at a greater distance; for, as the hypothenuse and base-line of an imaginary triangle that may be formed between the earth and any of them increase, the angle that they form opposite the third line diminishes; and as they diminish, it increases. From this relation of lines and angles not only the difference between the apparent and real position of heavenly bodies may be discovered, and their distances from us found, which have been explained, but also the direction in which they are displaced.

5. The effect of parallax always causes a body to appear nearer to the horizon than it is; that is, it always depresses it below its true position. View it when

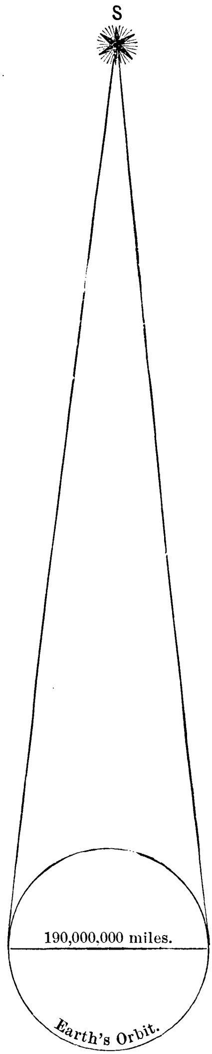

Fig. 70.—Annual Parallax

QUESTIONS.—Where is her parallax greatest? Is it so with other heavenly bodies? 4. What effect has change of distance of heavenly bodies on their parallax? Explain this. 5. Does parallax increase or diminish the altitude of heavenly bodies?

we may, its displacement is invariably in one direction, unless it is so far away, like many of the fixed stars, that it has no sensible parallax. Many of them are sunk so deep in space that they appear not to change their places in the least, though observations may be taken of them at cpposite points in the earth's orbit, which are one hundred and ninety millions of miles apart. (See Fig. 70.) The parallax of only a few stars that are most favorably situated near the axis of the earth's orbit has been measured, and it exceeds in no case—except in that of alpha (α) Centauri—one second. It is by ascertaining the value of the parallactic angle that the distance of any of them has been determined. When the parallax of a heavenly body that is comparatively near to us is taken at the horizon, it is called horizontal parallax; and when that of any fixed star is taken, it is called annual parallax, since it is by the change of the earth in making her annual period that it is obtained.

SECTION CXVI.

Proper Motion of the Stars.

1. THOUGH the structure and harmony of the universe were briefly noticed in a previous section, it may not be out of place to refer to them again, in connection with the proper motion of the stars. The whole universe of God seems to be divided into many grand divisions, each of which is millions of millions of miles in extent, and millions of millions of miles distant from each other, yet so physically related and bound

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QUESTIONS.—Have many of the fixed stars a sensible parallax? How can we take the parallax of any of them? Is it by discovering the parallax of a star that we find its distance? What is the parallax of a fixed star called? What is horizontal parallax?

SEC. CXVI.—1. Hcw does the whole universe seem to be divided? What is said of their dimensions and distances apart?

together as to insure their stability and perpetuate their existence. No special order is apparent in their distribution in space, neither is there any apparent limit to them; for wherever aided vision may chance to direct its gaze, space has its inhabitants, and to them there appears to be no end.

2. Each grand division is called, by common consent, an island universe, or starry cluster; and from analogy and discovery it may be inferred that others beyond our own division are similar to it. Our cluster embraces all of the visible heavens, and millions of stars and other objects which are brought to view by the aid of the telescope. It contains minor systems, in which sun revolves around sun, planet around planet, and system around system, all retaining their order and perpetuating their harmony by the motions which they have and the periods that they perform.

3. Here, as it were, on the threshold of nature's mechanism, discovery leads us to believe that all of the principal bodies and systems that compose our starry cluster, with all of the bodies that are dependent upon them, revolve around one common centre of motion, notwithstanding nearly all of them appear to be fixed. Dr. Halley, in 1717, obtained evidence, by observation and calculation, which he regarded as almost conclusive, in relation to the proper motion of some of the most prominent stars. He discovered that Arcturus, Aldebaran, and Sirius did not occupy the same positions in the heavens then that they had done nearly two thousand years previous. He found that they had changed their places, and that they appeared to be moving in certain determinate directions in the heavens.

4. So also has further discovery revealed the same to be true in relation to many of the stars. Some of them

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QUESTIONS.—What binds them together? Is there any known limit to them? 2. What is each grand division called? What does our cluster embrace? 3. What is said of the motions of all of the bodies and systems that compose our cluster? What discoveries were made by Dr. Halley? 4. What further discoveries were made?

have motions which are scarcely perceptible in thousands of years, whilst others are known to move with greater velocity. The star 61 Cygni, which has the greatest proper motion of any known star, moves through an arc of a little over five seconds annually, and to accomplish this travels with a velocity of not less than six thousand millions of miles per hour. Notwithstanding its velocity is so great, it has only undergone since the commencement of the Christian era a change of about $2\frac{1}{2}°$, in consequence of the immense distance that it is from us. Owing to the same cause, the motions of many of the stars that travel with inconceivable velocities may never be known, neither may any perceptible changes in their positions be discovered. Though a proper motion may be inferred as belonging to all of the stars, it has only been determined in relation to those that are most favorably situated.

5. Sir William Herschel, from observations and computations which he made, was of the opinion that the sun, which is comparatively near to us, has a proper motion. So also did Professor Struve arrive at the same result. The sun seems to be travelling from one quarter of the heavens towards the opposite region with a velocity of about four hundred and twenty-two thousand miles per day. There is an apparent change in the positions of the stars in the direction in which he is advancing, as well as in the positions of those from which he is receding. Those in advance of him seem to be separating, whilst those behind him seem to be coming closer together.

6. The constellation Hercules marks that region of the heavens towards which he seems to be travelling;

QUESTIONS.—How many seconds of an arc does 61 Cygni travel through annually? With what velocity does it travel? How many degrees has it changed since the commencement of the Christian era? Is it highly probable that all of the stars have a proper motion? 5. What were the conclusions of Sir William Herschel and Professor Struve in relation to the proper motion of the sun? Upon what did they base them, in part? 6. The sun seems to be moving in what direction?

and the great central sun, around which he and probably all of the stars that belong to our astral system are revolving, is supposed to be Alcyone. It is one of the seven largest stars of a cluster, called the Pleiades, in the constellation Taurus; and its distance from us is so great that it would require a ray of light more than five hundred years to reach the earth, travelling at its usual rate of twelve millions of miles per minute. Under these conditions, the sun would be more than eighteen millions of years in making one revolution around it; and how much longer must the periods of millions of other stars be, whose distances from this central sun are infinitely greater! The human mind cannot comprehend them, much less that boundless empire of Jehovah, the limits of which no aided vision can descry, and of which even this stellar universe of ours, with all its suns and systems, is only an infinitesimal part. May not the central sun of each island universe, attended with all its starry hosts, have an orbit in which it travels around one omnipotent central Sun, whose throne is established in the heavens, and whose government ruleth over all?

QUESTIONS.—What star is supposed to be the centre of our cluster? What may be the centre of the entire universe?

PART THIRD.

Uranography.

For the purpose of convenience, astronomers have divided the starry heavens into three grand divisions,—the northern hemisphere, the southern hemisphere, and the zodiac. The two former divisions are subdivided into sections or districts, which vary in extent and in the number of stars that each contains. The zodiac is situated between these divisions, quite round the heavens, and is divided into twelve equal parts, each of which extends thirty degrees east and west, and sixteen degrees in width. Before the revival of letters in Europe, these three grand divisions contained only forty-eight minor divisions; but with the advance of science other sections have been marked off, especially in the southern hemisphere, till the whole number amounts now to one hundred and six. The southern hemisphere contains between fifty and sixty minor divisions, and the northern between thirty and forty, not including the zodiac. In general, the minor sections are called constellations, but each group of stars has its own specific name, whereby it is known, and its own specific figure connected with it by which it is represented. These figures are in the likeness of men and monsters, and other objects, and were associated, espe-

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Questions.—*Uranography.* Into how many grand divisions are the starry heavens divided? Which is the middle division? Into how many minor divisions were the starry heavens divided by ancient astronomers? Into how many by modern astronomers? How many in the southern hemisphere? How many in the northern? What are these minor divisions called?

cially by the ancient astronomers, with the constellations, which are imperishable, so that the subjects of certain peculiarly-cherished memories might be celebrated throughout all time.

In addition to these general divisions and subdivisions, the stars themselves have been divided into sixteen classes, according to their different degrees of brightness. The brightest stars are considered as being of the first magnitude, the next brightest of the second magnitude, and so on, to the sixth, which consists of the smallest stars visible to the naked eye. The stars that compose the remaining ten classes are visible only by the aid of the telescope.

To aid the reader still further in the study of this subject, all of the stars in each constellation are classified and named according to their magnitudes in relation to each other. The letters of the Greek and English alphabets are used for this purpose; and when they are exhausted, the Arabic characters, 1, 2, 3, etc., are employed to supply the deficit. The Greek alphabet is used first, then the English, and afterwards the figures 1, 2, 3, etc. Alpha (α), the first letter of the Greek alphabet, represents the largest star in each constellation, whether it is of the first magnitude or not, and Beta (β), the second letter, represents the next largest, and so on, till both alphabets are exhausted. Besides these letters, etc., which represent the relative magnitudes of the stars that compose each constellation, some of the principal stars in the heavens have specific names like the planets; as, Sirius, Regulus, Aldebaran, Arcturus, etc. According to this method, except designating the stars by letters, etc., which we deem unnecessary in this work, since the most conspicuous and

QUESTIONS.—*Uranography.* What is associated with each? Has each a specific name? How are the stars classified? The stars of how many classes are visible to the naked eye? What further classification is made of the stars? What characters are used to represent them? Which alphabet is used first? What do the letters indicate? Have some of the most prominent stars specific names?

those of greatest interest have their names associated with them, we will now consider the most prominent constellations, and the principal bodies that they contain, in the order in which they present themselves to our view throughout each successive month of the year, commencing with those that are on the meridian in November.

NAMES AND CHARACTERS OF THE SIGNS OF THE ZODIAC.

♈ Aries, the Ram.	♎ Libra, the Balance.
♉ Taurus, the Bull.	♏ Scorpio, the Scorpion.
♊ Gemini, the Twins.	♐ Sagittarius, the Archer.
♋ Cancer, the Crab.	♑ Capricornus, the Goat.
♌ Leo, the Lion.	♓ Aquarius, the Water-bearer.
♍ Virgo, the Virgin.	♒ Pisces, the Fishes.

Questions.—*Uranography.* What is said of the order in which the constellations are considered?

CONSTELLATIONS VISIBLE IN NOVEMBER.

SECTION CXVII.

Cepheus.

THIS constellation has associated with it the figure of a man clad in regal attire, with a sceptre in his left hand and a crown of stars upon his head. He stands

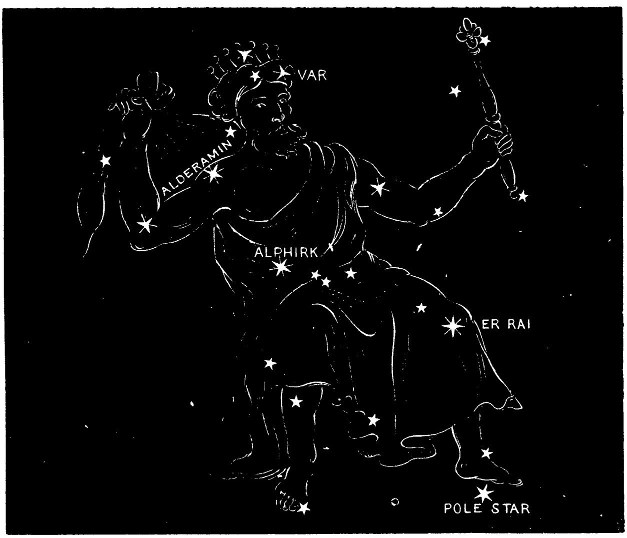

Fig. 71.—Cepheus.

with one foot on the solstitial colure and the other over the polar star. His head is in the Milky Way, and may be known by three stars of the fourth magni-

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QUESTIONS.—*Cepheus.* What figure is associated with this constellation? Describe the position of Cepheus. How many visible stars in this constellation?

tude, in the crown, which form an acute triangle. In this constellation there are about thirty stars visible to the naked eye. *Alderamin*, in the west shoulder, is the most remarkable star, on account of the glittering appearance of its light; and there are two others of the same magnitude, *Alphirk*, in the girdle, and *Er Rai*, in the right knee. By these three stars this constellation may be distinguished from others that surround it, as they form a line slightly curved from the shoulder, in the direction of the equinoctial colure. Its mean right ascension is 338°, and its mean declination is 68° north. It is on the meridian in November, and never sets to us, as it is within the line of perpetual apparition. The telescope reveals a number of double stars in this constellation, and a large rich cluster in the left elbow.

SECTION CXVIII.

Cassiopeia.

THIS constellation has associated with it the figure of a female, seated on a throne, in regal state, and holding in her left hand the branch of a palm-tree. Her chair and one foot rest on the arctic circle, and her head and body extend into the Milky Way. In this constellation there are about fifty stars visible to the naked eye, and four of them are of the third magnitude. It is on the meridian in November, and may be known by four stars of the third magnitude, and some other smaller ones, which seem to form an inverted chair. *Caph*, in the garland of the chair or throne, is nearly on the

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QUESTIONS.—*Cepheus.* Name the principal stars. How may this constellation be known? What is its right ascension? What is its declination? When is it on the meridian? What telescopic objects?

Cassiopeia. Describe the figure associated with this constellation. How many visible stars are in it? How may it be known? Of what magnitude are the largest stars? Name the most important stars.

equinoctial colure, and is of great importance to the mariner and surveyor, as it is used in connection with observations on the pole-star for determining the latitude of places, and discovering the magnetic variation of the needle. *Schedir*, located in the breast, is a variable star, its period from least to greatest brightness being about two hundred days. The mean right ascen-

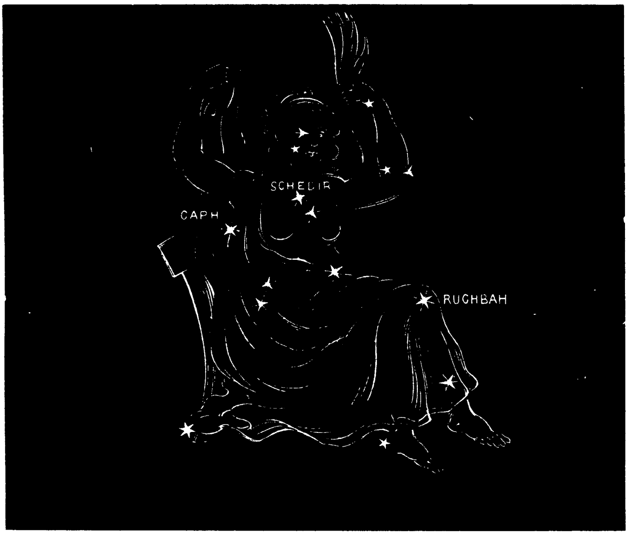

Fig. 72.—Cassiopeia.

sion of this constellation is 12°, and its mean declination is 60° north. When it is on the meridian it appears to change its position but little for several days, owing to its nearness to the pole. The telescope reveals a binary, a double and a quadruple star in this constellation, and also six clusters that vary in their richness and dimensions.

QUESTIONS.—*Cassiopeia.* What is its right ascension? What is its declination? What telescopic objects?

SECTION CXIX.

Andromeda.

THIS constellation has associated with it the figure of a woman with her arms extended and chained by the wrists to a rock. It is directly south of Cassiopeia, and contains about sixty-six visible stars, two of which

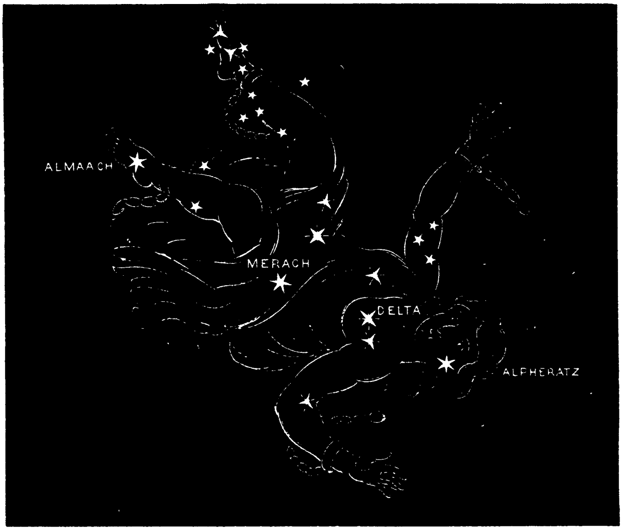

Fig. 73.—Andromeda.

are of the second magnitude and three of the third. *Alpheratz*, situated in the head and also on the equinoctial colure, is the principal star, owing to its magnitude, and the relation it sustains to Pegasus, being one of the

QUESTIONS.—*Andromeda.* Describe the figure associated with this constellation. In what direction is it from Cassiopeia? How many visible stars in it? Of what magnitude are the largest stars?

corners of his Square. *Almaack*, in the left foot, is a prominent star, and *Merach*, with two others of the third and fourth magnitude, form the girdle. This constellation is on the meridian at 10 o'clock on the 10th of November, and its mean right ascension is 14°, and its declination 30° north. The telescope reveals a double and triple star in this constellation, and two very remarkable nebulæ. The double star is in the right foot, and the triple star is in the right hand. There is an elongated nebula in the right foot, the centre of which appears black, and at each extremity of the black centre is a small star. An elliptical nebula also is near the girdle, composed of very minute stars, which is at times visible to the naked eye.

SECTION CXX.

Pisces, the Fishes.

THE figures of two fishes, known as the northern and western, are associated with this constellation, and their mean distance apart is about 20°. They are connected by a ribbon, each end of which is tied around the tail of each fish. Pisces is the twelfth sign, and at present the first constellation, of the *zodiac*, owing to the annual precession of the equinoxes, which has been explained. Pisces being now the twelfth sign and first constellation, the sun enters both on the 21st of March, at the time when the earth is at the vernal equinox. The northern fish is in the southern part of the constellation Andromeda, and has a mean length of 16° and breadth of 7°. Its mean right ascension is 15°,

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QUESTIONS.—*Andromeda.* Name the principal stars. When is this constellation on the meridian? What is its right ascension? What is its declination? What telescopic objects?

Pisces. Describe the figures associated with this constellation. What sign and constellation of the zodiac is Pisces? When does the sun enter this constellation?

and its declination 25° north. It is on the meridian on the 25th of November, and is a number of days in passing over it. The western fish lies along the equinoctial, and is between 25° and 30° west of the northern fish. This whole constellation is composed

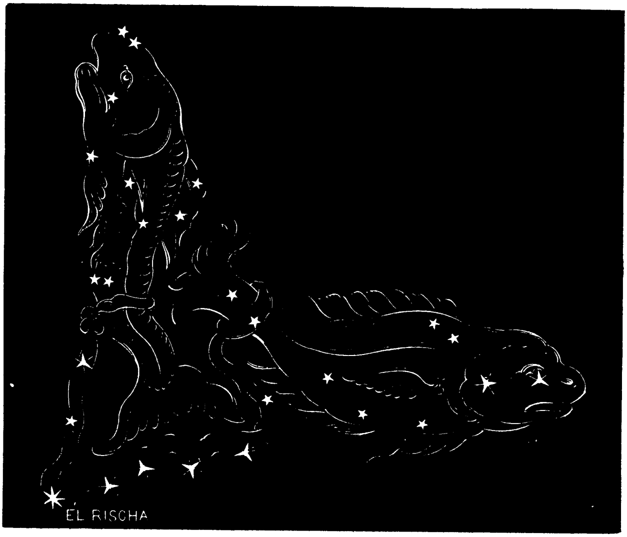

Fig. 74.—Pisces, the Fishes.

principally of small stars, the most important one being *El Rischa*, of the third magnitude, in the flexure of the ribbon, about 2° north of the equinoctial. The telescope reveals four double stars in this constellation, and a faint nebula in the eye of the western fish.

QUESTIONS.—*Pisces.* What is its right ascension? What is its declination? When is it on the meridian? Name the most important star. What telescopic objects?

SECTION CXXI.

Perseus, and Head of Medusa.

THE figures of a man and the head of a frightful gorgon are associated with this constellation. He holds a drawn sword in his right hand, and the head of Medusa in his left. To his ankles are attached wings,

Fig. 75.—Perseus, and Head of Medusa.

and upon the head which he holds in his hand is a crown of snakes. This constellation is on the meridian in December, and contains about sixty-five stars, twelve of which are in the head of Medusa, and two are of the second magnitude and four of the third. The most

QUESTIONS.—*Perseus, and Head of Medusa.* Describe the figures associated with this constellation. When is Perseus on the meridian? How many visible stars are in this constellation? How many of the second magnitude?

remarkable star is *Algol*, in the head of Medusa. It is variable, changing from the second to the fourth magnitude in about three and one-half hours, and, returning again in the same time to the same magnitude, remains for two and three-fourths days stationary, and then repeats the same variations. *Algenib* is also of the second magnitude, and is in the side of Perseus, and may be readily distinguished by being the brightest and most central star of a number that surround it. This constellation lies in the Milky Way, and is on the meridian on the 25th of December. Its mean right ascension is 46°, and its declination is 49° north. Five double stars and one quadruple star, also three clusters and five nebulæ, are revealed by the telescope in this constellation. One of the clusters is in the sword-handle, one in the right side, and one in the left knee.

CONSTELLATIONS VISIBLE IN DECEMBER.

SECTION CXXII.

Aries, the Ram.

With this constellation is associated the figure of a ram. Aries is the first sign, and at present the second constellation, of the zodiac, owing to the precession of the equinoxes, which has been explained. As they move westward about 50″ every year, they have gone through a whole sign since their places were assigned them first about twenty-two hundred years ago, so that the constellation Aries is now in the sign Taurus, Taurus in Gemini, Gemini in Cancer, and so on. The con-

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Questions.—*Perseus, and Head of Medusa.* Name the most remarkable star. Describe its variations. Where is this constellation situated? When is it on the meridian? What is its right ascension? What is its declination? What telescopic objects?

Aries. What figure is associated with this constellation? What sign and constellation of the zodiac is Aries?

stellation Aries is on the meridian in December, and contains about sixty-five stars, one of which is of the second magnitude, one of the third, and two of the fourth. *Arietes*, or *Elnath*, in the right horn, is a nautical star, and is at times of great importance to the navigator. *Sheratan*, near the left horn, and *Mesar-*

Fig. 76.—Aries, the Ram.

thim, in the left ear, hold conspicuous places also in this constellation. Its right ascension is 30°, and its declination is 22°. Three double stars, a triple star, a quadruple star, and also a round nebula, are distinctly revealed by the aid of the telescope in this constellation.

QUESTIONS.—*Aries.* When is Aries on the meridian? How many visible stars? Of what magnitude is the largest? Name the principal stars. What is the right ascension of this constellation? What is its declination? What telescopic objects?

SECTION CXXIII.

Cetus, the Whale.

With the largest constellation in the heavens is associated the figure of a whale. It contains about ninety-seven stars, two of the second magnitude, ten of the third, and eight of the fourth. The most brilliant

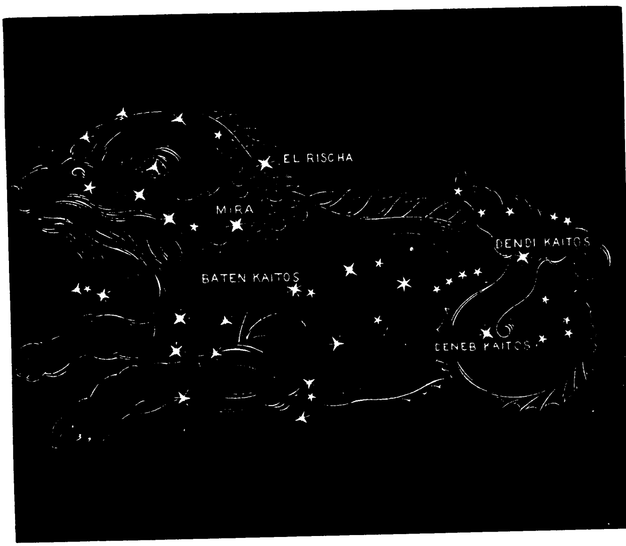

Fig. 77.—Cetus, the Whale.

star in this constellation is *Menkar*, in the nose, and the most remarkable one is *Mira*, situated in the neck. The latter is of the second magnitude, and variable, its light diminishing till it becomes entirely extinguished, and afterwards rekindling and returning again to its

---

Questions.—*Cetus.* How many visible stars does Cetus contain? Of what magnitude are the largest? Name the most remarkable stars. What is said of Mira?

former brightness. It remains at its greatest brightness about two weeks, and then decreases so as to become invisible in about three months, and remains invisible for about five months, and then increases in brightness for about eighty days. *Baten Kaitos*, in the heart, *Deneb Kaitos*, in the loop of the tail, and *Dendi Kaitos*, in the end of the tail, are the most conspicuous stars west of Menkar and Mira. It is on the meridian in December, and its right ascension is 25°, and its declination is 12° south. Three double stars, one long narrow nebula, a planetary nebula, and a bright round nebula, are visible in this constellation by the aid of the telescope.

CONSTELLATIONS VISIBLE IN JANUARY.

SECTION CXXIV.

Auriga, the Charioteer.

THE figures of a man, a she-goat, and her kids, are associated with this constellation. The man is in a reclining posture, being sustained by his right foot, which rests on the horn of Taurus. He holds a horse's bridle in his right hand, and the goat and her kids are sustained against his side and shoulder by his left hand. There are sixty-six stars visible in this constellation, one of which is of the first magnitude, and one of the second. *Capella*, which is the Latin name for goat, is the principal star in this constellation. It is situated in the left shoulder, and is one of the most brilliant stars in the heavens. *Menkalina*, situated in the right shoulder, is

QUESTIONS.—*Cetus.* When is this constellation on the meridian? What is its right ascension? What is its declination? What telescopic objects?

Auriga. Describe the figures associated with this constellation. How many visible stars in it? How many of the first magnitude? Name the most prominent stars.

a star of the second magnitude, and, in connection with Capella, suggests a singular coincidence in relation to two similar stars situated in the shoulders of Orion. Though on opposite shoulders in Orion as it regards their magnitudes, yet they are of the same magnitudes and the same distances apart. *El Nath*, which is in the right foot, and also in the northern horn of Taurus, is

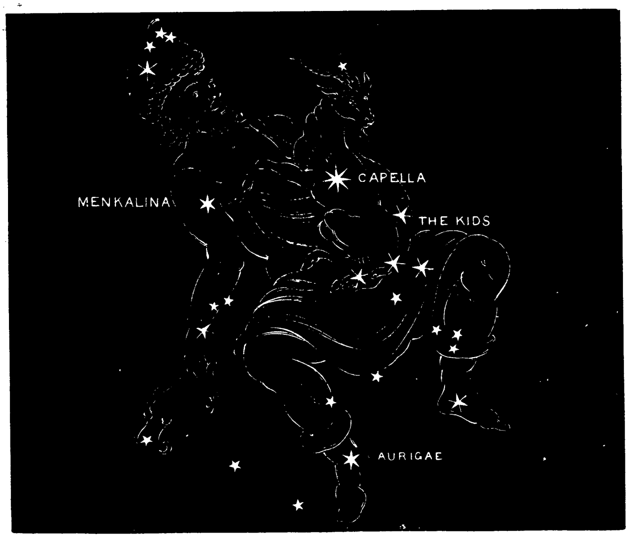

Fig. 78.—Auriga, the Charioteer.

common to both constellations. The right ascension of this constellation is 75°, and its declination is 45° north, and it is on the meridian in January. The telescope reveals in it a resolvable nebula, and a rich cluster of minute stars which in form resembles a cross.

QUESTIONS.—*Auriga.* What is said of Capella and Menkalina? What is the right ascension of Auriga? What is its declination? What telescopic objects?

SECTION CXXV.

Taurus, the Bull.

THIS is the second sign and third constellation of the zodiac, and has associated with it the figure of an enraged bull. There are about one hundred and forty visible stars in it, and two clusters, the Hyades and

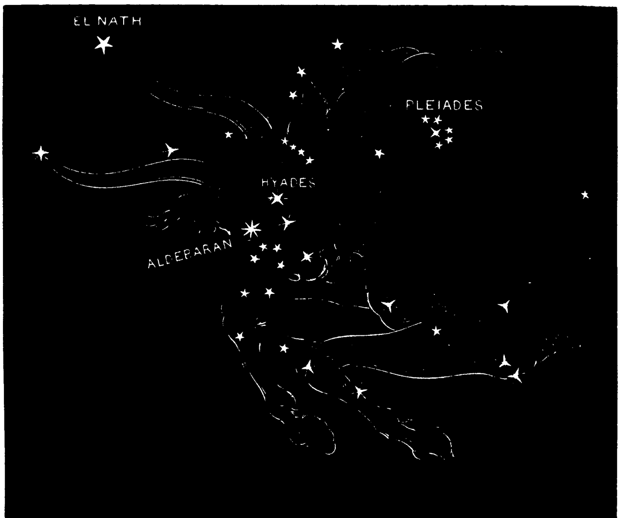

Fig. 79.—Taurus.

Pleiades. *Aldebaran* is a star of the first magnitude, and is situated in the eye. *El Nath* and another star, in the points of the horns, form the base of a triangle of which Aldebaran is the apex. *Alcyone* is of the

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QUESTIONS.—*Taurus.* What sign and constellation of the zodiac is Taurus? How many visible stars in Taurus? Name the clusters. What star of the first magnitude? Name the brightest star in the Pleiades.

third magnitude, and is the brightest star in the Pleiades, the remaining five which are visible being of the fourth and fifth magnitudes. The Hyades are composed of several stars, apparently near together, in the face of the bull, and the Pleiades are situated about 11° southeast, on his shoulder. In or near this constellation is supposed to be the centre of our stellar universe, around which the sun and stars revolve. This constellation is on the meridian in January. Its right ascension is 65°, and its declination is 16° north. The telescope reveals in it a large nebula, and a nebulous star with a faint luminous atmosphere surrounding it.

SECTION CXXVI.

Orion.

THIS constellation has associated with it the figure of a man resting on one knee. He holds in his right hand a large club, and in his left hand the skin of a lion as a shield. In his left hand is a sword; and his attitude indicates that he is about defending himself against an assault. It is on the meridian in January, and there are seventy-eight stars in it visible to the naked eye, two of which are of the first magnitude, four of the second, three of the third, and twelve of the fourth. *Betelguese*, on the right shoulder, and *Rigel*, in the left foot, are the most prominent stars. *Belatrix*, on the left shoulder, and *Mintaka*, *Anilam*, and *Almitak*, in the belt, are of the second magnitude. The three latter stars are called sometimes the "Bands of Orion," the

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QUESTIONS.—*Taurus.* Where are these clusters situated? What star is supposed to be at or near the centre of our stellar universe? What is the right ascension of this constellation? What is its declination? What telescopic objects?

Orion. Describe the figure associated with this constellation. How many visible stars in it? How many of the first magnitude? Which are the most prominent stars?

"Three Kings," "Jacob's Staff," the "Rake," "Our Lady's Wand," the "Ell and Yard," the "Golden Yard," "Napoleon," etc.; but they are generally distinguished by the name of the "*Three Stars.*" The right ascension of this constellation is 80°, and its decli-

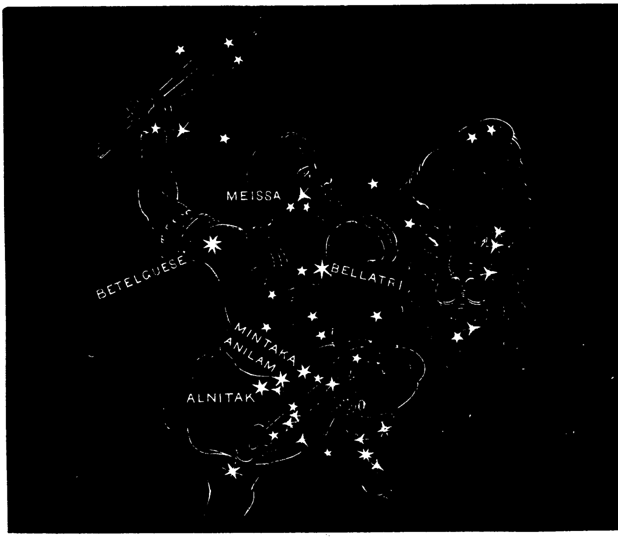

Fig. 80.—Orion.

nation is 0°, as it is on the equinoctial. Three double stars, a triple star, a sextuple star, and a decuple star, also a nebulous star, and the most conspicuous nebula in the heavens, are revealed by the telescope in this constellation.

QUESTIONS.—*Orion.* Name "The Three Stars." What is the right ascension of this constellation? What is its declination? What telescopic objects? What is a triple star? What is a sextuple star? What is a decuple star?

SECTION CXXVII.

Eridanus, the River Po.

THE figure of a stream separated into two branches, called the northern and southern, is associated with this constellation. The northern stream extends in an easterly direction about 40°; the southern stream extends nearly in the same direction for nearly the same

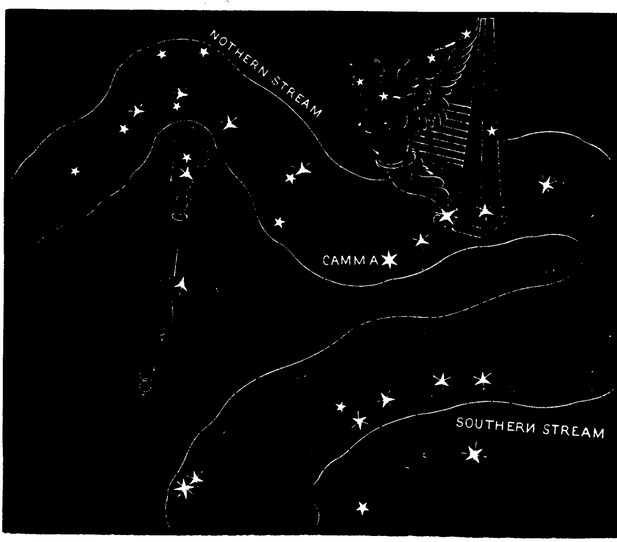

Fig. 81.—Eridanus, the River Po.

distance, and then turns in a gradual curve down towards the south, afterwards changing its direction to the southwest, and flows about 50° further. There are

QUESTIONS.—*Eridanus.* Describe the figure associated with this constellation.

about eighty stars visible to the naked eye in this constellation. One of them, which is situated in the extremity of the southern stream, is of the first magnitude, and in consequence of it being so far south is invisible to all of the inhabitants of the earth north of 32° north latitude. *Theemim*, in the southern stream, is a star of the third magnitude, and Gamma (γ), in the first bend of the northern stream, is of the second magnitude. It is on the meridian in January, and its mean right ascension is 60°, and its mean declination is 10° south. The telescope reveals in this constellation a milky-white nebula, which is very bright in the centre, and a planetary nebula also, of a grayish-white color.

CONSTELLATIONS VISIBLE IN FEBRUARY.

SECTION CXXVIII.

Gemini, the Twins.

WITH this constellation are associated the figures of two brothers, named Castor and Pollux, in a sitting posture, with their feet resting on the Milky Way. Gemini is the third sign and the fourth constellation of the zodiac, and contains eighty-four visible stars, two of the second magnitude, three of the third, and five of the fourth. The principal stars, *Castor* and *Pollux*, were named after the twins, and are situated in their heads. Pollux is a quadruple star, and Castor is a double

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QUESTIONS.—*Eridanus*. How many visible stars in it? How many of the first magnitude? Name the most prominent stars. What is its right ascension? What is its declination? What telescopic objects?

Gemini. Describe the figures associated with this constellation. What sign and constellation of the zodiac is Gemini? How many visible stars in this constellation? Of what magnitude is the largest? Name the principal stars What is said of them?

star, and variable, owing to the fact that it has another small star revolving around it. Its period is about three hundred and forty-five days. *Alhena*, in the left foot of the right twin, *Wasat* in the body and *Melucta* in the right knee of the left twin, are also prominent stars in this constellation. It is on the meridian in February, and its right ascension is 111°, and its declination 32°

Fig. 82.—Gemini, the Twins.

north. Two double stars, two triple stars, and a quadruple star are visible with the aid of the telescope; also three clusters, one on the right foot of Castor, another in the right leg of Pollux, and a dense cluster a little below his shoulder.

QUESTIONS.—*Gemini.* What is its right ascension? What its declination? When is this constellation on the meridian? What telescopic objects?

SECTION CXXIX.

Canis Minor et Monoceros, the Little Dog and the Unicorn.

WITH these constellations are associated the figures of a dog and a unicorn. Canis Minor is situated directly south of Gemini, and contains fifteen stars, one of which is of the first magnitude and one of the third.

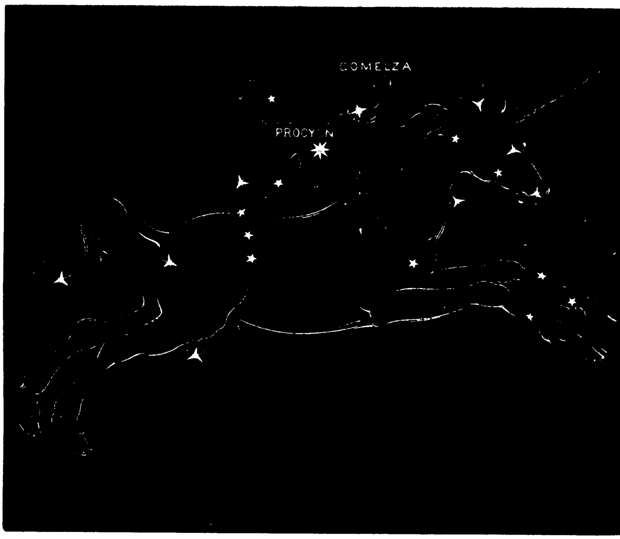

Fig. 83.—Canis Minor et Monoceros.

The brightest star is called *Procyon*, and is situated near the centre of the body. It forms with Pollux in Gemini, and Betelguese in Orion, a right-angled triangle, and with Betelguese and Sirius in Canis Major it forms

QUESTIONS.—*Canis Minor et Monoceros.* Describe the figures associated with these constellations. How many visible stars in Canis Minor? How many of the first magnitude?

an equilateral triangle. *Gomelza* is a bright star of the third magnitude, and is situated in the neck, northwest of Procyon. The right ascension of this constellation is 112°, and its declination is 50° north.

MONOCEROS is directly south of Canis Minor and north of Canis Major. It is situated on the equinoctial, and, as it contains no large stars, is not worthy of special notice. Two double stars, two triple stars, and a field between the unicorn's ears, rich with small stars, are revealed by the telescope. These constellations are on the meridian in February.

SECTION CXXX.

Canis Major, the Great Dog.

THE figure of a dog resting on his hind feet and holding up his paws is associated with this constellation. It contains about thirty visible stars, one of the first magnitude, four of the second, and two of the third. *Sirius*, situated in the nose, is the principal star, and is the largest and most brilliant in the heavens. It is supposed to be one of the nearest of the fixed stars to us, yet its distance is computed at many millions of millions of miles. The Egyptians and Romans watched its rising with great solicitude, as it betokened to them their success in husbandry for the ensuing year. The ancients gave the name of dog-days to a certain period in the year when this star seemed to blend its influence with that of the sun in increasing the heat of summer.

QUESTIONS.—*Canis Minor et Monoceros.* Name the most prominent stars. What is the right ascension of Canis Minor? What is its declination? What telescopic objects?

Canis Major. Describe the figure associated with this constellation. How many visible stars does it contain? Which of the first magnitude? What is said of it? When do dog-days commence and end?

They commence now on the third of July and end on the eleventh of August. *Mirzam*, in the left foot of the dog, and *Wesen*, in the back, are stars of the second magnitude. The right ascension of this constellation is 105°, and its declination is 12° south. Three stars,

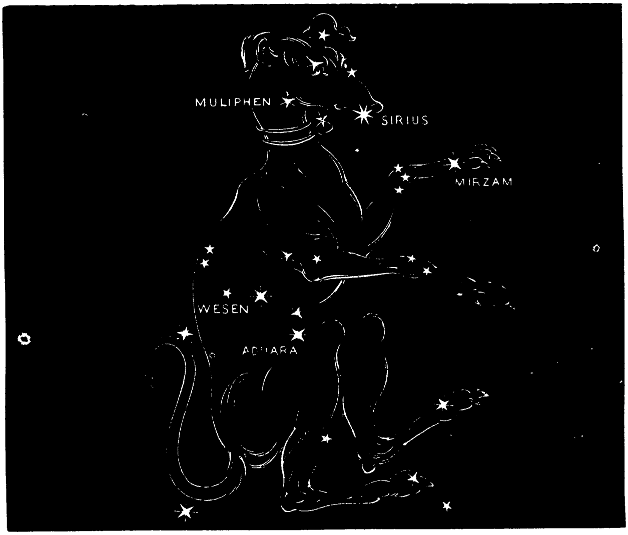

Fig. 84.—Canis Major, the Great Dog.

each with a distant companion, and two clusters, one in the back and one between Sirius and MONOCEROS, are visible by the aid of the telescope. This constellation is on the meridian in February.

QUESTIONS.—*Canis Major.* What is the right ascension of this constellation? What is its declination? What telescopic objects? When is this constellation on the meridian?

CONSTELLATIONS VISIBLE IN MARCH.

SECTION CXXXI.

Cancer, the Crab.

THE figure of a crab is associated with this constellation. It is the fourth sign and fifth constellation of the zodiac, and contains about eighty stars that are visible,

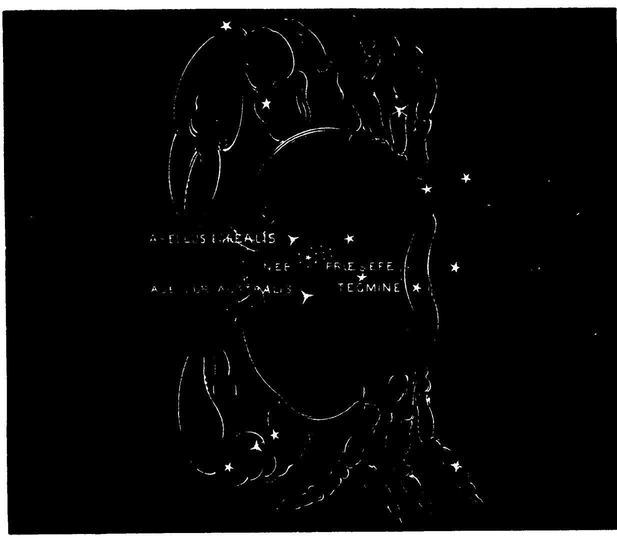

Fig. 85.—Cancer, the Crab.

one of which is of the third magnitude and six of the fourth. The most conspicuous stars are *Asellus Bore-*

QUESTIONS.—*Cancer.* What sign and constellation of the zodiac is Cancer? How many visible stars in this constellation? Of what magnitude is the largest?

alis, on the north side, and *Asellus Australis*, on the south side of the crab. *Tegmine*, in the hinder part, is the most remarkable star. It is composed of three stars, when viewed through the telescope, two of which are close together and one revolves around the other in about fifty-eight years, while the largest of the three makes one grand revolution in between five and six hundred years. In the crest of Cancer is a remarkable cluster called Prœsepe,—the Beehive,—which is visible to the naked eye. The right ascension of this constellation is 126°, and its declination is 20° north: consequently, it is on the meridian in March. The telescopic objects are two double stars, a triple star, also a rich loose cluster in the southern claw.

SECTION CXXXII.

Argo Navis, the Ship Argo.

WITH this constellation is associated the figure of a ship. It is situated south of the equator about 50°, and east of the Great Dog. It contains about sixty stars, two of the first magnitude, four of the second, and eight of the third. *Canopus*, and *Miaplacidus*, situated about 25° east of the former, are the largest and most brilliant stars, but, both being far south, are invisible to the inhabitants of the Northern States. *Markeb*, in the prow of the ship, is a star of the fourth magnitude, and is visible from this latitude. *Eta* is the most remarkable, as it is variable, and is situated in

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QUESTIONS.—*Cancer.* Name the most conspicuous stars. What is said of Tegmine? What remarkable cluster? What is the right ascension of Cancer? What is its declination? What telescopic objects?

Argo Navis. How is this constellation situated? How many visible stars does it contain? Of what magnitude are the largest? Name and describe them. Name the most remarkable star.

a vast stratum of stars and nebulæ. It varies from the brilliancy of a star of the first magnitude to one of the fourth. The right ascension of this constellation is 115° ; it is on the meridian in March, and contains a number of interesting telescopic objects. The nebula

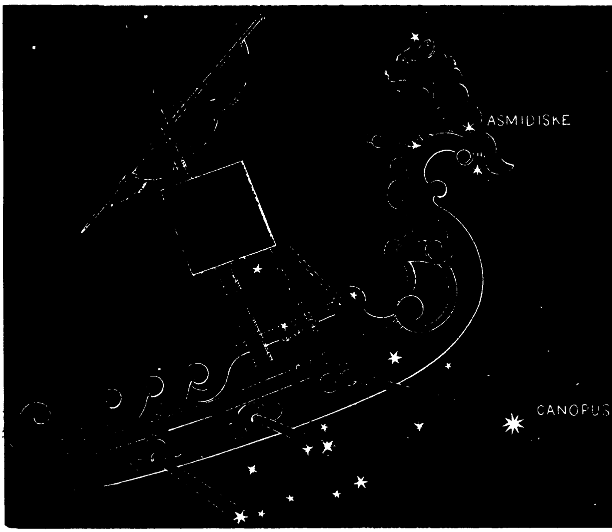

Fig. 86.—Argo Navis, the Ship Argo.

that surrounds Eta is large, and contains about six thousand small stars. Another celestial object like a comet has been discovered, a small cluster also, and a planetary nebula.

QUESTIONS.—*Argo Navis.* What is said of it? What is the right ascension of this constellation? What is its declination? What telescopic objects? What is said of the nebula that surrounds Eta? What is said of other telescopic objects?

CONSTELLATIONS VISIBLE IN APRIL.

SECTION CXXXIII.

Ursa Major, the Great Bear.

THE figure of a huge bear is associated with this constellation. It is situated about 30° south of the north pole, and may be known by a cluster of seven bright stars, which have been named the Dipper or Ladle by

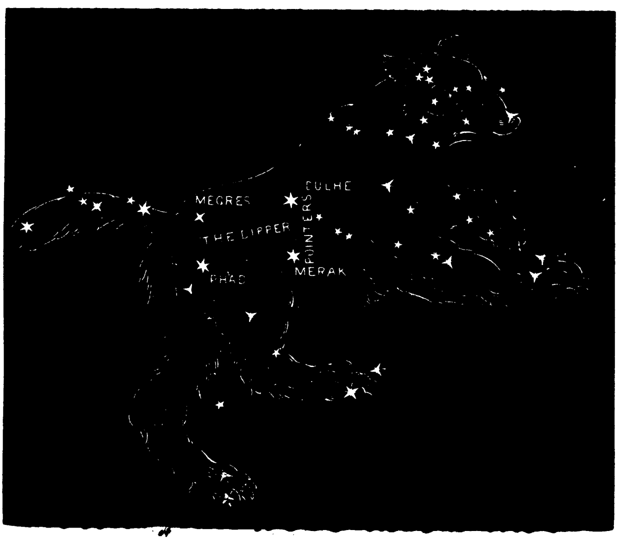

Fig. 87.—Ursa Major, the Great Bear.

some, and by others the Wagon, and also the Plough. *Benetnasch* is in the end of the handle of the dipper, or

QUESTIONS.—*Ursa Major.* Describe how this constellation is situated, and how it may be known.

tail of the bear, *Mizar* is in the middle, and *Alioth* is next to the bowl, or body. These three stars form the handle of the dipper, or tail of the bear. *Merak* and *Dubhe*, near the middle of the bear, are called the Pointers, because they always point towards the north pole. These two stars, together with *Megres* and *Phad*, in the hinder part of the bear, form what is imagined to be the bowl of the Dipper. The right ascension of this constellation is 153°; it is on the meridian in April, and contains a variety of objects peculiarly interesting when seen through the telescope. Five double stars are visible, and eight nebulæ,—two planetary, a round one with two stars in it, an oval one with a bright nucleus at its centre, together with four bright ones of various forms.

SECTION CXXXIV.

Leo, the Lion.

THIS constellation has associated with it the figure of a lion, and is situated south of Leo Minor and the Great Bear. It contains about ninety visible stars, and is the fifth sign and sixth constellation of the zodiac. *Regulus*, situated in the lower part of the breast, is a star of the first magnitude, and may be readily observed on account of its brilliancy. *Al Gicba*, situated in the shoulder, is a star of the second magnitude, and *Adhafera*, situated in the neck, is of the third magnitude. *Denebola*, in the end of the tail, is of the second magnitude, and is readily distinguished by its great brilliancy. The Three Stars, in the neck, and two in the breast, are sup-

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QUESTIONS.—*Ursa Major.* Name and describe the principal stars. Which are the Pointers? What is the right ascension of Ursa Major? What its declination? What telescopic objects?

Leo. How is this constellation situated? How many visible stars does it contain? What sign and constellation of the zodiac is Leo? Of what magnitude is the largest star? Name the principal stars.

posed to form the figure of a sickle; and this is a remarkable point in the heavens, owing to the fact that the November showers of meteors nearly always appear to radiate from this place. The right ascension of this constellation is 150°, and its declination is 15° north

Fig. 88.—Leo, the Lion.

The telescopic objects are a number of double stars, a triple star, and five nebulæ, one of which is spiral in form, and another elongated, with a figure like the edge of a scroll loosely rolled together near the centre. This constellation is on the meridian in April.

QUESTIONS.—*Leo.* What remarkable point in Leo? What is the right ascension of this constellation? What is its declination? What telescopic objects?

CONSTELLATIONS VISIBLE IN MAY.

SECTION CXXXV.

Virgo, the Virgin.

THIS constellation has associated with it the figure of a young woman clad with wings, and in the act of rising up on them to ascend to heaven. It is the sixth

Fig. 89.—Virgo, the Virgin.

sign and seventh constellation of the zodiac, and is situated east of Leo. It contains about one hundred visible stars, one of the first magnitude, six of the

QUESTIONS.—*Virgo.* Describe the figure associated with this constellation. What sign and constellation of the zodiac is Virgo? How many visible stars in this constellation?

second, and nine of the third. *Azimech*, or *Spica*, in the bunch of grain that is held in the virgin's left hand, is a star of the first magnitude, and may be known by its splendor and the great distance that it is from any other bright star. *Vindemiatrix*, in the side of the virgin, is a remarkable star, being composed of two, one revolving around the other in a period of about one hundred and eighty years. The right ascension of this constellation is 195°, and its declination is 5° north, and it is on the meridian in May. The telescopic objects are a number of double stars, a binary star, five nebulæ, and a wonderful nebulous region. One of the nebulæ is double, one spiral, and two of them are elliptical.

SECTION CXXXVI.

Centaurus, the Centaur.

WITH this constellation is associated the figure of a monster,—half man and half horse,—the man holding a spear in his right hand, with which he is piercing a wolf, which he holds in his left hand. It is situated about 50° south of Virgo, and contains over thirty visible stars, two of the first magnitude, one of the second, and five of the third. The principal star is *Burgula*, situated in the left fore leg, and sixty degrees south of the equator. It is one of the brightest stars in the southern hemisphere, and is one of the nearest to us of any whose distance has been computed. *Algena*, situated a little behind the right fore leg, and a little out-

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QUESTIONS.—*Virgo*. Of what magnitude is the largest? Name the principal stars. What is said of Vindemiatrix? What is the right ascension of Virgo? What is its declination? What telescopic objects?

Centaurus. Describe the figure associated with this constellation. How is the constellation situated? How many visible stars in it? How many of the first magnitude? Name the principal star.

side of the Milky Way, is also a star of the first magnitude. The right ascension of this constellation is 200°, and its declination is 50° south: consequently, it is on the meridian in May. The telescope reveals to us in this constellation a number of remarkable objects. A

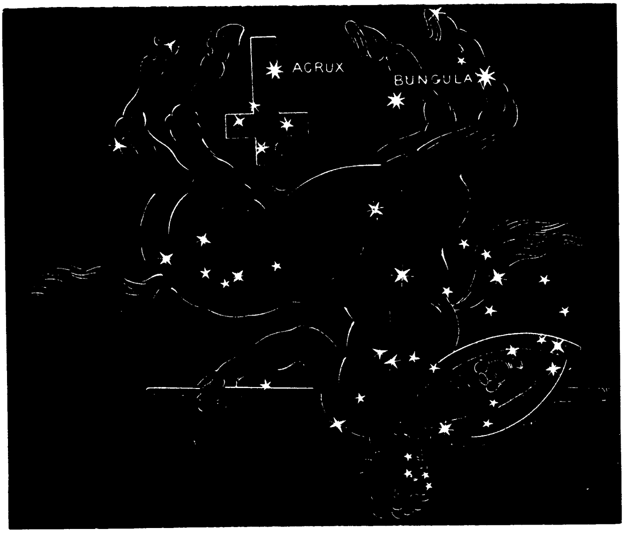

Fig. 90.—Centaurus, the Centaur

cluster which appears as a single star to the naked eye, when examined under the most favorable circumstances, is found to be composed of thousands of stars; and a small round nebula containing three small stars, and a double nebula with a white streak between the parts, also manifest themselves.

QUESTIONS.—*Centaurus.* What is the right ascension of this constellation? What is its declination? What telescopic objects?

CONSTELLATIONS VISIBLE IN JUNE.

SECTION CXXXVII.

Libra, the Scales.

THIS constellation has associated with it the figure of a pair of scales. It is the seventh sign and eighth constellation of the zodiac. It is east of Virgo, and con-

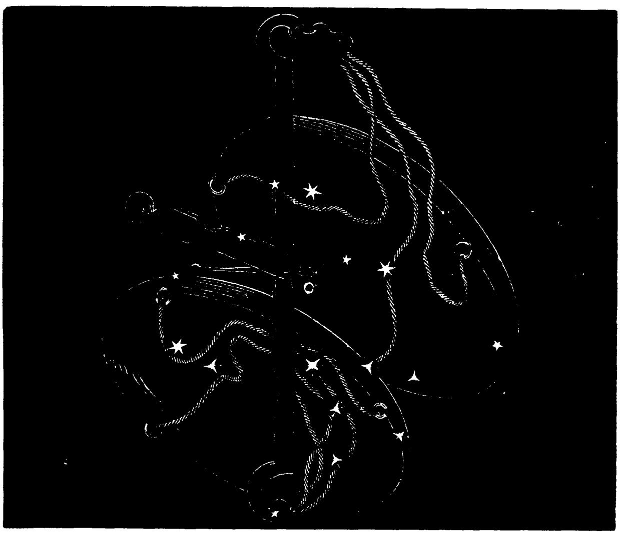

Fig. 91.—Libra, the Scales.

tains about fifty stars, two of the second magnitude, three of the third, and eleven of the fourth. It may be known by four of the largest stars, which represent

QUESTIONS.—*Libra.* What sign and constellation of the zodiac is Libra? How is it situated in relation to Virgo? How many visible stars does it contain?

the corners of a four-sided figure that lies in a northeast and southwest direction. About twenty-two hundred years ago, the sun entered this constellation on the 23d of September; but, owing to the annual precession of the equinoxes, which has been explained, he does not enter the constellation Libra now till about the 26th of October. Its right ascension is 226°, and its declination is 8° south: consequently, it is on the meridian in June. The telescopic objects are several double stars, a triple star, and two clusters. In the cluster which is over the beam, the stars appear to be crowded upon one another near the centre, as if they were joined together; and in the other they are indistinct, resembling a nebulosity.

SECTION CXXXVIII.

Bootes et Canis Venatici, the Bear-Driber and Greyhounds.

THE figure of a man with a club in his right hand and a thong in his left hand, together with those of two greyhounds, to which the thong is attached at each end, are associated with these constellations. They are situated north of Libra, and thirty degrees north of the equinoctial, where Boötes seems to be pursuing, with the dogs, Asterion and Chara, the Great Bear around the north pole. They are on the meridian in June, and contain about seventy-five stars that are visible, one of the first magnitude, seven of the third, and eleven of the fourth. *Arcturus*, situated in the left knee, is the principal star, and is supposed by some astronomers to be nearer to us than any other star in the northern

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QUESTIONS.—*Libra.* How is it distinguished? When does the sun enter it? What is the right ascension of this constellation? What is its declination? What telescopic objects?

Boötes et Canis Venatici. Describe the figures associated with these constellations. How are these constellations situated? Of what magnitude are the largest stars? What is the principal star?

hemisphere. *Mirac*, in the girdle, is a star of the third magnitude, and is remarkable, owing to the fact that it is double. One of its component parts revolves around the other in a period of nearly a thousand years. The

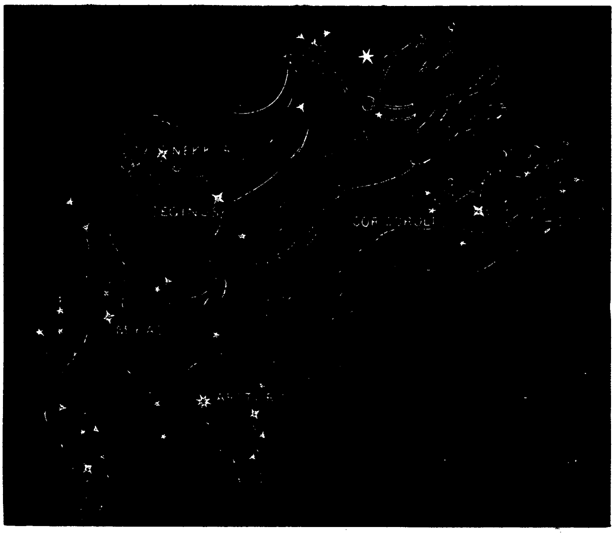

Fig. 92.—Bootes et Canis Venatici.

right ascension of Boötes is 212°, and that of Asterion is 200°, and declination 40° north. Several double stars, a triple star, a rich group of stars, and two nebulæ, are visible by the aid of the telescope.

Boötes et Canis Venatici. What is the most remarkable star? What is the right ascension of these constellations? What is their declination? What telescopic objects?

SECTION CXXXIX.

Ursa Minor, the Lesser Bear.

WITH this constellation is associated the figure of a small bear. It is situated near the north pole, and contains twenty-four visible stars, including three of the third magnitude and four of the fourth. The number

Fig. 93.—Ursa Minor, the Lesser Bear.

of stars that attracts the eye of the observer most is seven, which are called the Little Dipper. These stars correspond to the seven in the Great Bear which form the dipper in it, with this exception, that those that form the bowl are reversed in position. The north polar

QUESTIONS.—*Ursa Minor.* Where is this constellation situated? How many conspicuous stars are in it? What is the most remarkable star?

star, called *Cynosura*, is the most prominent and remarkable star in this constellation. It is situated in the end of the handle of the dipper, or tail of the bear, and is now about one degree and a half distant from the true pole, which, however, is generally considered and practically dealt with as coinciding with this star, which is regarded as a fixed point. The position of the pole is constantly changing: it will continue to approach slowly towards the pole-star for over two hundred years, till it will come within less than half a degree of it; then it will recede from it for about thirteen thousand years, when it will be about 49° distant from it. For the cause of this variation, see the sections on the precession of the equinoxes and nutation. The right ascension of this constellation is 235°, and its declination is 75° north: consequently, it is on the meridian in June. The pole-star, when viewed through a powerful telescope, appears double, like a telescopic star, situated near the middle of the body.

CONSTELLATIONS VISIBLE IN JULY.

SECTION CXL.

Scorpio, the Scorpion.

THE figure of a scorpion is associated with this constellation. It is situated southeastward of Libra, and is the eighth sign and ninth constellation of the zodiac. It is on the meridian in July, and contains about forty visible stars, one of the first magnitude, one of the second, and ten of the third. *Antares*, situated in the

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QUESTIONS.—*Ursa Minor.* How far is it from the celestial pole? Is the pole constantly changing? What is the right ascension of this constellation? What is its declination? What telescopic objects?

Scorpio. How is this constellation situated? What sign and constellation of the zodiac is Scorpio? How many visible stars in it? How many of the first magnitude?

heart, is the principal and most remarkable star, owing to its brilliancy and its red appearance. Antares, Fomalhaut, Aldebaran, and Regulus, were formerly associated with the solstitial and equinoctial points, and, consequently, were objects of great prominence and utility in describing other heavenly objects, and computing distances. *Graffias* is a star of the second magni-

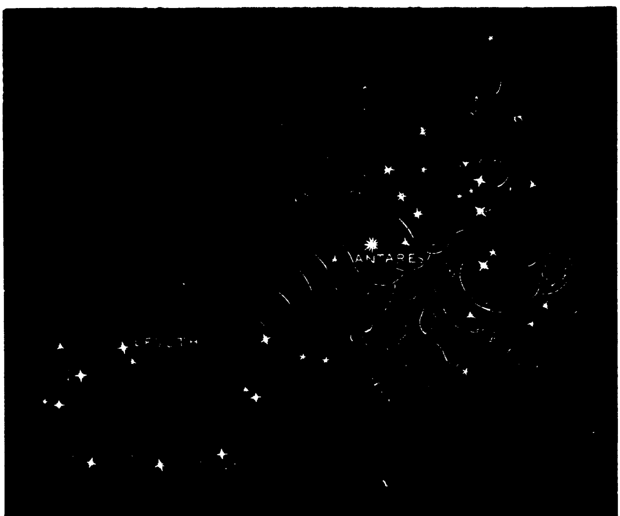

Fig. 94.—Scorpio, the Scorpion.

tude, and is situated in the scorpion's head, in the midst of a vast number of very small stars, which resemble, in shape, a cometary nebula. The right ascension of this constellation is 244°, and its declination is 26° south. A number of double stars, and three clusters, are visible by the aid of the telescope.

QUESTIONS.—*Scorpio.* For what is it remarkable? What other remarkable stars are noticed? What is the right ascension of Scorpio? What is its declination? What telescopic objects?

SECTION CXLI.

Serpentarius et Serpens, the Serpent-Bearer and the Serpent.

THE figures of a man and a serpent are associated with these constellations. The name of the man is Ophiuchus, and he holds the serpent by both hands, the head of which extends near to Corona Borealis, and the

Fig. 95.—Serpentarius et Serpens.

tail in a northwesterly direction, terminating in the Milky Way. These constellations are situated north of Scorpio and south of Hercules. They lie on each side of the equinoctial, and are divided nearly equally by it. They are on the meridian in July, and contain

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QUESTIONS.—*Serpentarius et Serpens.* Describe the figures associated with these constellations. How are these constellations situated? How many visible stars do they contain?

about one hundred visible stars, three of the second magnitude, seven of the third, and eleven of the fourth. *Ras-al-Hague* is the principal star, and is near the northern extremity, while *Rho* marks the southern boundary of Serpentarius. *Unuk-al-Hay*, in the neck of the serpent, is a star of the second magnitude, and is directly south of the Northern Crown. The right ascension of Serpentarius is 260°, and its mean declination is 13° south. The telescope reveals a number of double stars, a multiple star, and three globular clusters in these constellations.

SECTION CXLII.

Hercules.

THE figure of a man in a kneeling posture, invested with a lion's skin, with a club in his right hand and a three-headed dog, Cerberus by name, in his left, is associated with this constellation. It is situated north of Serpentarius, and south of Draco, and east of the Northern Crown. It is on the meridian in July, and contains over one hundred stars visible to the naked eye, two of the second magnitude, and eight of the third. *Ras-Algethi* is the principal star, and is situated in the head, not far distant from Ras-al-Hague in the head of Ophiuchus. This constellation may be known by the star in the head and one in each shoulder, which form a regular triangle, and also by being west of Vega, a star of the first magnitude, situated in the Harp. It

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QUESTIONS.—*Serpentarius et Serpens.* Of what magnitude are the largest? What is the principal star? What star marks the southern boundary of Serpentarius? What is the right ascension of Serpentarius? What is its declination? What telescopic objects?

Hercules. Describe the figures associated with this constellation. How is it situated? How many visible stars in it? Of what magnitude are the largest? What is the principal star?

is towards this constellation that the sun is now travelling, accompanied by all of the bodies that revolve around him, in making his annual journey of over eighteen millions of our years around the star Alcyone, in Taurus, or some point comparatively near to it,

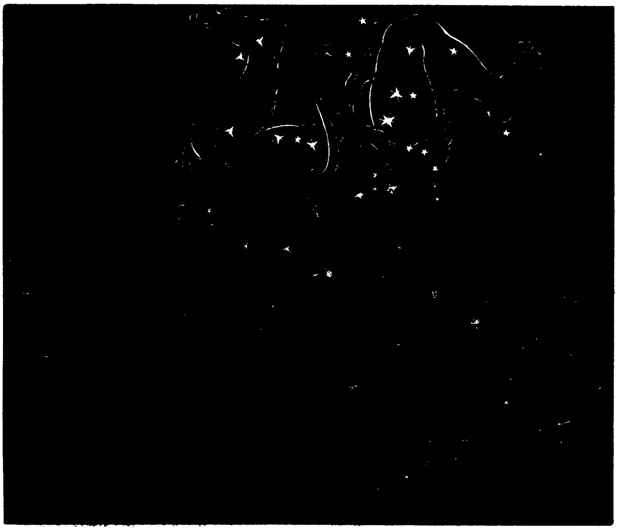

Fig. 96.—Hercules.

which is supposed to be his centre of motion. The right ascension of this constellation is 255°, and its declination is 22° north. The telescopic objects are a number of double stars, two clusters, and two planetary nebulæ.

QUESTIONS.—*Hercules.* What is said of the sun in relation to this constellation? What is the right ascension of this constellation? What is its declination? What telescopic objects?

CONSTELLATION VISIBLE IN AUGUST.

SECTION CXLIII.

Sagittarius, the Archer.

THE figure of a monster, part horse and part man, is associated with this constellation. It is situated east of Scorpio, is the ninth sign and tenth constellation of the

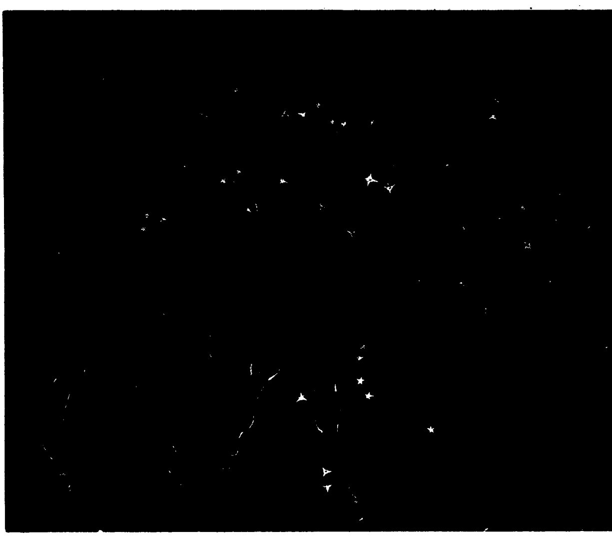

Fig. 97.—Sagittarius, the Archer.

zodiac, and is on the meridian in August. It contains about seventy stars visible to the naked eye, four of the

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QUESTIONS.—*Sagittarius.* Describe the figure associated with this constellation. How is it situated? What sign and constellation of the zodiac is Sagittarius? How many visible stars are in this constellation?

third magnitude, and eleven of the fourth. It may be readily known by means of five stars, four of which form a quadrilateral figure resembling the bowl of a dipper, and in consequence of this resemblance, and being situated also in the Milky Way, it is called the milk-dipper. Five small stars form the head of the archer, and three others on the back of the horse form a small triangle. Directly south of it, and 8° south of the equinoctial, there is a star of the first magnitude, called Altair, in Aquila. The right ascension of this constellation is 285°, and its declination is 33° south. The telescopic objects are a multiple star, a triple star, and three clusters, one in the upper end of the bow, one a little north of the archer's head, and the other between his head and the solstitial colure.

CONSTELLATIONS VISIBLE IN SEPTEMBER.

SECTION CXLIV.

Capricornus, the Goat.

WITH this constellation is associated the figure of a monster,—half goat and half fish. It is situated east of Sagittarius and south of the Dolphin, and is the tenth sign and eleventh constellation of the zodiac. It is on the meridian in September, and contains about fifty visible stars, three of the third magnitude and four of the fourth. It may be known by three stars in the head which are north of the ecliptic, and are apparently

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QUESTIONS.—*Sagittarius.* How may it be distinguished? In what direction is Altair? What is the right ascension of Sagittarius? What its declination? What telescopic objects?

Capricornus. Describe the figure associated with this constellation. How is this constellation situated? What sign and constellation of the zodiac is Capricornus? How many visible stars in this constellation?

near together, and nearly in a straight line, extending from the ecliptic north. *Giedi* and *Dabih* are the most prominent stars of the three, and are of the third magnitude. Its right ascension is 310°, and its mean declination is 20° south. The telescope reveals in this constellation many remarkable objects, among which are

Fig. 98.—Capricornus, the Goat.

double stars, a quintuple star, and two clusters, one of which is pale white, and the other globular and only one-thirteenth of a degree in diameter, with the stars apparently touching each other, like diamond points that are placed in contact in a fancy piece of jewelry.

QUESTIONS.—*Capricornus.* Name the most prominent. What is the right ascension of this constellation? What is its declination? What telescopic objects?

SECTION CXLV.

Cygnus, the Swan.

THE figure of a swan with outstretched wings, as if flying down the Milky Way in a southwest direction, is associated with this constellation. It is on the meridian in September, and contains about eighty visible stars,

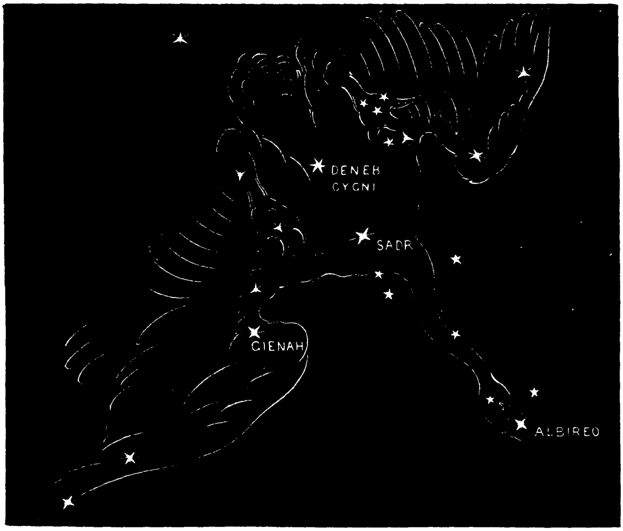

Fig. 99.—Cygnus, the Swan.

one of the second magnitude, five of the third, and thirteen of the fourth. It may be readily distinguished by five bright stars, situated so as to form a cross. *Deneb Cygni*, the most brilliant star in the constellation,

QUESTIONS.—*Cygnus*. Describe the figure associated with this constellation. How many visible stars in it? How is it distinguished? What is the most brilliant star?

is in the upper end of the cross and in the body of the swan. *Albiero* is in the point of the bill and the foot of the cross; and the three bright stars that form the cross are in the breast and butts of the wings. The most remarkable star in this constellation is a small star, familiarly known by the name of 61 Cygni, situated about 8° southeast of Deneb Cygni. It is supposed to be one of the nearest stars to our system, as no other star is known to have so rapid a proper motion, and it will be ever memorable, owing to the fact that it was the first star which was discovered to have a parallax. It is a double star, and one revolves around the other in a period of about five hundred and fifty years. The only star which is known to be nearer to us than it is Alpha Centauri; which is computed to be twenty billions of miles from the earth. The right ascension of this constellation is 308°, and its declination is 42° north. The telescopic objects are several double stars, a quadruple star, two clusters, and a nebula that is remarkable owing to the fact that it resembles two classes of celestial objects, the planetary nebulæ and the nebulous stars.

CONSTELLATIONS VISIBLE IN OCTOBER.

SECTION CXLVI.

Aquarius, the Water-Bearer.

THE figure of a man pouring water from an urn is associated with this constellation. It is the eleventh sign and twelfth constellation of the zodiac, and is situated east of Capricornus and south of Pegasus. It

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QUESTIONS.—*Cygnus.* What is the most remarkable star? For what is it remarkable? What is the right ascension of this constellation? What is its declination? What telescopic objects?

Aquarius. Describe the figure associated with this constellation.

is on the meridian in October, and contains about one hundred visible stars, the largest of which are of the third magnitude. It may be known by four stars that are situated in the handle of the urn, which form the letter γ. Its right ascension is 335°, and its mean declination is 14° south. Some of the most remarkable

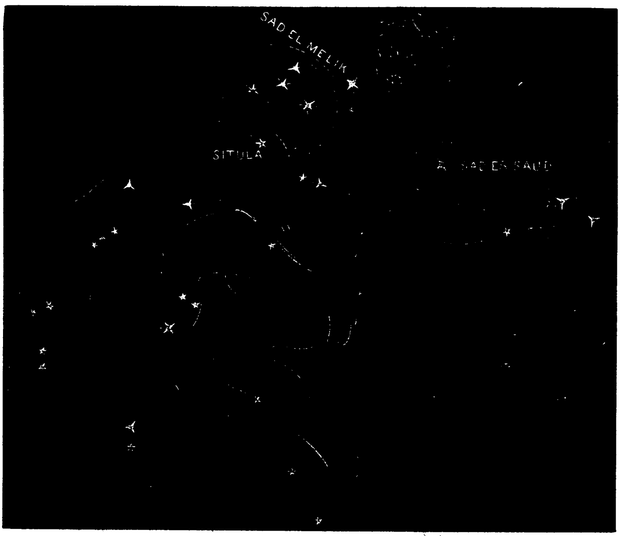

Fig. 100.—Aquarius, the Water-Bearer.

telescopic objects are a double star in the urn, a binary star in the wrist, a double star in the stream, a globular cluster in the neck, composed of thousands of minute stars, and a planetary nebula in the scarf, resembling in form and size the planet Venus.

QUESTIONS.—*Aquarius.* What sign and constellation of the zodiac is Aquarius? How is it situated? How many visible stars in it? How is it distinguished? What is the right ascension of Aqrarius? What is its declination? What telescopic objects?

SECTION CXLVII.

Pegasus, the Flying Horse.

THE inverted figure of the head and shoulders of a horse with wings, is associated with this constellation. It is situated north of Aquarius and west of Pisces, and is on the meridian in October. It occupies a large space

Fig. 101.—Pegasus, the Flying Horse.

in the heavens, and is more than a month in passing our meridian. There are four bright stars, from twelve to sixteen degrees apart, by which it may be known. They form a quadrilateral figure, familiarly known as the

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QUESTIONS.—*Pegasus.* Describe the figure associated with this constellation. How is it situated? How is it distinguished? Name these stars, and where situated.

Square of Pegasus. *Markab*, situated in the shoulder, *Scheat*, on the fore leg, Alpheratz, in Andromeda, on the equinoctial colure, and Algenib, near the equinoctial colure, in the edge of the wing, are the stars referred to. *Eniff* is another bright star in this constellation, and is situated in the mouth. The right ascension of this constellation is 340°, and its mean declination is 14° north. Some of the most remarkable telescopic objects are a double star, a globular cluster, and an elongated nebula situated in the horse's mane.

QUESTIONS.—*Pegasus.* What other bright star in this constellation? What is the right ascension of Pegasus? What is its declination? What telescopic objects?

Since it is foreign to the design of this work to introduce topics that are of minor importance, and since the great majority of the constellations which have not been described are comparatively dim, and many of them very obscure, mention is made only of their names, and the hemispheres in which they are situated.

NORTHERN CONSTELLATIONS.

NAMES.	TRANSLATION.
Antinoüs.	Antinoüs.
Aquila.	Eagle.
Camelopardalus.	Camelopard.
Coma Berenices.	Berenice's Hair.
Cor Caroli.	Charles's Heart.
Corona Borealis.	Northern Crown.
Delphinus.	Dolphin.
Draco.	Dragon.
Equuleus.	Little Horse.
Honores Frederici.	Frederick's Glory.
Lacerta.	Lizard.
Leo Minor.	Lesser Lion.
Lyncis.	Lynx.
Lyra.	Lyre.
Mons Mænalus.	Mænalus' Mountain.
Musca Borealis.	Northern Fly.
Quadrans Muralis.	Mural Quadrant.
Sagitta.	Arrow.
Scutum Sobieski.	Sobieski's Shield.
Tarandus.	Reindeer.
Taurus Poniatowski.	Poniatowski's Bull.

NAMES.	TRANSLATION.
Telescopium Herschelii.	Herschel's Telescope.
Triangulum.	Triangle.
Triangulum Minus.	Lesser Triangle.
Vulpecula.	Fox.

SOUTHERN CONSTELLATIONS.

Antlia Pneumatica.	Air-Pump.
Apparatus Sculptoris.	Sculptor's Workshop.
Apus.	Bird of Paradise.
Ara.	Altar.
Avis Solitarius.	Owl.
Cela Sculptoris.	Graver's Tools.
Chameleon.	Chameleon.
Circinus.	Compasses.
Columba.	Dove.
Corona Australis.	Southern Crown.
Corvus.	Crow.
Crater.	Cup.
Crux.	Cross.
Dorado.	Sword-Fish.
Equuleus Pictoris.	Painter's Easel.
Felis.	Cat.
Fornax Chemica.	Chemical Furnace.
Globus Æthereus.	Balloon.
Grus.	Crane.
Horologium.	Clock.
Hydra.	Water-Serpent.

NAMES.	TRANSLATION.
Hydrus.	Water-Snake.
Indus.	Indian.
Lepus.	Hare.
Lupus.	Wolf.
Machina Electrica.	Electric Machine.
Microscopium.	Microscope.
Mons Mensæ.	Table Mountain.
Musca Australis.	Southern Fly.
Norma.	Rule and Square.
Octans.	Octant.
Officina Typographia.	Printing-Press.
Pavo.	Peacock.
Phœnix.	Phœnix.
Pisces Australis.	Southern Fish.
Pisces Volans.	Flying Fish.
Psalterium Georgianum.	George's Harp.
Pyxis Nautica.	Mariner's Compass.
Reticulus.	Net.
Robur Caroli.	Charles's Oak.
Sceptrum Brandenburgium.	Sceptre of Brandenburg.
Sextans.	Sextant.
Solarium.	Sundial.
Telescopium.	Telescope.
Triangulum Australis.	Southern Triangle.
Toucana.	American Goose.

EXPLANATION

OF

ASTRONOMICAL TERMS AND PHRASES.

Aberration of Stars—Their apparent change of place caused by the velocity of light and the motion of the earth in its orbit.

Absorbent Media—Substances which absorb the rays of light and heat.

Acceleration—An increase of the motion of a moving body.

Acronycal—Rising or setting with the sun.

Acute Angle—One less than a right angle.

Aeriform—Having the form of air.

Aerolite—A meteoric substance.

Altitude of a heavenly body—Its height above the horizon.

Amphiscii—Inhabitants of the torrid zone.

Amplitude—The distance which heavenly bodies rise or set north or south from the east or west point of the horizon.

Analemma—A figure drawn on the artificial globe, from one tropic to the other, on which is marked the sun's declination for each day in the year.

Angle—The space where two lines meet.

Angular Distance—The distance between certain objects which is represented by the angle formed by straight lines drawn to them from a given point.

Annual Equation—A periodical inequality in the motion of a planet, or the moon going through its changes during a year.

Annual Parallax—The difference of the position of a body as seen from opposite points in the earth's orbit.

Annual Revolution of the Earth—Her yearly revolution round the sun.

Annular—Having the form of a ring.

Anomalistic Year—The time that the earth is in moving from perihelion to perihelion again.

Anomaly—The sun's angular distance from the apogee, or the earth's from aphelion.

Antarctic—Southern.

Antarctic Circle—A circle 23° 28′ distant at all points from the south pole.

Antipodes—Persons who live on the sides of the earth directly opposite.

Antœci—Persons who live on the same side of the earth, equally distant north and south from the equator.

Aphelion—That point in the orbit of a planet which is farthest from the sun.

Apogee—That point in the orbit of the moon farthest distant from the earth.

Apparent Diameter—The distance from one side of a heavenly body to the other, as seen from the earth.

Apsides—The points in an orbit at the greatest and least distance from the centre around which a heavenly body revolves.

Aquarius—A sign of the zodiac.

Arc—A part of the circumference of a circle.

Arctic—Northern.

Arctic Circle—A circle 23° 28′ distant at all points from the north pole.

Areas—Portions of the plane embraced within the orbit of a celestial body.

Aries—A sign of the zodiac.

Ascending Node—The point on the ecliptic where the moon passes north of it.

Ascensional Difference—The difference between oblique and right ascension.

Aspect—The relative appearance of heavenly bodies in relation to position, angular distance, &c.

Asteroids—Small planets which revolve around the sun between the orbits of Mars and Jupiter.

Astronomical Time—Time reckoned from noon of one day till noon of the next.

Atmosphere—A transparent, elastic, fluid substance which surrounds the whole earth.

Attraction—The tendency which all bodies have of coming together.

Aurora—The morning twilight.

Aurora Borealis—The Northern Light.

Austral—Southern.

Autumnal Equinox—That point in the equinoctial through which the earth passes in September, when day and night are equal.

Axes of an Ellipse—The lines that cross each other at right angles at the centre of the figure and divide it into four equal parts.

Axis of a Great Circle—The straight line that passes through its centre perpendicular to its plane.

Axis of Rotation—An imaginary line around which a revolving body turns.

Azimuth—The difference of distance between the amplitude of heavenly bodies and 90° measured from north and south.

Binary System—Two stars revolving around each other.

Bissextile or Leap Year—Every fourth year, in which February has twenty-nine days.

Calendar—An almanac or record of the divisions of time.

Calendar Months—The months as marked in the calendar.

Cancer—A sign of the zodiac.

Capricorn—A sign of the zodiac.

Cardinal Points—East, west, north, and south.

Celestial Horizon—An imaginary circle where the plane of the rational horizon touches the heavens.

Celestial Sphere—The apparent concave surface of the heavens.

Centrifugal Force—A force which causes a body to move forward in a straight line.

Centripetal Force—The force which causes a revolving body to tend towards its centre of motion.

Chord—A straight line extending to each end of an arc.

Circle—A plane figure bounded by a circumference equally distant at all points from its centre.

Circle of Illumination—The circle that separates the unenlightened portion of the earth from what is enlightened.

Circle of Perpetual Apparition—The boundary of that space around the elevated pole where the stars never set.

Circle of Perpetual Occultation—The boundary of that space around the depressed pole within which the stars never rise.

Circles of Daily Motion—Circles described by the heavenly bodies in their apparent daily motion from east to west.

Circumference—The curved line that bounds a circle.

Circumpolar Stars—Stars around the pole that do not sink below the horizon.

Colures—Meridians which pass through the equinoctial and solstitial points of the ecliptic.

Comets—Rare bodies that revolve around the sun.

Complement of an Arc—What it wants of 90°.

Concave—Hollow surface of a sphere.

Concentric Circles—Circles having a common centre.

Cone—A solid with a circular base and tapering up to a point.

Conjugate Diameter—The shortest diameter of an ellipse.

Conjunction—A planet is in conjunction when it is in a line with the earth and the sun.

Constellations—Groups of stars.

Convex—Round, like the surface of a ball.

Corona—A crown.

Cosmical—Pertaining to heavenly bodies.

Culminate—To arrive at the highest point attainable in the heavens.

Culmination—To pass the highest point attainable in the heavens.

Cusps—Extremities of the moon's crescent.

Cycle of a Planet—A period in which a planet passes through its various positions in relation to the sun and earth.

Cycle of the Moon, or Metonic Cycle—A period of nineteen years, when the changes of the moon return to the same days of the month.

Cycle of the Sun—A period of twenty-eight years, when the same days of the month return to the same days of the week.

Declination—The distance of a heavenly body north or south from the equinoctial.

Degree—The three-hundred-and-sixtieth part of the circumference of a circle.

Descending Node—The point on the ecliptic where the moon passes south of it.

Dial—An instrument that shows the time of the day by the shadow of its gnomon, or hand.

Diameter—A straight line that passes through the centre of a figure and terminates at its surface.

Diameter of the Celestial Equator—The diameter of the earth's equator extended to the starry heavens.

Dichotomized—Divided into equal parts.

Digit—The one-twelfth part of the apparent diameter of the sun or moon.

Dionysian Period—A period found by multiplying the cycles of the sun and moon together, and is equal to five hundred and thirty-two years.

Direct Motion—Motion eastward.

Disc—The apparent face of a body.

Diurnal Arc—The arc described by a heavenly body from the time it rises till it sets.

Diurnal Parallax—The difference between the apparent and true place of a body.

Diurnal Revolution—Daily motion of a body on its axis.

Dominical Letter—The letter in the calendar representing Sunday.

Dominical Letters—The first seven letters of the alphabet, used to represent the first seven days of the year.

Earth—The sphere on which we live.

East—The direction in which the sun rises when the days and nights are equal.

Eccentric—Out of the centre.

Eccentric Circles—Circles that are wholly or partially within each other, with different centres.

Eccentricity—Distance from the centre of an ellipse to either focus.

Ecliptic—The apparent annual pathway of the sun among the stars.

Element—A fundamental principle, or constituent part.

Ellipse—An oval figure.

Elongation—The angular distance of certain heavenly bodies from the sun.

Emersion—Reappearing.

Epact—The age of the moon at the beginning of the year.

Epicycles—Curves described by the point of one circle revolving upon another.

Epoch—A particular time or period.

Equation of Time—Time to be added to or subtracted from sun time to find mean time.

Equator—An imaginary great circle passing round the earth east and west, everywhere equally distant from the poles.

Equatorial Diameter—An imaginary line passing through the centre of a body at right angles to the polar diameter.

Equinoctial—An imaginary circle where the plane of the equator touches the heavens.

Equinoctial Points—Points where the equinoctial cuts the ecliptic.

Equinox—Day and night equal in length.

Evection—A periodic inequality in the motion of the moon.

Firmament—The starry heavens.

First Meridian—That point from which longitude is reckoned.

Fixed Stars—Self-luminous heavenly bodies which appear to retain their relative positions.

Focus—The point to which rays converge, or one of the elements of an ellipse.

Galaxy—The Milky Way.

Geocentric—Having the earth as a centre.

Gibbous—The moon is gibbous in appearance when more than half, and not entirely, full.

Globe—A sphere.

Golden Number—The number of years in the cycle of the moon since the epact was nothing.

Graduated Circle—An artificial circle divided into parts, called degrees, minutes, and seconds.

Gravity—The force which draws all bodies towards each other.

Greatest Elongation—The greatest angular distance of a planet from the sun.

Harvest Moon—The full moon at or near the autumnal equinox.

Heliacal—Pertaining to stars that rise a little before the sun rises, or set a little after he sets.

Heliocentric—Having the sun as the centre.
Heliometer—A sun-measurer.
Hemisphere—Half a sphere.
Heteroscii—The inhabitants of the temperate zones.
Higher Apsis—That point in an orbit at the greatest distance from the centre of motion.
Horizon, or Sensible Horizon—The circle where the sky and earth appear to meet.
Horizontal—Parallel to the horizon.
Horizontal Parallax—The diurnal parallax of a body at the horizon.
Hour Circle—A small circle near the north pole of an artificial globe, having marked on it the hours of the day.

Immersion—Disappearing.
Inferior Conjunction—A body is in inferior conjunction when it is between the earth and the sun, in a line with both.
Inferior Planets—Those that are always nearer the sun than the earth.
Intercalation—Inserting extra time into some of the divisions of time.

Julian Period—A period of seven thousand nine hundred and eighty years, which is the product of the cycles of the sun and moon and the Roman indiction.
Julian Year—A period of three hundred and sixty-five and one-quarter days.

Latitude—Distance north or south of the equator.
Latitude in the Heavens—Distance north or south from the ecliptic.
Leap-Year—Every fourth year in which one day is added
Leo—A sign of the zodiac.
Libra—A sign of the zodiac.
Librations of the Moon—Periodic oscillations of her four cardinal limbs.
Limb—A portion of the curved edge of the sun or moon's disc.
Line of Collimation—The imaginary line in a telescope which joins the centres of the object- and eye-glasses.
Line of the Apsides—The line that unites the two apsides.
Line of the Nodes—The imaginary line that unites the ascending and descending nodes of the moon's orbit.
Longitude—Distance east or west of any given meridian, measured on the equator.
Longitude in the Heavens—Distance eastward from the first point of Aries, measured on the ecliptic.
Lower Apsis—That point in an orbit at the least distance from the centre of motion.
Lunar—Pertaining to the moon.

Lunar Distance—Distance of the moon from a given celestial object.
Lunar Month—The time from one change of the moon till the next.
Lunation—Average length of the lunar month.

Mass—Quantity of matter in a body.
Mean Motion—Average motion.
Medium—In astronomy, any substance through which light and heat will pass freely.
Meridian—A great circle passing through the poles.
Meteor—A rare substance that becomes luminous as it passes through the air.
Meteorite—A dense substance which sometimes falls upon the earth.
Minute—The sixtieth part of an hour or degree.

Nadir—The lower pole of the horizon.
Neap Tide—The less tide.
Nebulæ—A name given to celestial objects that have the appearance of luminous clouds or mist.
New Style—The present mode of reckoning time, established by Gregory XIII.
Nocturnal Arc—The arc described by a heavenly body during the night.
Nodes—The points of the moon's orbit where it crosses the ecliptic.
Nonagesimal Degree—The highest point of the ecliptic above the horizon.
Nucleus—The densest part.
Nucleus of a Comet—The head.
Nutation—An oscillating motion of the earth's axis, caused by the attraction of the sun and moon on the excess of matter at the equator.

Oblate Spheroid—A sphere flattened on the opposite sides.
Oblique—Deviating from a perpendicular.
Oblique Ascension—That point in the equinoctial which rises with a body in an oblique sphere.
Oblique Descension—That point in the equinoctial which sets with a body in an oblique sphere.
Oblique Sphere—That on which the circles of daily motion are oblique to the horizon.
Obliquity of the Ecliptic—The difference between the plane of the equinoctial and the plane of the ecliptic, marked by degrees.
Obtuse Angle—One greater than a right angle.
Occidental—Westward.
Occultation—The eclipse of a star by another heavenly body.
Octant—The eighth part of a circle.
Old Style—The mode of reckoning time which Gregory XIII. reformed.
paque—Dark, not luminous.

Opposition—When two bodies are on the opposite sides of another body, they are in opposition.

Orbit—The line which a body describes as it revolves around another body.

Orbital Motion—The motion of a heavenly body around its centre of motion.

Parallactic Angle—The angle formed by observing a body from twc different points.

Parallactic Motion—Angular motion which is perceptible.

Parallax—The apparent difference in position of a body when viewed from different points.

Parallel Lines—Lines equally distant from each other at all points.

Parallels of Altitude—Small circles parallel to the horizon.

Parallels of Declination—Small circles parallel to the equinoctial.

Parallels of Latitude—Small circles parallel to the equator.

Parallel Sphere—That in which all the circles of daily motion are parallel to the horizon.

Penumbra—A dim shadow.

Perigee—The nearest point of the moon's orbit to the earth.

Perihelion—The nearest point to the sun of the orbit of a planet.

Periodic Inequality—Irregularity in the motion of a heavenly body.

Periodic Time—The time required for a body to revolve around its centre of motion.

Periœci—Persons who live equidistant from the equator, on opposite sides of the earth.

Periscii—Persons who live in the frigid zones.

Perturbations—Deviations in the direction of moving bodies.

Phases—An increase or diminution in quantity of the enlightened surface of a heavenly body when viewed from the earth.

Phenomena—Various manifestations of natural objects.

Pisces—A sign of the zodiac.

Plane—Surface without thickness.

Plane of a Circle—Surface extended indefinitely, in which the whole circle is contained.

Planet—An opaque body that has the sun for its centre of motion.

Pleiades—Seven stars in the constellation Taurus.

Pointers—Two stars in the Great Bear.

Polar Circles—Circles twenty-three and one-half degrees at all points from the poles.

Polar Diameter—An imaginary line about which a body rotates.

Polar Distance—Angular distance from the poles.

Polar Star—A star near the north pole of the heavens, of the second magnitude.

Poles, Celestial—Points in the heavens where the earth's axis would touch if produced.

Poles, Terrestrial—Extremities of the earth's axis.

Precession of Equinoxes—A westward motion of the equinoctial points on the ecliptic.

Prime Vertical Circle—The circle which passes through the east and west points of the horizon.

Prolate Spheroid—An elongated sphere.

Quadrant—Quarter of a circle. An instrument by which angles are measured.

Quadrature—The moon is in quadrature when half full, or quarter of a circle from the sun.

Quadrilateral—A geometrical figure with four sides.

Quartile—Ninety degrees apart.

Quiescent—At rest.

Radiate—To emit rays.

Radius—A straight line drawn from the centre of a circle to its circumference.

Radius-Vector—An imaginary line extending to the sun from the earth.

Rational Horizon—The circumference of a plane parallel to the plane of the sensible horizon, which divides the earth into two hemispheres, the upper and lower.

Rectilinear—Straight-lined.

Reflection—Throwing off the rays of light or heat.

Refraction—The breaking of rays of light as they pass through media that differ in density.

Repulsion—The property which some bodies have which has a tendency to separate them.

Resisting Medium—An exceedingly subtle fluid, which is supposed by some to pervade all space.

Retrograde Motion—Apparent motion from east to west.

Revolution of a Body—Motion of a body till it returns to the point that it left.

Right Angle—One equal to 90°.

Right Ascension—Distance measured on the equinoctial from the first point of Aries.

Right Line—A straight line.

Right Sphere—One in relation to which all the apparent daily revolutions of the heavenly bodies are in circles perpendicular to the horizon.

Roman Indiction—A period of fifteen years.

Rotation—Motion of a body on its axis.

Satellite—The moon. A secondary planet.

Scorpio—A sign of the zodiac.

Secondary Circles—Circles that are perpendicular to others on which they depend.

Secondary Planets—Those that revolve around the primary planets.

Sector of a Circle—Area enclosed by an arc and two radii, which is less than a semicircle.

Secular Inequalities—Variations in the motion of heavenly bodies, that have long periods.

Segment—Part of a circle enclosed by an arc and chord.

Semicircle—Half a circle.

Sextant—The sixth part of a circle.

Sidereal—Pertaining to the stars.

Sidereal Day—The time from one transit of a star till the next over the same meridian, caused by the rotation of the earth on its axis.

Sidereal Year—The length of time taken by the earth to perform one entire revolution in her orbit.

Sign—The twelfth part of a circle.

Solar—Pertaining to the sun.

Solar Day—The time from noon of one day till noon of the next.

Solar System—The sun, planets, moons, and comets, in their natural order.

Solstitial Points—Those two points on the ecliptic where the sun is at his greatest distance north and south of the equator.

Sothis, or Sirius—The Dog-star.

Sphere—A globe or ball.

Spherical—In the shape of a sphere.

Spheroid—Resembling a sphere.

Spring Tide—The greater tide.

Stationary—Occupying one position.

Summer Solstice—That point on the ecliptic where the sun is at his greatest distance north of the equator.

Superior Conjunction—A body is in superior conjunction when it is outside of the earth from the sun, and in a line with both.

Superior Planets—Those that are at a greater distance from the sun than the earth.

Synodic Month—The time from new moon till new moon again.

Syzygies—Points in the moon's orbit where she changes and fulls.

Taurus—A sign of the zodiac.

Terminator—A line that divides between the illuminated and shaded portions of a heavenly body.

Tide—The flux and reflux of the waters of the ocean.

Transit—Passing over.

Transit of a Star—Its passage over any given meridian.
Transit of Mercury—Mercury passing over the sun's disc.
Transit of Venus—Venus passing over the sun's disc.
Transverse Diameter—The longest diameter of an ellipse.
Triangle—A figure bounded by three sides.
Tropic of Cancer—A small circle distant north from the equator 23° 28′ at all points.
Tropic of Capricorn—A small circle distant south from the equator 23° 28′ at all points.
Tropical or Solar Year—The time that it requires the earth to depart and return to the same solstice.
True Place of a Planet—The place where it would appear if seen from the centre of the earth.
Twilight—Refracted and reflected light visible before sunrise and after sunset.

Umbra—A dark shadow.
Universe—A large cluster of stars. The whole material creation.
Uranography—A description of the heavens.

Vernal Equinox—That point in the equinoctial through which the earth passes in March, when day and night are equal
Vertex—The top.
Vertical—Towards the centre of the earth.
Vertical Circle—A circle in a vertical plane.
Vertical Plane—A plane coinciding with a vertical line perpendicular to the horizon.
Virgo—A sign of the zodiac.

Waning—Declining, or decreasing.
Wind—Air in motion.
Winter Solstice—That point on the ecliptic where the sun is at his greatest distance south of the equator.

Zenith Distance—The angular distance of a heavenly body from the zenith.
Zodiac—A zone extending clear round the heavens, 8° on either side of the ecliptic, containing twelve signs.
Zone—A portion of the earth's surface, limited by circles parallel to the equator.

THE END.

TABLE OF DISTANCES, DIAMETERS, AND PERIODS OF PLANETS AND SATELLITES.

SUN'S DIAMETER, 887,036 MILES; TIME OF AXIAL ROTATION, 25 DAYS, 10 HOURS.

	Diameter in miles.	Distance from the Sun.	Length of Yearly Periods.	Length of Daily Periods	Velocity per hour.
			D. H. M. S.	H. M. S.	Miles.
Mercury,	2,950	36,890,000	87 23 15 44	24 5 28	109,757
Venus, .	7,500	68,770,000	224 16 49 8	23 21 8	80,000
Earth, . .	7,912	94,298,260	365 6 9 9	23 56 4	68,288
Mars, . .	4,500	145,205,000	886 23 30 41	24 37 20	50,927
Jupiter, .	88,780	495,817,000	4332 days.	9 56 0	28,074
Saturn, .	73,984	909,028,000	29 yrs. 6 mos.	10 16 4	21,107
Uranus, .	35,000	1,828,071,000	84 years.	Unknown.	15,000
Neptune,	33,000	2,862,457,000	164 yrs. 3 mos.	Unknown.	11,931

SATELLITES.

	Diameter in miles.	Distance from Primary.	Sidereal Period.
MOON, ...	2,160	238,900	27 d. 7 h. 43 m. 11 s.
JUPITER'S MOONS.			
1st, ...	2,440	278,500	1 d. 18 h. 27 m. 34 s.
2d, ...	2,190	443,000	3 13 14 36
3d, ...	3,580	707,000	7 3 42 33
4th, ...	3,060	1,243,500	16 16 31 50
SATURN'S MOONS.			
Mimas, ...	1,000	78,000	0 d. 22 h. 36 m. 18 s.
Enceladus, . . .	Unknown.	112,000	1 8 53 7
Tethys, ...	500	148,000	1 21 18 26
Dione, ...	500	240,000	2 17 44 51
Rhea, ...	1,200	296,000	4 12 25 11
Titan, ...	2,850	738,000	15 22 41 25
Hyperion, . . .	Unknown.	900,000	21 4 20 0
Japetus, ...	1,800	2,228,000	79 7 54 41

SATELLITES—*Continued.*

	Diameter in miles.	Distance from Primary.	Sidereal Period.			
MOONS OF URANUS.						
Ariel, ...	Unknown.	123,000	2 d.	12 h.	0 m.	0 s.
Umbriel, ...	"	171,000	4	4	0	0
Oberon, ...	"	376,000	10	23	0	0
Titania, ...	"	281,000	13	11	6	55
5, ...	"	Unknown.	Unknown.			
6, ...	"	"	"			
MOONS OF NEPTUNE.						
1st, ...	Unknown.	Unknown.	Unknown.			
2d, ...	"	"	"			

PROBLEMS.

EXPLANATION.—As the earth turns once on its axis from west to east every twenty-four hours, the sun appears to move from east to west $\frac{1}{24}$ of 360° every hour. If the number of hours in a day is divided into 360° of longitude, it will give 15°, the number corresponding to each hour. Fifteen degrees (15°) are equal to (one hour) sixty minutes, consequently 1° is equal to 4 minutes, and 1′ is equal to four seconds, of time.

To Convert ° ′ ″ to Time.

RULE.—Divide ° ′ ″ by 15, according to the rule for division of compound numbers, and mark the quotient hours, minutes, seconds.

Example 1.—Convert 16° 17′ 30″ into time:

$$15\overline{)\,16^\circ \quad 17' \quad 30''}$$
$$1 \text{ h.} \quad 5 \text{ m.} \quad 10 \text{ sec.}$$

Example 2.—If the sun rises to-day at 6 o'clock, at what time did it rise 2 S 20° 11′ 3″ east longitude?

Example 3.—If the sun sets to-day at 6 o'clock, at what time will it set 25° 13′ 6″ west longitude?

Example 4.—Boston being 71° 4′ west of Greenwich, what is the time at Greenwich when it is noon at Boston?

Example 5.—Teheran being 51° east of Greenwich, what is the time at Teheran when it is noon at Greenwich?

To Convert Hours, Minutes, and Seconds into Degrees, &c.

RULE.—Multiply the time by 15, according to the rule for the multiplication of compound numbers, and mark the product $^\circ\ '\ ''$.

Example 1.—Convert 1 h. 5 m. 10 sec. into degrees:

1 h.	5 m.	10 sec.
		15
16°	17′	30″

Example 2.—If noon is 4 h. 44 m. 16 sec. earlier at Greenwich than Boston, how many degrees is Greenwich east of Boston?

Example 3.—If noon is 3 h. 25 m. 8 sec. later at San Francisco than Boston, how many degrees is San Francisco west of Boston?

Example 4.—The master of a vessel sails east on the equator, and after several days he finds on examination that sun and chronometer time do not agree by 3 h. and 27 m., how many miles has the vessel sailed?

Example 5.—Two persons standing on the equator during a solar eclipse, the moment of greatest darkness occurred to A at 12 o'clock and to B at 10 minutes after 12, how many miles were A and B apart, and which was furthest west?

Example 6.—Mercury is 2 S. 20° 40′ 10″ east of the sun, Venus is 6 S. 12° 25′ 15″ east of Mercury, and Mars is 5 S. 15° 31′ 23″ east of Venus, how many degrees is Mars east of the sun, and what time would elapse till Mars and the sun will be in the same longitude?

Example 7.—The longitude of a certain star is 2 S. 16° 12′ 20″, and the longitude of Mars 10 S. 25° 20′ 40″, how many degrees will Mars have to travel in his orbit, and what time would elapse till he would be in the same longitude with the star?

Problems for Celestial Globe.—To determine the Latitude and Longitude of any Heavenly Body.

RULE.—If the object is north of the ecliptic, place that end of the quadrant of altitude which is marked 90° on the north pole of the ecliptic, or if the object is south of the ecliptic, place it on the south pole of the ecliptic, then move it till it touches the object on the globe; the number of degrees between the ecliptic and the object is the latitude, and the number of degrees counted from the first point of Aries on the ecliptic to the quadrant is the longitude.

Examples.—What is the latitude and longitude of Sirius in the Great Dog? Of Regulus in Leo?

To Find the Right Ascension and Declination of any Heavenly Object.

RULE.—Bring the star or object under the brass meridian, the degree marked over the object will indicate its declination, and the number of degrees counted from the first point of Aries on the equinoctial to the brass meridian is its right ascension.

Examples.—What is the right ascension and declination of Rigel in Orion? Of Arcturus in Scorpio?

To determine the Distance between Heavenly Objects.

RULE.—Place the quadrant of altitude over any two objects, with the zero point over one of them, and the number of degrees marked on the quadrant between them will show their distance apart.

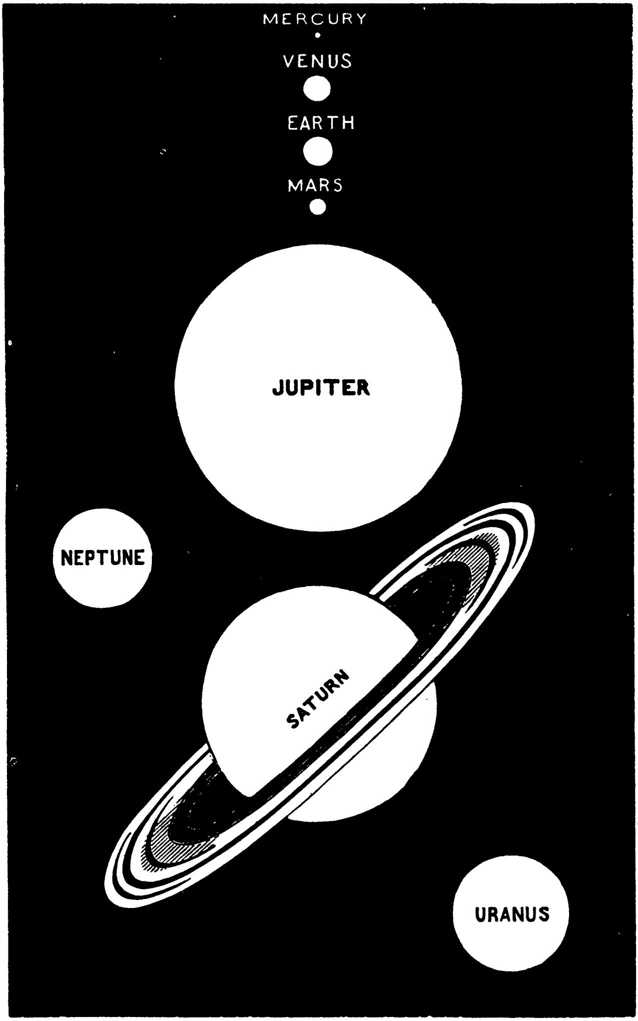
Examples.—What is the distance between Arcturus and Sirius? Between Spica and the North Star?

As an explanation of the methods for finding the diameters, distances, and periods of the planets, &c., has been given in the body of this work, it is unnecessary to repeat rules or examples in this connection. Prof. Bode's law of distances, however, remains to be considered. He discovered that if 4 is taken to represent the distance to Mercury from the Sun, 3 added to 4 will represent the relative distance to Venus, and 3 x 4 added to 4 will represent that of the Earth, and the relative distances of the other planets, except that of Neptune, are found in their order by annexing successively 2 as a factor.

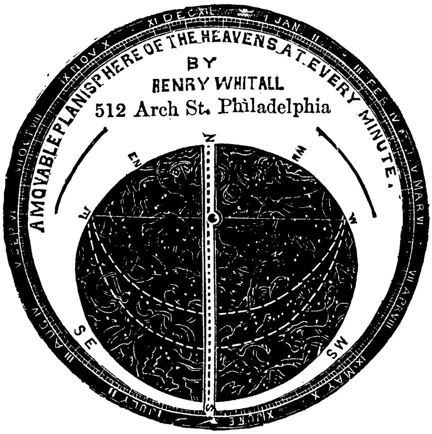
Relative Distances.

Mercury, . .	4	$= 4$
Venus, . .	$4 + 3$	$= 7$
Earth, . .	$4 + 3 \times 2$	$= 10$
Mars, . . .	$4 + 3 \times 2 \times 2$	$= 16$
Asteroids, .	$4 + 3 \times 2 \times 2 \times 2$	$= 28$
Jupiter, . .	$4 + 3 \times 2 \times 2 \times 2 \times 2$	$= 52$
Saturn, . .	$4 + 3 \times 2 \times 2 \times 2 \times 2 \times 2$	$= 100$
Uranus, . .	$4 + 3 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$	$= 196$

Relative Sizes of the Planets.



THE MOVABLE PLANISPHERE.



THIS INSTRUMENT is designed for the use of Schools, Academies, Seminaries, and Families, and serves a similar purpose in determining the relative positions of the stars and constellations that terrestrial maps do in indicating the relative positions of countries and localities on the earth.

It is composed of a permanent frame fifteen inches in diameter, and a movable horizon. The frame has imprinted on it, in circular form, three hundred and sixty-five equal divisions, corresponding to each day in the year. Within this graduated circumference, all the prominent stars that compose each constellation to the distance of *one hundred and forty degrees* from the North Pole, are marked in relation to each other; and the Equinoctial and Ecliptic are correctly drawn and properly graduated.

The movable horizon which answers to the natural one, turns on the point that designates the North Pole as its centre of motion, and its circumference is divided into *fourteen hundred and forty* equal parts, corresponding to the number of minutes in each day.

The inner part of this movable horizon is elliptical, and has marked on it the letters that indicate the various points of the compass. Across this horizon is a meridian scale, which is divided into *one hundred and eighty degrees*, the zenith being in the centre, and the North Pole being *forty degrees* from the horizon.

By the use of this instrument the azimuth, altitude, amplitude, right ascension and declination of any heavenly body can be determined at any given time, also the time when the sun rises and sets, the difference between sidereal and mean time, the equation of time, the variation of the magnetic needle, the beginning and ending of twilight, the position of the Milky Way, the longitude and latitude of a ship at sea, if any star on the meridian is visible; and it also illustrates the change of seasons, the increase and decrease of day and night, the harvest moon and the Sun in his most northern declination, while the full Moon is in her most southern declination, and vice versa.

In addition to the foregoing phenomena, a great deal of other interesting and useful knowledge can be illustrated by the Planisphere to the eye, which even the uneducated cannot fail to comprehend.

To the teacher and the pupil in the study of the starry heavens, this instrument has by its use proved itself of great interest and value, and thereby commends itself to all who may desire to avail themselves of its advantages.

Each instrument weighs only one pound, is not liable to get out of order, and is accompanied with a sufficient number of examples and rules, to explain its proper use.

For Sale by all Booksellers and Agents who sell the Planetelles, Heliotellus and Lunatellus, the "Introduction to Astronomy," and "Elements of Astronomy."

APPENDIX.

THE results of computations which have been made, from other data than that obtained by the last transit of Venus in 1769, of the diameters and distances of the planets from the Sun, are as follows:

	DISTANCES IN MILES.	DIAMETERS IN MILES.
Mercury,	35.393.000	2.962
Venus,	66,130.000	7.510
Earth,	91.430,000	7.901
Mars,	139.312,000	4.000
Jupiter,	475,693.000	85.390
Saturn,	872.135.000	71.904
Uranus,	1,752.851.000	33.024
Neptune,	2,746,271,000	36,620

Average distance of the asteroids, 260,000,000 miles.

One hundred asteroids have been discovered.

The relative volume, weight, and density of Mercury, those of the Earth being taken at 100, are as follows: volume, 5 to 100; weight, 7 to 100; density, 124 to 100; consequently his attraction for objects on his surface would still be less than that of the Earth for objects on her surface, notwithstanding his density is so much greater.

METEORIC THEORY OF THE SUN'S HEAT.—This theory assumes that millions of meteoric bodies are constantly falling on the Sun, and are thereby generating by their collision with him the solar heat.

KIRCHHOFF'S HYPOTHESIS OF THE PHYSICAL CONSTITUTION OF THE SUN, STARS, AND NEBULÆ.—He inferred from examinations which he made with the

Spectroscope of the light emitted from those bodies, that the Sun is a burning body—that his photosphere is composed of particles of various metals and other substances in a state of intense heat, and that it is surrounded by an atmosphere composed of vapors of the bodies that are *incandescent* in the photosphere; also that the physical constitution of the stars is very similar to that of the Sun; also that there are *bodies* in the heavens that *are nebulous*, and that they are composed principally of nitrogen and hydrogen gas, at a white-hot heat; also that comets are at least partially self-luminous, and at a high temperature.

New discoveries that may be made in this science will be inserted by the author in each successive edition.