
J.W.ORR N.Y.

ASTRONOGRAPHY,

OR

ASTRONOMICAL GEOGRAPHY,

WITH THE USE OF THE GLOBES.

ARRANGED EITHER FOR SIMULTANEOUS READING AND STUDY IN CLASSES, OR FOR STUDY IN THE COMMON METHOD.

BY EMMA WILLARD.

TROY, N. Y.:
MERRIAM, MOORE & CO.
1854.

TO

CHARLES DAVIES, ESQ.,

THE FRIEND OF EDUCATION, AND THE MATHEMATICAL EDUCATOR
OF HIS COUNTRY,

This Work is Inscribed,

IN TOKEN OF ADMIRATION OF HIS WRITTEN AND OTHER LABORS
IN THE CAUSE OF HUMAN IMPROVEMENT,

OF ESTEEM FOR HIS VIRTUES,

AND OF THE SACRED REMEMBRANCES OF MANY YEARS OF
UNCLOUDED FRIENDSHIP;

BY

EMMA WILLARD

PREFACE.

WHEN the Author was requested by the Publisher of this work, to write for him a small volume to accompany and explain the Globes, she undertook the task with pleasure; having, in the long course of her duties as Principal of the Troy Female Seminary, felt the need of new aids in fully understanding them; and she had long entertained the opinion, that a radical error was committed in elementary works on Astronomy as connected with Geography, in putting down the definitions of the Horizon, Zenith, and other positions depending on the location of the Observer, as something of the same kind, as the Equator and Poles of the Earth, and all those definitions which refer to objects determinate by nature, and unchangeable in place,—these, together with the Ecliptic and its accessories, being mingled indiscriminately together. But as she went on, she found her way beset with difficulties, which could by no other means be surmounted than that the new arrangements introduced, must have appropriate language to express them; which, not existing, she was obliged to give new and technical significations to such words as most nearly gave her meaning. The first word of the title is, however, a term composed for the occasion.*

But before the ideas existing previously in the author's mind were fully developed, the nascent subject shot forth new branches, and these still others, until the three Spherical Systems, with each its accessories, were devised, and their intersections shown; they being permanent or movable according to their systems. When the figure representing these was completed, the author being asked to explain it, said, 'It is three things, instead of three hundred.' Would not even

* Explained at length in a note on page 274.

the learned astronomer find that he had gained an advantage, if, in speaking on astronomical subjects, he could use terms so general, and yet so clearly defined to the comprehension of the young, as are the Spherical Systems?

But in venturing so far from the beaten track, much reading and reflection were required; lest, in forming a new and useful ladder on which the young might climb to high subjects, the grand edifice of Astronomy should be marred. The growth of the work was therefore slow and laborious.

In the study of the Terrestrial Globe—indispensable on account of the false impressions given by comprehensive maps, especially maps of the world—the author has also devised some new and useful methods; particularly, that of the sweeping measurement of all distances from the observer's position, by terrestrial Almacantars.

Since no human production is perfect, notwithstanding care, this work will have its errors; but the author will correct them as soon as known, whether indicated by friend or foe. She regards herself as peculiarly fortunate, in having written at a time when Herschel's "Outlines of Astronomy" had recently been revised, and Humboldt's "Cosmos" just issued from the press,—the best and most unimpeachable of authorities.

The opening sentence of this work is not an idle flourish; but a pledge conscientiously redeemed, by so managing the subjects as to enlarge and invigorate the mind, and to establish such mental habits and tones of thought, as shall lead the pupils, as they advance into life, to moral as well as intellectual greatness;—to become the servants of God, and the friends of man.

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To read with ease and fluency is a rare accomplishment, and only to be acquired *by much practice.* And whoever will look back upon his early school-days, will find that nothing is more indelibly impressed upon his mind than the words and subjects of his reading-lessons. Following these ideas, the author—an experienced teacher—has laid it down as an axiom, that young learners should, in all possible cases, be taught to *read what they study, and to study what they read.* It is a plan which makes the reading-hour answer two important purposes, saving the time both of the instructor and pupil.

This book is therefore arranged for making the same time serve two purposes; first, to teach reading, and second, Astronomy as connected with Geography; although nothing is done to injure it for ordinary study and recitation, where that method is preferred by the teacher.

We suppose the class to begin the book with the beginning of the term, and that the Globes stand on a desk or table in full view. If the class understand that they now commence a study, on which they are, at the close of the term, to be examined, it will quicken their powers of attention. In the first instance, we recommend that they give their principal attention to learning *to read the lessons well*;—distinctly, audibly, and with correct articulation, pronunciation, and emphasis. The daily time allotted to this reading, should, if possible, be as much as three-quarters of an hour a day.

It is the common practice with good teachers to continue explaining the meaning of words and sentences until they are convinced that the pupils understand them. They cannot otherwise emphasize properly, or give the suitable tone and manner. The Globes and the text will mutually explain each other; and the blackboard is indispensable to good teaching.

The pupils having read the lesson, the questions at the bottom of the page, or others, can, at the option of the teacher, be asked, and in the first time going over, they may answer them from their books. Thus the knowledge of the subject will be insensibly entering their minds, while, at the same time, they are learning the correct manner of reading aloud.

Towards the close of the term, we recommend that the class give their attention to the *subject-matter*, as at the first, to the manner of reading.

By proposing this method, with a book designed to afford a connected view of an important subject, we do not expect, or desire to dispense with reading-books in schools. Those are needed for first lessons; and they afford rules and examples for *Rhetorical Reading*. But the teacher, whose classes read their studies in the method here laid down, will find his pupils prepared to learn rhetorical reading,—as the writing-master, who first teaches a good common hand, finds his scholars prepared to learn the flourishes of ornamental chirography.

In the summer of 1840 the author of this work was elected by the freemen of a parish in her native town, Kensington, in Connecticut, to superintend, for a season, their Common Schools. The classes of the five existing schools were examined together at the close of the summer term by HENRY BARNARD, Esq., State Superintendent of Schools,—by the eminent Educator to whom this work in dedicated, and many others. Mr. Barnard's Report of the results, to the State Legislature, was extensively quoted, and referred to as describing an improved method in education. It was thought wonderful that so much was accomplished in so short a time, especially in the use of language, oral and written; not only in reading naturally and without toning, but in spelling correctly, and in composing off-hand on subjects given at the time by the examiners. OUR CLASSES HAD STUDIED WHAT THEY READ, AND THEY HAD READ WHAT THEY STUDIED. They read understandingly, and they became familiar with the right spelling of words, and their arrangement in sentences; and thus time was saved for the practice of off-hand composition, and for other purposes.

The Exercises between the chapters are written in a more free and conversational style than the chapters themselves. The author supposes the teacher will probably give these to the pupils to study between the times of reading the chapters, for the purpose of directing their observations to be made on the Starry Heavens and on the Globes. But every good teacher has his own methods.

ASTRONOGRAPHY,

OR

ASTRONOMICAL GEOGRAPHY.

CHAPTER I.

INTRODUCTION.—DEFINITION OF ASTRONOMICAL GEOGRAPHY.—THE ARTIFICIAL TERRESTRIAL GLOBE.—GRAVITATION.—THE NATURE AND PROPERTIES OF A SPHERE, AS APPLICABLE TO ASTRONOMICAL GEOGRAPHY; OR, THE DOCTRINE OF THE SPHERE.—DEFINITIONS.

1. THE writer of a work of elementary instruction, in any particular branch of science, should perform the duty in the spirit of the conscientious teacher,—desirous not only to advance the pupils in that one science, but to promote their general improvement; and most, in the best things.

2. The subject of which we treat tends to cultivate youth in the knowledge and adoration of the God of Nature, and in the habit of closely observing his works, both on the Earth and in the Heavens; and, also, to give strength and accuracy to the reasoning powers, and enlargement to the imagination;—kinds of improvement which lay the foundation of moral and intellectual greatness.

3. GEOGRAPHY is that science which describes the

CHAPTER I.—1. In what spirit should the writer of a work to teach youth the elements of any particular science, perform the duty? With what desire? In what should the teacher seek most to improve his pupils?—2. In what has Astronomical Geography or Astronography a tendency to improve youth? Of what are these two kinds of improvement the foundation?

Earth; and to us, whose home is in this planet, no knowledge can be more interesting. But the condition of the Earth, signally depends upon the Sun, is much influenced by the Moon, and in a lesser degree affected by the other heavenly bodies. So that the very foundation of Geography is laid in ASTRONOMY.* This science treats of the heavenly bodies, and of the Earth, as composing one of their number; so that there is one portion of Geography which is Astronomy, and one portion of Astronomy which is also Geography:† and these parts of the two sciences, together compose ASTRONOMICAL GEOGRAPHY; or, in one word, ASTRONOGRAPHY.

4. The Artificial Terrestrial Globe represents the great globe, or Earth, which man inhabits. To the centre of the Earth all things upon its surface tend, being *drawn towards that point by a force*, called THE ATTRACTION OF GRAVITATION. An Artificial Globe cannot, in this respect, be made to resemble that on which we live; but it must itself, with whatever is upon it, be attracted to the Earth. With regard to every individual of the human race, *down*, signifies directly *towards the centre of the Earth;* and *up*, directly away from that centre; and this is the case on whatever part of its surface any one may live; whereas, on this Artificial Globe, there is but one position, which we term the *Upper Vertex*, where a little figure, representing a man, could be made to stand. His feet would, in that place alone, point towards the centre of the artificial globe, and, as ours do, towards the centre of the

* Astronomy, from two Greek words, *αςτερ*, a Star, and *νομος*, a law.

† Geography, from *γε*, the Earth, and *γραφε*, description.

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3. Define Geography: On what does the Earth's condition depend? Define Astronomy: What, in view of these definitions, is Astronomical Geography?—4. What is represented by the Artificial Terrestrial Globe? What force is here spoken of? What effect, with respect to the Earth, is produced by the Attraction of Gravitation? In what respect is it impossible that an Artificial Globe should truly represent the Earth? With regard to mankind, what direction is *down?* What direction is *up?* What difference is there between the Earth and the Artificial Globe, in regard to a position on which to stand?

Earth. The globe is therefore arranged, so that we can always make the Upper Vertex the place of the First Observer.

5. The *First Observer* is an imaginary personage, to whose position on the Earth many of the definitions of Astronomical Geography refer. For the place of this located Observer, we shall continue to use the term *Upper Vertex.* Pupils, in their first lessons in this science, should have the Observer kept in their view, with his place of residence; for it is intelligent mind beholding things as they appear, as well as a certain place on the Earth's surface, which is the object of consideration. Afterwards the place of the Observer may alone be used, as circumstances dictate: as when we say "the Meridian of London," for the Meridian of the Observer at London; "the Zenith of Boston," for the Zenith of the Observer at Boston.

6. The terms *Globe* and *Sphere* are in meaning synonymous; but in the manner of their use there is a difference. The word Sphere is most used in Mathematics; and the portion of that great science, which treats of the properties of the Sphere, is called *Spherics.* From ancient times we have the phrase "the Doctrine of the Sphere." Without some knowledge of this "Doctrine," no progress can be made in Astronomical Geography. *A Globe or Sphere is a solid body, with a single surface which is everywhere equally distant from a point within, called its centre.* It follows from this, that *all straight lines drawn from the centre to the circumference of a Sphere, are equal.* One such straight line is a *Radius of the Sphere;* two or more are *Radii of the Sphere.*

7. Any two radii, so meeting at the centre as to be in one and the same straight line, constitute a *Diameter* of the Sphere. Therefore the diameter of any circle is equal

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5. What is said concerning the First Observer?—6. What difference is there in the terms *Globe* and *Sphere?* What is meant by Spherics? What can you say of the "Doctrine of the Sphere?" What is a Globe or Sphere? What follows from this definition? What is a Radius of a Sphere? Radii?—7. How may we suppose the Diameter of a Sphere to be constituted?

to two of its radii. Any straight line passing through the centre of a Sphere, and cutting the surface in opposite points, is a diameter. The diameter is the longest straight line which can be included in a Sphere. All the diameters of a perfect Sphere are equal.

8. The Earth is not a perfect Sphere. Its diameter at the Equator is longer by 26 miles than that from north to south, which is identical with the Earth's axis. By being thus a little flattened at the poles, the Earth approaches in form to an *oblate spheroid*. Yet its variation from a perfect sphere is so little, that for any purpose, appertaining to our present study, it is not necessary to notice the difference; but we are to study the Globe as if the Earth, which it represents, were a perfect sphere.

9. We find drawn around artificial globes many circles, some of which are great circles, and some small or lesser circles. A *Great Circle* is one whose *plane* divides the Sphere into *two equal parts*, or *Hemispheres*. A *Lesser Circle* is that whose plane divides the sphere into two unequal parts. To understand this, we must consider that *to every circle belongs a plane, as well as a circumference and a centre.*

10. For illustration, suppose I take this round apple to represent a Sphere. Any Sphere, cut by a plane which passes through its centre, will be divided into two equal half-spheres, or *Hemispheres;* and the meeting of the plane with the surface of the Sphere will be a great circle of that Sphere. I hold my knife level, and cut the apple through the centre. The line of the divided skin represents the *circumference* of a great circle of the little Sphere, and the *plane* within, is the plane of that circle; the middle point being the centre. Suppose the halves of the

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7. What further may be said of the Diameter of a Sphere?—8. What is said on the question whether or not the Earth is a perfect Sphere? What kind of Sphere is it?—9. What are the two equal parts or halves of Spheres called? What are Great Circles of Spheres? What are Lesser Circles? What three things belong to every circle?—10. How may the circumference, plane, and centre of a circle be illustrated?

apple are put together, so that no plane can be seen, we can now *imagine* the plane to be extended out to any desired distance from the apple; like this paper circle which is inserted between its two halves.

Fig. 4.

11. The *Circumference* and *Diameter* of any Great Circle of a Sphere is the circumference and diameter of that Sphere. Any diameter may be termed an *Axis* of the Sphere; for it is a line about which it might revolve, if there were a force to set it in motion. Any axis of a Sphere being given, the Great Circle and Poles connected with that axis may be found. For the meeting of the axis with the surface at two opposite points of the Sphere constitute the Poles of that axis. And its *Great Circle is that circle of the Sphere, whose plane the axis meets at right angles at the centre of the Sphere.* A line is at right angles, or perpendicular to a plane, when it does not incline to either side.

12. *Lesser circles, belonging to any Sphere*, are those which the axis cuts at right angles between the Great

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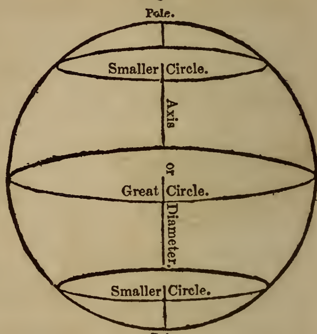
10. How can you form an idea of the plane of a circle being extended?—11. What is the diameter and circumference of any Sphere equal to? Why may any diameter of a Sphere be taken for its axis? Suppose an axis of a Sphere to be given, what may be known? Define the *Great Circle* belonging to any axis.—12. Define the *Lesser Circles* belonging to any axis.

Circle and the Poles. Of the axis of the Earth, the *Equator* is the Great Circle; the *two Tropics* and the *two Polar Circles*, and all circles of latitude are Lesser Circles; and its poles are the *Poles of the Earth.*

Fig. 5.



13. Angles are measured by arcs of circles. An *arc* is any part of a circle less than the whole, and is said to be an arc of a certain number of degrees. To find the measure of arcs and angles it becomes necessary to divide the circle (that is, any or all circles) into a certain number of equal parts. By common consent *every circle, whether great or small, is divided into* 360 *equal parts, called degrees.* For the purpose of exact measurement, degrees are divided into minutes and seconds. A *minute* is the 60th part of a degree, and a *second*, a 60th part of a minute. *A degree of a Great Circle of the Earth is* 60 *geographical miles, or* 69* *English miles.* Hence a minute and a geographical mile are the same measure, but both exceed the English mile.

* When the circumference of the Earth was estimated at 25,000 miles, it was usual to state the number of statute miles of a degree 69½, which number was, even at that calculation, a little too large; since $360° \times 69\frac{1}{2} = 25{,}020$. But taking the number now more generally adopted from Sir John Herschel, 24,856, the nearest approach to correctness, without running into inconvenient fractions, is 69 statute miles to a degree; since $360° \times 69 = 24{,}840$, which approaches within 16 miles of the present calculations of the Earth's mean circumference.

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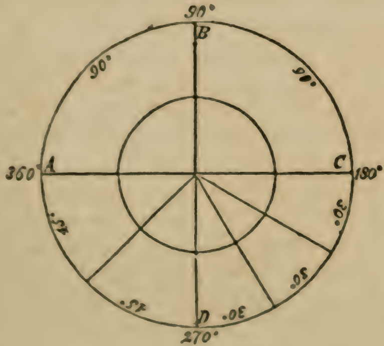
12. What is the Great Circle belonging to the Earth's axis? What the Lesser Circles?—13. How are angles measured? What is an arc of a circle? What must be done in order to obtain a method by which the measure of arcs can be determined? How are circles divided? What more minute divisions are used? If we take a Great Circle of the Earth (which is the measure of the Earth's circumference), to what is each degree, or 360th part, equal? How is this reckoned? (*See Note.*)

14. We insert a diagram to illustrate the division of the circle and the measures of angles. The circle A B C D is divided by two diameters, A C and B D, so crossing each

Fig. 6.



other at the centre as to divide the circle into four equal parts. The four angles at the centre are equal, and they are all *right angles.* Since the measure of the circle is 360 degrees, that of a quarter of a circle is 90 degrees. An arc of 45° subtends half a right angle, and an arc of 30°, a third of a right angle.

15. Universally, all angles are *measured by the arcs which subtend them ;* and it makes no difference whether the circumference of the circle, whose arc measures the angle, be great or small. The two circles of the diagram having a common centre, are CONCENTRIC CIRCLES. *If an angle be placed at the common centre of concentric circles, its sides will cut all the circles proportionally.* If

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14. If a circle is divided by two diameters, which cross at the centre, making equal angles, what are those angles? By what arcs of the circle are they measured? If the circle were divided by 8 equal angles, by what arc would these angles be subtended? If there were 12 equal angles, what number of degrees would there be in each of these angles?—15. What universal principle is herein illustrated? What are Concentric Circles? Suppose an angle be placed at a common centre of concentric circles?

its sides include 90 degrees in the smaller, they will include 90° in the larger circles, and so of any number of circles and any number of degrees.

16. When a Convex Sphere is so inclosed by a Concave Sphere or hollow Globe, that the centre of the Convex is also the centre of the Concave Sphere, then *these two Spheres are Concentric;* and the axis of the Convex and the plane of its Great Circle may be produced to the Concave Sphere, becoming its axis and Great Circle,—the Poles in each being, by definition, the extremities of the axes. This is the case with the Convex Terrestrial and the Concave Celestial Sphere by which it is surrounded.

17. A Spherical System, as we shall use the term, *is composed of the Axis, Poles, and Great Circle of a Sphere;** and may be accompanied with certain adjuncts; as *the parallels of the Great Circle*, which are small circles, lessening towards, and finally vanishing in the Poles; and *the secondaries of the Great Circle*, which are great circles cutting it at right angles, and crossing each other at the Poles. Thus the Axis, Poles, and the Equator of the Earth, are a Spherical System, which may be considered with or without the adjuncts or accessories, which are *parallels of latitude* and *circles of longitude*, or hour circles.... When any body is in circular motion around a central point, that motion is reckoned according to the degrees of the circle passed over, and is called *angular motion.* The distance between any two bodies, or between any two points situated on the same circle, is the number of degrees of the part of the circle intercepted between them. This is called *angular distance.*

* See Fig. 1.

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16. What are Concentric *Spheres?*—17. What is here called a Spherical System? What is angular motion? What is angular distance?

EXERCISES.

NOTE TO TEACHERS.—We recommend that these Exercises should be pursued in *the use of the blackboard*, as well as in *that of the Globes, and in the study of the visible Heavens*. The pupils will thus improve in the education of the eye and the hand, as well as in the correctness of mental conceptions. No scholar should be discouraged if in his first attempts at drawing, he makes wrong lines, for the wrong line often shows where the right is to be made, and chalk marks are easily displaced. It is far better that an author should, on these great subjects, write *graphically*, and the pupils make the figures indicated by his language, than that a book should be filled with be-littleing visible representations of inconceivably great things; and by drawing the figures of the book on a blackboard, instead of being cramped and confined by their present size, they can be made large, and their divisions distinct. The measurement by arcs and angles is so fundamental, that we recommend that questions on this subject be frequently given to the class.

PROBLEM.—*To put the Observer in the Upper Vertex.*—First find his latitude on the Terrestrial Globe. Suppose his place to be Philadelphia. We do not expect that any person will study this work who would not know whereabouts upon a map to look for all prominent cities, especially those of his own country; but their latitude may be unknown or forgotten. Find Philadelphia then, and turn the Globe until you bring it under the brazen meridian, on which you will find, directly above it, 40°, the number of degrees which Philadelphia is from the Equator. This is the latitude. Then elevate the North Pole (since the place sought is in north latitude) as many degrees above the Horizon as Philadelphia is north of the Equator. Our Observer will then be in the Upper Vertex, at a point everywhere equally distant from the Horizon.

If a circle be divided into 8 equal parts, of how many degrees will be each part? If a circle be divided into 12 equal parts, of how many degrees will be each part? If into 24 equal parts, of how many degrees will be each part? How great a part of the circumference of a circle is 4 degrees? How great a part is 30°? How great a part is 15°? How great a part is 60°? 180°? 90°? 45°?

From the Artificial Terrestrial Globe, define the position of the Earth's Equator, as to the oceans, seas, continents, countries, and islands through which it passes.

CHAPTER II.

USES AND DIFFERENCES OF THE CELESTIAL AND TERRESTRIAL GLOBES. —THE FIXED STARS.—THEIR DISTANCES.—THE CONSTELLATIONS. —ANTIQUITY OF ASTRONOMY.

1. WHILE the two Globes, the Celestial and Terrestrial, are placed together before a class, who are more or less acquainted with geography, the pupils are easily made to conceive, that the Terrestrial Globe, covered as it is by a continuous map, represents the Earth; and thus they readily understand its use. But they find difficulties in the study of the Celestial Globe, which partly arise in consequence of its differences from the Terrestrial.

2. The Celestial Globe is made of the same size as its mate, the Terrestrial; whereas, the Sphere which it represents is immeasurably larger than the Earth. The Terrestrial Globe is *convex*, as is the Earth which it represents. But the Celestial Globe, while it is convex, represents the VAST CONCAVE of the Starry Heavens, which concentrically surrounds the Earth.

3. While the Terrestrial Globe presents a familiar map, dividing its surface into oceans, seas, islands, and continents, the Celestial Globe is covered with uncouth figures of all monstrous things — strange men and women, mingled with beasts, birds, fishes, and serpents. These grotesque figures represent the CONSTELLATIONS, into which the surface of the concave Heavens is divided,—as is the convex surface of the Earth into seas and countries; and as the Geographer learns them, and the cities which they contain, from the Terrestrial Globe, so does the Astronomer learn the names and places of the Constella-

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CHAPTER II.—1. Which of the two globes is most easily understood, and why?—2. In what respects are the two globes different? What is here said of the concave of the Heavens?—3. What do the uncouth figures on the Celestial Globe represent? What are Constellations?

tions, and the principal stars which they include, from the Celestial.

4. Of the STARS, the first division is into *fixed* and *wandering.* The *fixed stars*, of which our Sun is regarded as one, are those which do not perceptibly change their position, with regard to each other. The wandering stars, which do, are *Planets* and *Comets.* The Earth is a planet. The wandering stars have no place given them on a Celestial Map; *the Constellations* which fill it, being wholly *composed of groups of fixed stars.* But as the journey of a traveller can be made known to a reader who understands a geographical map of the fixed places through which he passes, so can the course of a wandering star be made perfectly intelligible to the person who understands the astronomical map, with which the Celestial Globe is covered.

5. The Sun *appears* to change his position in regard to the fixed stars, but does not in reality. His *apparent* yearly course through the Constellations is in that great circle, belonging solely to the Celestial Sphere, called the ECLIPTIC. As the Sun is to us the King of Stars, his apparent track through the Heavens is properly made the first or metropolitan circle of Astronomy. Hence astronomical latitude is reckoned from the Ecliptic, as geographical is from the Equator. A belt in the Heavens, extending eight degrees on each side of the Ecliptic, and comprising the orbits of all the planets except the Asteroids, is called the ZODIAC. The twelve Constellations of the Zodiac should be learned from the Celestial Globe, in their proper order, and the signs made familiar to the eye.

6. The fixed stars surround the Earth on every side; although in the day-time they are concealed by the dazzling rays of the Sun. In eclipses of the Sun, stars are visible by day, and when viewed through large telescopes. It has been commonly asserted that the stars are

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4. What is said of fixed stars? Of wandering stars? Since they are not placed on Celestial maps, how can their course be made intelligible?—5. Is the Sun's motion real, or only apparent? What is said of the Ecliptic? What is the Zodiac?—6. Where in regard to the Earth, are the fixed stars

also seen by day from the bottoms of deep wells; but this is doubted by the great traveler and philosopher, Humboldt, who has never found a well or mine, from whose depth, gaze as he might, he has been able to distinguish stars above. The fixed stars are *luminous;* that is, they shine by their own light; the planets are *opake*, having no light of their own, but shining by the reflection of the light of the Sun. All the planets known to us are, like the Earth, *secondaries* to the Sun. If the fixed stars, as is believed, have, in the same manner as the Sun, opake secondaries revolving around them, this could not be known to us, on account of their immense distance.

7. Though the intellect of man has achieved wonders in measuring the diameters and distances of the heavenly bodies, yet it is not until recently that an approach has been made towards any positive knowledge of the distances of the fixed stars from the Earth,—other than this, that it is vast, beyond the human powers of calculation, or even of thought. But an astronomer of Prussia, Professor Bessel, has now determined, with a show of accuracy, the distance of a fixed star. It is a binary, or double star, in the Constellation Cygnus, the Swan, which, according to his calculation, is more than half a million of times further from the Earth, than that it is from the Sun. Such is its distance that light, which moves at the rate of 192,000 miles in a second, would be $9\frac{1}{4}$ years in coming from that star to us. There are reasons for believing that this star is nearer to the Earth than other fixed stars, which are much more brilliant; and the fact is thus established that the fixed stars are of very unequal sizes. Some are supposed to be much larger than our Sun. *Sirius* (the Dog Star) in the Constellation *Canis Major* (the Great Dog) is regarded as the most brilliant of the fixed stars. It is calculated that its light and heat are 34 times greater than the Sun's;

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6. How do the fixed stars differ from the Planets in regard to their light? What is said of the fixed stars having, like our Sun, opake Planets revolving around them?—7. What is said of the distances of the fixed stars? What is said concerning a binary star in the Swan? What fact is established? What is said of Sirius?

but astronomers have thus far been baffled in all attempts to measure its distance.

8. The fixed stars are divided into *visible* and *telescopic*; and to these might be added, the *nebulous*. The *visible*, those which are seen by the naked eye, are divided, *according to their apparent sizes, into six magnitudes*. Observe on the Celestial Globe the different characters used, by which each may be known. The largest stars are not numerous, only 18 being regarded as of the first magnitude. These may therefore be easily learned from the globe, so that they may be known when seen in the Heavens. They have each a proper name, and are to the map of the Heavens what great cities are to that of the Earth. The Astronomer as well knows where is *Aldebaran*, in the Constellation *Taurus*, as the Geographer, where is London, in Great Britain.

9. Of the *visible* fixed stars, there have been counted about 4,000. This number is small compared with the *telescopic stars*, or those which are brought to view by means of the telescope. Of these, 50,000 have been counted over a small space in the Milky Way; and if more powerful instruments were invented, more stars would doubtless be discovered. These stars thus presumed to exist are *nebular*.

10. Spots in the Heavens, like small luminous clouds, called *nebulæ*, long excited the curiosity of Astronomers. They were at length, under the magnifying power of the great telescope of Sir William Herschel, found to be clusters of stars. Some part of the broad luminous tract of the Heavens, called the *Milky Way*, has been thus resolved into congeries of small stars; and Astronomers believe that telescopes will yet be made, with a magnifying power sufficiently large to show, that the whole of this immense tract is composed of myriads of stars, distant from us beyond all the powers of the boldest imagination to conceive. The Milky Way, or *Via Lactea*, has the

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8. How are the fixed stars divided? How are the visible stars ordinarily divided? How many are there of the first magnitude, and what is said of them?—9. Of the visible fixed stars, how many have been counted? What are telescopic stars? How many?—10. What are nebulæ? What have these been found to be, and by whom? What is said of the Milky Way?

general form of a great circle, which crosses the *Equinoctial* at an angle of about 60°.

11. Celestial Globes have sometimes been made so large that the student could go within, and see from the centre the Constellations; which, in this case, were painted on the inner or concave surface. This would give him a correct idea of their positions. If we suppose that such a large globe stood under the open sky, that the painting was transparent, and the globe rectified for the place and the hour, then the Observer at the centre might look through the painted Constellations of his transparent globe directly to the corresponding real Constellations in the Heavens. If, for example, he looked towards the north, and through the Great Bear drawn on his globe, he would see in the Heavens—not the figure of a bear, it is true, but the six beautiful stars, which, both on the globe and in the Heavens, form the well-known Dipper; and he would see the two stars in the front, called on the globe *Merac* and *Dubhe*, pointing to a smaller star called *Cynosura* in the Little Bear; around which, if his great concave globe were slowly turned from east to west, to imitate apparent diurnal motion, he would see the Dipper and the other stars revolve; and this is the Polar-Star.

12. The cultivation of Astronomy goes back to the earliest dawn of history. When Alexander the Great took Babylon, B. C. 331, he found reason to believe that this first of human sciences had begun in Chaldea, antecedent to the founding of the Hebrew nation by Abraham. In the Book of Job, one of the very earliest writings of antiquity, the most beautiful Constellation of the Heavens, *Orion*, is called by its present name,—as is also, *Arcturus*, a star of the first magnitude, now ranged in the Constellation *Bootes*, and the most interesting group of the Celestial Sphere, "the *Pleiades*," in Taurus.

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11. What if a transparent Celestial Globe were made so large, that an Observer could go into the Earth's place at the centre? What would such an Observer see at the north?—12. What is said of the date of the science of Astronomy? What evidence have we that it had begun as early as the date of the Book of Job? —13. What is said of the origin of the Constellations? Of their use?

13. Why the beautiful stars were arranged according to such fantastic shapes, as we see on the Celestial Globe, cannot in all cases be decided. But there is a significancy in many of the names and figures; and others commemorate heroes and heroines, familiar to ancient story. Neither can the origin of the names of countries always be traced, yet the Geographer avails himself of them as they exist. So is it with the Astronomer in regard to the Constellations. Their odd names and strange shapes may serve to fix them in his memory.

EXERCISES.

Observe on the Globes whatever they are designed to represent, especially when connected with the present lesson.

The *Hour Circle* on the artificial Globe is a small circle, sometimes of Brass, with an index or pointer fixed to the North Pole; it is divided into 24 equal parts, to represent the 24 hours of the day. The noon, XII, is on the upper or *superior* part of the Meridian, and the midnight, XII, is on the lower or *inferior* part of the Meridian.

The Wooden Horizon represents the true or Rational Horizon, and has marked upon its surface several circles. One contains the 12 signs of the Zodiac, through which the Sun appears to revolve in a year. Another circle contains the signs of the Zodiac, divided into degrees and the days of the month to which they correspond.

A *Quadrant of Altitude* is a thin slip of brass divided into 90°, and may be screwed on to the brass meridian at the zenith. It is used to measure distances.

Set the North Pole of the Celestial Globe towards the north. Elevate it above the wooden Horizon a number of degrees equal to your latitude. The North Pole Star will then be in the situation in which you will see the Polar Star in the Heavens every cloudless night; and the Equinoctial on the Globe will have the same slope at which, in your latitude, it always appears. There are stars which mark the imaginary, though determinate place of this Circle. They will each in its turn appear and disappear, but the line is ever in the same place, and will ever make with your Horizon an angle which is the complement of your latitude. Let the student fix the place of the Equinoctial well in his mind, by learning as fast as possible, from the Celestial Globe and the actual Heavens, the Constellations through which it passes, and the single bright stars, or the groups of stars on or near it. Observe the Sun's course on the 20th of March and September,—at the time of the Equinoxes. The line he then describes is the Equinoctial.

Find on the Celestial Globe the following Constellations named in the preceding chapter: *Ursa Major*, the Great Bear; *Ursa Minor*, the Little Bear; *Cygnus*, the Swan; *Taurus*, the Bull; *Canis Major*, the Great Dog; *Orion;* and *Bootes*, the Herdsman, with his Dogs. Which of them does the Equator pass through, and which the Ecliptic? What stars of the first magnitude do you find on or near the Equator? What on or near the Ecliptic? Name and describe them.

Where is *Cynosura?* Where is Sirius? and how many degrees is it from the Equator? (*Measure by passing it under the brazen Meridian.*)

Learn from the Terrestrial Globe the position of the Tropic of Cancer. Through what seas and countries of America does it pass? Through what of Africa? Of Asia? How are Canton and Calcutta situated with respect to the Tropic of Cancer? How is Havana situated with respect to the Tropic of Cancer?

CHAPTER III.

THE STUDIES OF THE CELESTIAL GLOBE MAY BE PURSUED BY OCULAR EXAMINATION OF THE HEAVENS.—THE VIEW ON THE EARTH LIMITED.—THE SENSIBLE HORIZON.—THE SOLAR SYSTEM.—THE PRINCIPAL PLANETS AND ASTEROIDS.—THE SATELLITES.—COMETS.—THE SUN AND ITS INFLUENCES.—SIR JOHN HERSCHEL'S ILLUSTRATION OF THE COMPARATIVE SIZES OF THE BODIES OF THE SOLAR SYSTEM.

1. IN the studies of the Earth and Heavens, by means of the Terrestrial and Celestial Globes, there is this further difference. The student having by the aid of his Celestial Globe, with such assistance from the living teacher as he may be able to obtain, learned to know the principal Constellations, with their most remarkable stars, can then go forth at evening and pursue his studies, by tracing out his subjects upon the starry concave of the blue vault above. There, by the remarkable stars through which they pass, he can locate the circles of the Ecliptic, the Equinoctial or Equator of the Heavens, the two Colures, and the other re-

CHAPTER III.—1. What further differences are here noticed between the studies of the Earth and Heavens by means of the two Globes?

markable positions of Astronomy. But we cannot, in the same manner, trace out upon the Earth's real surface the places where are the Equator, the Tropics, or any of the imaginary circles, which belong to Geography.

2. For the SENSIBLE HORIZON, *which is the boundary of the actual view, either on land or water*, which the human eye can at once take in, is extremely limited. In water, or on a level plain, it extends only three miles each way from the Observer, whose eye is raised 5 feet from the surface. Its extent increases in proportion to the Observer's elevation. Let him be raised 100 feet above the surface, and his view will extend 10 miles in every direction. From Dwalghiri, the highest peak of the Himalaya mountains, 28,000 feet high, if the view were unobstructed, the Observer's eye might faintly see at the distance of 147 miles. This we infer from the fact that this peak is seen at that distance.

3. Sir John Herschel argues from these facts that our sight may convince us of the convexity of the Earth, wherever, at sea or on land, the view is unobstructed. Every particle of solid matter and every drop of water alike gravitate to the centre of the Earth; thus forming around it a Globe. The particles of water moving among themselves, settle when agitated, and the unruffled ocean is like one vast convex mirror. An Observer's eye being placed close to its surface, or to that of a vast level on land, his vision would extend in a plane, *tangent* to (or touching) the Earth at the place of his eye. This plane is parallel to the Rational Horizon, and is always meant when the *Plane of the Sensible Horizon* is mentioned. But let the Observer's eye be elevated, and the line of his vision will no longer lie in this tangent plane; but his

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2. What is the Sensible Horizon? What is its extent at the natural height of the Observer's eye, or about 5 feet? How does it increase? What is its extent at the elevation of 100 feet? What is said in this connection, of the mountain-summit Dwalghiri? What inference is mentioned?—3. What argues Sir John Herschel from these premises? What may be said of the surface of the unruffled ocean? When would the Observer's vision lie in a plane tangent to the Earth's surface? What is this plane parallel to, and what is it called?

Sensible Horizon will droop or *dip*. Imagine a line drawn from the elevated eye to the convex surface of the Earth, and passing onwards to the concave Heavens, and then this line revolved,—where it touched the Earth, it would describe *the extreme circle of the Observer's Terrestrial view*, and where it met the Heavens describe *the extreme circle of the Observer's Celestial view;* and both these circles will be enlarged in proportion to the Observer's elevation, and the consequent increased *Dip of the Horizon.* The line revolved, produces an *imaginary cone.*

4. The Earth, by its convexity, gradually recedes beyond the circle of terrestrial vision. We will suppose a ship at sea, yet below the circle, but approaching the Observer,—the top of the mast will first rise above his dipping Horizon, and be seen,—then the lower parts of the masts; and last of all, there heaves in sight the hull, or body of the ship, which is its largest part. Since these phenomena occur in every part of the world, and since nothing but a convex figure could produce them, the Earth must therefore be everywhere convex; that is, it must be a globe. To such certainty and practical exactness are these principles reduced, that the height of an object is calculated from its distance, or its distance from its height.

5. It is evident that heavenly bodies will appear in different positions, viewed by Observers on different parts of the Earth's surface; and hence that observations made at any one place on the surface will not be of general use. Astronomers, to rectify this inconvenience, have adopted the method of making all calculations upon heavenly

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3. In what case will the Sensible Horizon droop or *dip?* What line are we to imagine? If we suppose this line revolved, what imaginary figure will be produced? And what circle on the Earth will be produced by the revolution of the touching point? If the supposed line meet the Heavens, what circle will it there produce? (*All these lines and circles the pupils may be taught to illustrate by drawing them on a blackboard.*)—4. Illustrate by the appearance of an approaching ship. State the argument by which such phenomena prove the convexity of the Earth. Have these principles certainty and utility?—5. On what point have all Astronomers agreed as the place of Astronomical observations? Why was it found necessary to come to such an agreement?

bodies, as if all saw them from the same spot; and this one imaginary point of Astronomical view, is *the centre of the Earth*, 4000 *miles* from its surface.

6. And where is the EARTH? It is floating in space; but not like a leaf in the wind. For not more has the railroad an appointed track, than has the Earth its path in space. To other worlds—and such we deem the stars to be—the Earth appears as a star. It belongs to a group of Celestial bodies, of which the SUN (or *Sol*, as called by the Latins) is the great central source of light, of heat and of attraction.

7. Of the bodies which belong to the Solar System, there is, in the first place, the great SUN itself, whose diameter is 887,000 miles. In the second place, there are the PRIMARY PLANETS, of which eight are principal Planets, whose names, in the order of their distance from the Sun, are as follows: *Mercury*, *Venus*, *Earth*, *Mars*, *Jupiter*, *Saturn*, *Uranus or Herschel*, *Neptune or Leverrier*.

8. Besides these, there are, between Mars and Jupiter, several small, and newly discovered Planets, called *Asteroids*. These are also called Primary Planets, as they revolve directly about the Sun, and are thus distinguished from the next or third class of bodies belonging to the Solar System, which are termed SECONDARY PLANETS, *moons, or satellites*. These revolve around certain of the Primary Planets, and are at the same time carried with them around the Sun. Of the Secondary Planets, there are at least *twenty-one*. Of these

The Earth has	1	Uranus or Herschel . .	6
Jupiter	4	Neptune or Leverrier . .	2
Saturn .	8 { This planet has also a broad, luminous ring.		

6. Where is the Earth, and under what circumstances does Astronomy portray this abode of man?—7. What is the diameter of the Sun? What is the order of the eight principal planets, as to their distance from the Sun?—8. What and where are the Asteroids? Why are these, as well as the eight larger, called Primary Planets? What is said of the Secondary Planets? How many are there known to be in the Solar System, and to what Planets do they belong?

9. The Comets are the fourth class of bodies belonging to the Solar System. They revolve about the Sun in orbits very elliptical. They are divided into *Interior* and *Exterior.* The interior Comets are those whose orbits are at their *aphelion*, or greatest distance, from the Sun, wholly within the range of that of Neptune, the outermost of the known Planets. Of these there are six, whose orbits and periodic times have been calculated; and which return in periods of from three to seven years. Of the exterior Comets, the number is unknown, but it is supposed to comprise at least 500. In 1847 the catalogue of those observed amounted to 178.

10. "Comets," says the Baron Humboldt, "possess the smallest mass, and occupy the largest space, of any bodies in the Solar regions." It is only the large Comets, or those which come very near to the Earth, which are visible to the naked eye. They appear unfrequently, and at such irregular times, that the ancients supposed them to portend great and disastrous events—such as war and pestilence.

11. The Earth is nearly 8000 miles in diameter. It is larger than the two Planets, Mercury and Venus,—which are called *Inferior* because their orbits are within that of the Earth; but our Planet is very much smaller than the great bodies Jupiter, Saturn, Uranus, and Leverrier. These four Planets, together with Mars and the Asteroids, are called *Superior Planets*, because their orbits are without that of the Earth.

12. The Earth's distance from the Sun is 94 millions

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9. What is the fourth class of bodies belonging to the Solar System, and into what are they divided? What is aphelion? What are interior Comets? What exterior? What is said of the numbers of the Comets whose times have been ascertained? Of the conjectural number of the Comets belonging to the Solar System?—10. What is said of Comets by a celebrated writer? What is further said of Comets?—11. What is the ordinary estimate of the Earth's diameter? When are Planets said to be *inferior?* When *superior?* What Planets are in each of these classes? What comparison of the Earth's size to that of the other Planets is here made?—12. What is the Earth's distance from the Sun?

of miles. One million of miles is more than forty times the circumference of the Earth, and our distance from the SUN is 94 millions! Mercury's distance is a little more than a third of 94 millions, and Venus a little more than two-thirds. Mars is about once and a half the Earth's distance, the Asteroids about double; Jupiter, the largest of all the Planets, is more than five times the Earth's distance from the SUN; Saturn, with his *two broad concentric rings*, is more than nine times; Uranus 19—and Leverrier 30 times as far from the source of light and heat as ourselves.

13. The Planets have their set times as well as their set places. The time which the Earth takes in moving once round the Sun, is called, in our language, *a year*. It is 365 days, 5 hours, and 43 minutes. The time of the Earth's rotation about its axis is called a *day*, and is divided into 24 hours. The year of some of the Planets is shorter, and that of others much longer than our own, as is also their day. These subjects are fully treated in the table which follows this chapter.

14. The time of the revolution of the Moon around the Earth, doubtless gave rise to the idea of dividing time by *moonths* or *months*. Though now, in order to divide the year into 12 parts, nearly equal, and having the year always begin with the beginning of a month, the yearly months are from one to three days longer than the *Lunar months*. *Lunar* is from the Latin word *Luna*, the Moon. A *Lunation* is the time which elapses between the changes of the Moon, or from new Moon to new Moon again.

15. To recapitulate,—the bodies which belong to the Solar System, are 1st the Sun, 2d the Planets, of which the Earth is third in distance, 3d the Moons or Satellites, and 4th the Comets. Of all these bodies the Sun alone shines by his own light, or is *luminous*. The others all

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12. What is the distance from the SUN of the other principal Planets, compared with that of the Earth? By what is Saturn distinguished?—13. What is said of the Earth's time? Of that of the other Planets?—14. What is said of time as measured by the Moon's revolution around the Earth?—15. Recapitulate the bodies which belong to the Solar System.

borrow their light from him, and are thus known to be *opake*. The bodies belonging to the Solar System are of different densities. Jupiter is less dense than the Earth. A portion of that Planet, equal in bulk to the Earth, would weigh only a quarter as much. The same portion of the Sun would weigh still less; its density being to that of the Earth as 1 to $4\frac{1}{2}$. The Sun's density is about equal to that of water.

16. The Sun revolves about its own axis once in 25 days; as is known by the movement of certain *dark spots* upon its disk. Astronomers believe these spots to be openings in that wonderful investment of fiery light and radiant heat, with which the Sun is surrounded. It is supposed that within this, as these dark openings indicate, may be an atmosphere of clouds, genial to life; and that beings of a high order may have the Sun as their magnificent abode. His surface is 1,400,000 times greater than that of the Earth, and 500 times greater than all other bodies in the Solar System combined. That the Planets are inhabited, there are so many reasons to believe, that no rational mind can entertain a doubt. God made them, and he does nothing in vain.

17. For aught we know, the Sun may be the blessed abode of glorified spirits, who have passed through a purifying process in other regions. That, however, is mere conjecture. What we know is, that of all material objects, the Sun is the most glorious image of his Maker. By his attraction the Solar System is kept in place and in order. By means of his genial warmth the air is attempered for respiration, without which there is no animal life. The heat of the Sun keeps the waters in a fluid state, thus giving a

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15. What shows the Sun's superiority to all the other bodies of the Solar System? How do the bodies of the Solar System compare with each other in regard to density?—16. What revolution has the Sun? What is said of the spots in the Sun? and what do some suppose concerning the interior surface? How much is the Sun's surface greater than that of the Earth? Than that of the other bodies of the Solar System combined? Does your author believe that the Planets are inhabited?—17. What conjecture has been made concerning the Sun as a place of habitation? What do we know of the Sun?

home to myriads of fishes. The same heat produces evaporation, by which clouds are formed, and dews and rains descend. The heat of the Sun thus nourishes all vegetable life, and thus produces food for the animal creation. The Sun is also the fountain of light, which, falling on the eye, "the curtain of the Universe" is lifted, and man becomes sensible of the beauties of external nature. Utility, as well as beauty—improvement, as well as pleasure, is conferred upon man by the great gift of sight, which we could not enjoy without the light of the SUN.

18. We have not furnished an engraving of the Solar System, because we believe that such often hinder the sublime impressions which descriptions might otherwise give, and so belittle the subject. The great Astronomer, Sir John Herschel, speaks with contempt, in the following extract, of orreries and paper diagrams, as conveying no adequate ideas of the Planetary Worlds. Yet some illustrations are necessary. We should seek to vary them so as not to have the learner forget, in them, the principal subject.*

19. "We shall close this chapter," says the younger Herschel, "with an illustration calculated to convey to the minds of our readers a general impression of the relative magnitudes and distances of the parts of our system. Choose any well-levelled field or bowling-green. On it place a globe, two feet in diameter; this will represent the Sun; Mercury will be represented by a grain of mustard-seed, on the circumference of a circle 164 feet in diameter for its orbit; Venus a pea, on a circle 284 feet in diameter; the Earth also a pea, on a circle of 430 feet; Mars a

* The pupils of the Troy Female Seminary were many years ago arranged by the author of this work, into a species of planetarium, so that in a large room they walked the Solar System. This cost much attention and time, but the young ladies entered into it with spirit, and were well repaid. But the observation of the actual Heavens is that which most enlarges our minds, and assists our conceptions.

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18. Why has no engraving of the Solar System been furnished for this work?—19. What says Sir John Herschel of paper circles and orreries? Give some account of his illustrations of the Solar System, as to the different sizes of the several bodies, and their comparative distances from the central body.

rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1000 to 1200 feet; Jupiter a moderate-sized orange, in a circle nearly half a mile across; Saturn a small orange, on a circle of four-fifths of a mile; Uranus a full-sized cherry, or a small plum, upon the circumference of a circle more than a mile and a half; and Neptune a good-sized plum on a circle about two miles and a half in diameter. *As to getting correct notions on this subject by drawing circles on paper, or, still worse, from those very childish toys called orreries*, it is out of the question."

TABLE *of the Magnitudes, Distances, and Revolutions of the Principal Primary Planets.**

NAME.		Diameter.	Distance from the Sun.	Annual revolution.		Diurnal rotation.
		miles.	miles.	years.	days.	hours.
Inferior Planets.	Mercury .	3,200	37,000,000		88	24
	Venus . . .	7,700	68,000,000		224	23½
	Earth . . .	8,000	95,000,000		365¼	24
Superior Planets.	Mars	4,200	142,000,000	1	321	24½
	Asteroids.	. . . .	. . . .	. . . .		. . . .
	Jupiter . .	89,000	485,000,000	11	314	10
	Saturn . .	79,000	890,000,000	29	170	10½
	Uranus . .	35,000	1,800,000,000	84	5	9½
	Neptune .	37,000	2,850,000,000	164	225	. . . .

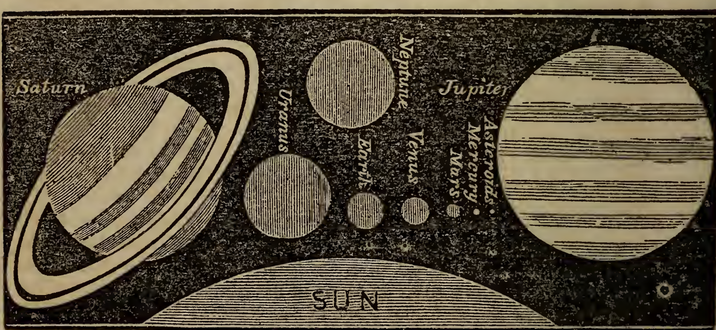

TABLE *of Asteroids all situated between the orbits of Mars and Jupiter.* It will be seen that the four principal are Vesta, Juno, Ceres, and Pallas. The first discovered was Ceres, by M. Piozzi, of Palermo, in 1801; the second was Pallas, by M. Olbers, of Bremen, in 1802. Mr. Hind, of England, has discovered several.*

NAME.	Diameter.	Distance from the Sun.	Annual revolution.	
	miles.	miles.	years.	days.
Flora	....	210,000,000	3	98
Vesta	270	225,000,000	3	230
Iris	....	227,000,000	3	250
Metis	....	227,000,000	3	251
Hebe	....	231,000,000	3	285
Astrea	....	245,000,000	4	51
Juno	1,400	254,000,000	4	134
Ceres	1,600	263,000,000	4	222
Pallas	2,100	263,500,000	4	226
Hygeia	....	298,000,000	5	199
Parthenope	....	234,000,000	3	305
Clio	....	222,000,000	3	206
Egeria	....	245,000,000	4	44
Irene	....	246,000,000	4	54
Eunomia	....	252,000,000	4	113

NOTE.—It is useful for pupils to make out for themselves tables of the Planets in the order of their size—of the length of their day, and of their year. Observe the difference between the nearest and most distant from the Sun of the Asteroids.

EXERCISES.

NOTE TO TEACHERS.— *We anticipate that we may be called to account, for introducing into these Exercises, terms, such as the Equinoctial Points, and the Colures, which we have not yet explained. But we desire the learners to be able to locate these on the globe, and in the visible Heavens, as fast as possible; that when they are explained in the text, their minds may be prepared for the explanation. None would say that a child must not see a city or learn its place on the map until it had been first described.*

* Since this work has been in the press, other Asteroids have been discovered.

We now wish our learners to commence in earnest to learn from the actual Heavens the grand scheme which science has furnished for the foundation of Astronomical Geography, requiring nothing which the faithful scholar cannot accomplish. We will begin with the Northern Heavens. There the stars perform their circles around the Pole without ever setting, and hence they can be studied every clear evening of the year; and it better suits our purpose, because the upper Poles of our three systems range from the zenith north. The stars Merac and Dubhe, in the front of the Dipper, are the *pointers*, because they point to CYNOSURA, the Polar Star. Now observe the smallest star of the Dipper, MEGREZ, which joins the handle to the bowl. Look at it in connection with the *Polar Star* CYNOSURA. Measure the distance between them with your eye in the Heavens and on the Celestial Globe. You will find by examining the globe that it is a little more than 30°; but that is sufficiently accurate for our present purpose. Trace from Megrez to Cynosura, then carry your eye onward in the same direction, and at the same distance (30°) you will see another bright star. This is CAPH, in the Constellation Cassiopeia. *These three stars, Megrez, Cynosura, and Caph, mark the place of the Equinoctial Colure*, which is as the Meridian of the Heavens,—the principal secondary to the Equinoctial; from the Vernal half of which *right ascension* is reckoned.*

To make our language precise it is necessary to consider this circle as divided at the Poles into two semicircular Colures, and we shall call that half circle which passes from Cynosura through Caph to its intersection with the Equator and Ecliptic at the Vernal Point—the VERNAL COLURE; and that semicircle which passes from Cynosura through Megrez to the Autumnal intersection of the same two great circles, the AUTUMNAL COLURE. Study this lesson thoroughly, both on the Celestial Globe and in the Heavens. It contains the key to our system of the study of the visible Heavens. We begin with the ever-present and well-known stars of the North. Learn as many Constellations, bright stars, and groups, which lie along the course of the Colures, as will make their places in the Heavens familiar.

On the *Terrestrial Globe* study the Tropic of Capricorn as to the parts of the Earth through which it passes. What *Oceans* lie in this circle? What *Seas?* What continents? What countries? What islands? and what large cities in South America lie on or near it? Compare the quantity of land passed over by the two Tropics. What great difference do you find?

* Neither Megrez nor Caph are *exactly* in the Colure, but sufficiently so for our purpose.

CHAPTER IV.

DEFINITIONS.

Distinction of Positions into Permanent and Movable.

1. In pursuing the subject of Astronomical Geography, there are many definitions and explanations which are made necessary by the imperfection of the human faculties. We do not describe for beings who know as God knows,—every thing as it is, and every thing at once; and who at the same moment can see all sides of all spheres, within and without. Our language must meet the understanding of Man,—an Observer, whose Sensible Horizon bounds his view of the Earth and the Heavens; and whose nature compels him, on whatever side of the Globe he may stand, to regard the point over his own head as the very topmost centre of the Heavens, and that radius of the Earth which touches his feet to be the direct line downwards, not only to the centre of the Earth, but indefinitely beyond.

2. Since this natural impression must be recognized in arranging the elements of Astronography, we shall distinguish its definitions into two classes:

First, such as are determinate, and fixed in place by nature, and by universal consent; as the Equator on the Earth, and the Ecliptic in the Heavens.

Second, such as have of themselves no determinate location, but are merely terms, which express relations of place to a located Observer; as the Horizon, a Vertical

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Chapter IV.—1. Are human sciences addressed to a Perfect Being? In what manner does God see and know? In regard to the language used respecting Astronomical Geography, to whose understanding is it addressed?—2. Into what two classes does your author distinguish its definitions? What are the first called? What the second?

Circle, &c. The positions of the first class will be called PERMANENT POSITIONS; those of the second, MOVABLE POSITIONS.

3. The Earth's situation, with respect to the Sun, gives rise to certain determinate points and circles, and these are by nature PERMANENT POSITIONS. The AXIS OF THE EARTH is the fundamental line, or Axis of Permanent Positions. It is by nature a Permanent Position; for

Fig. 7. Permanent Positions.

although it is not a solid material line, yet the Earth as unchangeably revolves in its daily rotation around it, as if it were. It is represented on the Artificial Terrestrial Globe by the iron wire or rod on which it turns. The axis of the Earth being extended to the Celestial Sphere, becomes THE AXIS OF THE HEAVENS. The points where the Terrestrial Axis meets the Earth's surface are THE POLES OF THE EARTH. Those points where the Celestial Axis meets its own Sphere, are THE POLES OF THE HEAVENS. That Celestial Pole which meets the Sphere in the Constellation Ursa Minor, or Little Bear, very near

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3. What gives rise to Permanent Positions? What is remarked concerning their fundamental line or Axis? What is the Axis of the Celestial Sphere? What are the Poles of the Earth? Of the Heavens?

a star named *Cynosura*, is called the NORTH POLE OF THE HEAVENS. The Terrestrial Pole corresponding to this is the NORTH POLE OF THE EARTH. The opposites are the Southern Terrestrial and Celestial Poles. The star Cynosura is the *North Polar Star.* There is no correspondent Southern Polar Star.

4. The Axis of the Earth has for its Great Circle the EQUATOR, or *equal-divider*, whose plane separates the Earth into Northern and Southern Hemispheres. This plane being extended to the Celestial Sphere, describes there the EQUINOCTIAL. This is the term by which Astronomers designate the *Equator of the Heavens.* The place of the Equinoctial we should learn to trace as we look out by day or by night upon the sky. It passes through the Constellation Orion, the brightest and most beautiful in the firmament; and in every latitude, the line which the Sun, in his daily motion, describes upon the Heavens, when the days and nights are of equal length, is the Equinoctial.

5. These concentric circles of the two Spheres, the Equator and Equinoctial, are of primary importance to our science. The terms by which they are designated are not synonymous: Equator refers to an equal dividing in *place;* and Equinoctial, from *Equinox*, a word signifying equal-night, refers to an equal dividing of *Time.* The Equator, although in one sense an imaginary line, as no visible object like the Chinese wall will be found upon the Earth to mark its course, is nevertheless by nature a real and a Permanent Position. It is the central circle of the Sun's direct influence upon the Earth, the intermediate station between the Poles, and it is connected with the equal division of time.

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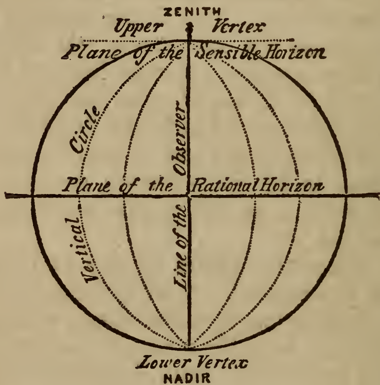
3. Where is the North Pole of the Heavens? Of the Earth? The South Pole of each? What star is the North Polar Star?—4. What is the Great Circle of the Earth's Axis? Of the Axis of the Heavens? How should we learn to trace the Equinoctial in the actual Heavens?—5. What is remarked concerning two concentric circles, and of the names by which they are designated? In what sense is the Equator an imaginary line? But what is it, notwithstanding? Which are the fundamental Permanent Positions?

6. Since the Movable Positions depend on the location of the First Observer, and since any point on the Earth's surface may be taken as his place, therefore all the apparatus of imaginary circles, lines, and points made in the science to accommodate man's limited view, are *Movable;* and all depend on and move with that point of the Earth's surface assumed as the Place of the First Observer, and called the UPPER VERTEX.

Fig. 8. Movable Positions.



7. That place on the Earth on which the First Observer stands, and which we have called the UPPER VERTEX (*see Fig.* 8), has been incorrectly regarded as the Zenith; but it is a point on the Terrestrial Sphere; and the Zenith is its corresponding point in the Heavens, and belongs solely to the Celestial Sphere. If we imagine a line, of which the Observer, as he stands, forms a part, descending from his feet downwards to the centre of the Earth, and from thence to the opposite surface, this, which we call the LINE OF THE OBSERVER, is a diameter of the Earth,—and every diameter of a Sphere may become an Axis.

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6. How does it appear that all the Movable Positions depend on and move with the Upper Vertex?—7. How has the Observer's place been regarded? What is the Zenith? What is here meant by the Line of the Observer?

This Line will be THE AXIS OF THE MOVABLE POSITIONS. Its Terrestrial Poles are the Upper Vertex, and its opposite, which we name the LOWER VERTEX. If it be continued to the Heavens, it there becomes *the Celestial Axis of Movable Positions, and the Pole corresponding to the Upper Vertex is the* ZENITH, *and that corresponding to the Lower Vertex is the* NADIR. The *Great Circle* of the Terrestrial Line of the Observer (or Axis of Movable Positions) is the RATIONAL or REAL HORIZON, and the corresponding Concentric Great Circle of the Heavens is the CELESTIAL HORIZON. The Hemispheres into which these Horizons divide both the Heavens and the Earth are *the Upper and Lower Hemispheres.*

8. The two Horizons, the Terrestrial and Celestial, though moving as the Observer moves, and for different Observers passing over different portions of the Earth and the Heavens, are yet represented on each of the Globes by a large fixed wooden circle. But, to meet our comprehension, instead of moving the Horizon to suit the place of our Observer, we must move the assumed place of the Observer; as but one spot on an Artificial Globe could seem to us an Upper Vertex. Therefore if we take New York or London, or any other assumed place as that of our First Observer, we must elevate that Pole to which he is nearest, a number of degrees equal to his latitude, and then revolve the Globe on its Axis until the place chosen is under the brazen ring, which represents the Meridian of the Observer. Then our chosen Observer will be in the Upper Vertex, and the wooden Horizon will be his Horizon. If we then revolve the Globe on its Axis, we at

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7. What other appellation may be given to this Line? What are the Terrestrial Poles of the Line of the Observer? When the Line of the Observer is extended to the Heavens, what are there its extremities or Poles? What is the Terrestrial Great Circle of the Line of the Observer? What the Celestial? What Hemispheres are the Earth and Heavens divided into by their Horizons?—8. How must we arrange the artificial Terrestrial Globe, to put the First Observer in the place where each fancies himself to be? Suppose, after putting a located Observer under the Meridian, you then turn the globe on its axis?

once turn that Observer out of his place, and leave the wooden Horizon a thing without meaning.

9. When we wish to understand the Earth's motion, as by turning once a day on her Axis, she presents her different sides successively to the Sun,—or when in her Planetary Orbit she revolves in space once a year around the Sun, then divesting ourselves of the notion of an absolute up and down, east and west, we must consider that ourself being first Observer,—these movable positions—Zenith, Nadir, and Horizon, will go with us wherever we go. A man may lose his fortune or his character, but his Zenith, and his Horizon—never.

10. Uranography (from the Greek words *Uranus*, the Heavens, and *grapho*, to describe) signifies a description of the Heavens. It constitutes that portion of Astronomy with which Geography is most intimately connected. We have already shown two systems under the head of Permanent and Movable Positions, the Axes of the two being the Earth's Axis, and the Observer's Line. *A third system* combines with these, as we bring in the study of Uranography, of which the Axis is the *Axis of the Ecliptic*, the Poles are *the Poles of the Ecliptic*, and the Great Circle is *the Ecliptic* itself. (*See Fig.* 1.)

11. This system refers to appearances produced by the annual motion of the Earth around the Sun, by means of which the Sun appears to move around the Earth once in a year, keeping the same invariable track through 12 of the Constellations. This track constitutes the first Great Circle of Uranography, and is the Ecliptic. *The Positions of this system are by nature Permanent*, and will be understood by studying them on the Celestial Globe. The Axis of the Ecliptic makes, with the Axis of the Earth's Sphere, an angle of $23\frac{1}{2}°$, and of course

9. In what cases must we seek to divest ourselves of the idea of an absolute up and down, east and west?—10. What is Uranography? What two systems have been mentioned? What third system is here introduced?—11. To what does the third system refer? What angle does its Axis make with the Earth's? What angle is made by the two Great Circles? Where are the Polar Circles and the Tropics drawn? What may each of the three systems be called? Of which two are the Positions Permanent?

the Great Circles of these two Axes, the Ecliptic and Equinoctial, cross each other at the same angle. Through the Terrestrial Poles of the Ecliptic are drawn *the Polar Circles*, parallel also to the Equator. Touching the Ecliptic at its greatest distance from the Equator, are drawn the two Circles called *the Tropics*. . . . Of the three systems, the first, having for its primary element the Earth's Axis, may be called the *System of the Earth;* the second, having for its starting point the Upper Vertex, may be called the *System of the Observer;* and the third, having for its first element the Sun's track in the Heavens, may be called, in reference to the two former, the *System of the Heavens*. The Positions of the first and third are Permanent; of the second, Movable.

12. A subject of the first importance to Geography is Terrestrial LATITUDE. Circles of Latitude are Permanent Positions. The Latitude of any place on the Earth's surface is its distance from the Equator, reckoned in degrees on some *Secondary* to that Great Circle; that is, on *some other Great Circle which cuts it at right angles and passes through its Poles*. On the artificial Globe the brass ring, or Brazen Meridian, is that Secondary of the Equator on which we reckon Latitude. All places between the Equator and the North Pole are in *North Latitude*, and all between the Equator and the South Pole in *South Latitude*. The number of degrees and minutes mentioned, determines the distance of the place North or South from the Equator. A degree of any Great Circle on the Earth is equal to 60 Geographical, or about 69 English miles. The degrees of Latitude on the Globe are marked on the Brazen Meridian, its degrees being for convenience numbered, on one of its sides, from the Equator to the Poles, and on the other from the Poles to the Equator. To find the Latitude of any place on the Globe, bring the place to the Brazen Meridian, and the number above will show.

13. The word MERIDIAN is from the Latin *Meredies*, mid-day. The most simple idea of a *Meridian*, or *noon-*

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12. What is Latitude? When North or South? To what is a degree of any Great Circle on the Earth equal?

line, is such a line as would coincide precisely at noon with a shadow projected at the place of some Observer, by a perpendicular rod. Suppose such a Meridian-line to be extended North and South until its extremities pass into each Pole, the Circle thus produced would be the TERRESTRIAL MERIDIAN of that Observer. If its plane be extended to the Heavens, it is there his CELESTIAL MERIDIAN. His Zenith is in the upper point of this Celestial Meridian, and his Nadir in the lowest point of the opposite Semicircle. The Meridian, considered as a Circle, divides both Spheres into *Eastern and Western Hemispheres.*

14. The *Longitude of any place is the distance of its Meridian from some other fixed Meridian, measured in degrees and minutes on the Equator.* The Meridian of any observer is not a permanent position, like the Equator; nor is it so entirely movable as the Horizon, since it must always remain a Secondary of the Equator. It therefore belongs not wholly to either of our two classes of definitions, but in part to both. A Meridian may coincide with *a line or semicircle of Longitude*, and it may be used as an *Hour Circle.* When some one Meridian is by common consent adopted as the first Meridian, and a system of semicircles of longitude accordingly made out, and, with parallels of latitude, placed on maps and globes, longitude is then to be regarded as equally permanent with latitude,—the Equator being connected with both. Circles of Latitude are its parallels, and of Longitude its secondaries,—and both, *accessories to the Earth's system.*

15. The *Angle of the Latitude* of any First Observer, or of his place of residence (which is the same thing), is the angle made at the centre of the Earth, by the Line of

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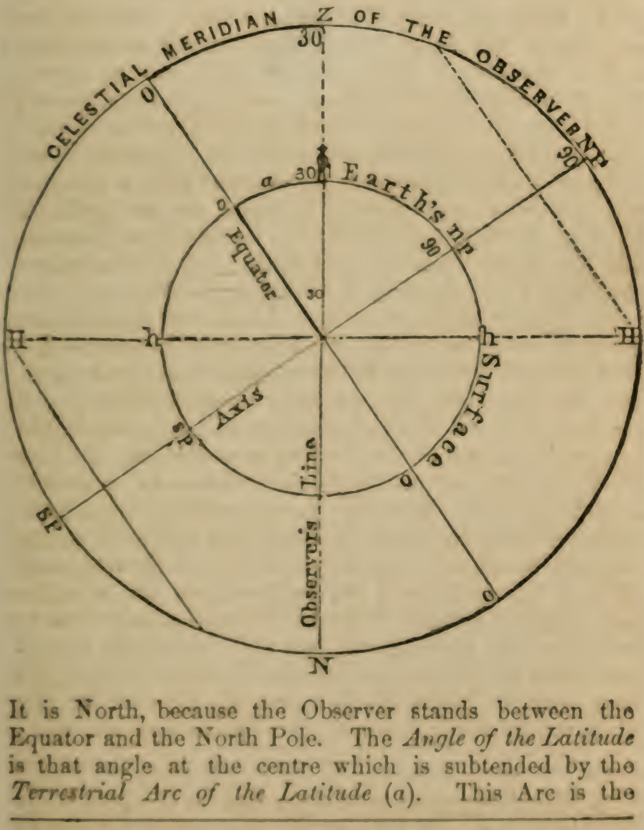
13. What is the most simple idea of a Meridian? How may a noon-line be extended to form the Observer's Terrestrial Meridian? his Celestial Meridian? Where are the Zenith and the Nadir? Into what Hemispheres does the Meridian divide both the Spheres?—14. What is Longitude? Does the Meridian belong to the Permanent or the Movable Positions? For what may a Meridian be used? In what case do Meridians belong wholly to the Permanent Positions?—15. (*Draw and explain the figure.*) What is the angle of any Observer's Latitude?

that Observer, with the line of the intersection of the Equator's plane with that of the Observer's Meridian. The Arc of the Latitude is that Arc of the Meridian intercepted between these two lines. And that Arc will have the same number of degrees, whether it be taken on the Terrestrial or the Celestial Sphere. In the accompanying figure the Latitude of the Observer is 30° North.

Fig. 8.



It is North, because the Observer stands between the Equator and the North Pole. The *Angle of the Latitude* is that angle at the centre which is subtended by the *Terrestrial Arc of the Latitude* (*a*). This Arc is the

15. What is the arc of Latitude in each Sphere?

part of the Earth's surface between the Observer and the Equator. The *Celestial Arc of the Latitude* is the Concentric Arc on the Meridian intercepted between the Line of the Observer and the Equinoctial. It subtends and is measured by the same angle as the Terrestrial Arc, and is likewise an Arc of 30°. In this figure there are eight angles at the centre; of which four are equal to the Observer's Latitude, and the four alternates are equal to the complement of his Latitude (what it lacks of 90°), or (which is the same thing) to his *co-latitude.* So that the elevation of the nearer Pole is always equal to the Latitude of the place. In the same way it may be shown that the elevation of the Equator is always equal to the co-latitude of a place. And since opposite Vertical Angles are equal, the depressed Pole is below the Horizon just as many degrees as the elevated Pole is above—viz., 30°—and its depression is equal to the Latitude. Thus, of the eight angles at the centre in this figure, four are of 30° equal to the Latitude, and the four alternates are of 60° equal to the co-latitude.

16. If our Observer had been located at the Equator, the Equinoctial would in that case have passed directly over his head from East to West; but if he moved North 20°, the place over his own head always appearing uppermost, and his Horizon moving as he moves, it has appeared to him that the Heavens moved South, and that the Equinoctial and all the heavenly bodies had gone 20° in that direction. And the Northern Polar Star, which, while he lived under the Equator, was in his Northern Horizon, would, for every degree which his Horizon went below it, apparently rise one degree above. So, when he had advanced 20°, the Equinoctial would seem to him to have gone 20° to the South, and the North Polar Star to have risen 20° above his Northern Horizon. That is, the Permanent Positions, the Pole and the Equator, remain, while the Movable Positions, the Zenith and the Hori-

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15. What is the complement of the Latitude of any Observer, or his co-latitude? To what are the eight angles of the centre equal?—16. Suppose the Observer located at the Equator?

zon, change with the changing place of the Observer, while to him it seems the reverse.

17. All maps are made by learning the situations of coasts, rivers, mountains, &c., in respect to Latitude and Longitude, and then putting them down in their proper places. The mariner, in order to reach a certain place, must first know where it is; and he must, when on the trackless ocean, know exactly from day to day where in Latitude and Longitude he himself is: else how could he know in what direction to steer his course? The most simple of the several methods by which observations on the heavenly bodies enable a mariner, or a geographer, to find his Latitude, is that of measuring the altitude of the Polar Star. That, as we have seen, is always equal to the Observer's Latitude. . . Since on the days of the Equinoxes the Sun describes the Equinoctial Line on the face of the Heavens, if his altitude, as he comes to the Meridian, is measured, his distance from the Zenith will be that arc of the Observer's Meridian which designates the distance of his Zenith from the Equinoctial, which is the arc of his Latitude; and the arc of the Meridian intercepted between the Sun's place and the point South, is what his Latitude lacks of 90°—that is, it is his co-latitude.

EXERCISES.

In the preceding Chapter we have seen that there are three Spherical Systems—1st, that of the Earth; 2d, that of the Heavens; and 3d, that of the Observer—which are comprised in the science of Astronomical Geography. Look now to the Heavens, and rectify the Celestial Globe so that it may aid you. Elevate its North Pole a number of degrees equal to your latitude, and if the evening is cloudless and you can see the Dipper, make its place on the Globe the same as in the Heavens,—with respect to the North Pole, the Meridian, and the Horizon; and then the whole Heavens will be truly represented by the

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17. To what practical uses are these principles subservient, both as regards Navigation and the science of Geography? What appears to be the simplest method of finding the Latitude of any place? Could it be found by taking the Sun's altitude?

Globe, and every Circle and Constellation will be in its proper place. Hereafter you may learn a more exact and scientific mode of elevating the Celestial Globe to represent the visible Heavens at any specified place and hour; but this will answer for the present purpose.

Since the two Spheres, Celestial and Terrestrial, are concentric, and the Earth's is in their common centre, every Diameter of the Earth may be supposed to be extended, and thus to become an Axis of the Heavens, and to have its Celestial as well as Terrestrial Poles; and an Axis which has thus its Poles in the Heavens must of necessity pass through the centre of the Earth; but since only one—*i. e.*, the Upper—Hemisphere, is visible to us, we can see only one Pole of each of our three Systems. But if we can see the place of one Celestial Pole in the sky, we shall know the direction of the Axis with which it connected, and learn by degrees how to find that part of its Great Circle which is within the visible Heavens. Seeing the place of the Pole, we shall know the direction of the Axis, because it is by definition a straight line from the Pole through the centre of the Earth.

The Celestial Pole of the System of the Earth is at the North Star. If you stretch out your right arm directly towards it, your left directly opposite, your two arms will be in the line of this Axis, and your two hands will point to the North and South Poles.

We will next take the System of the Observer, because this is easier understood than the System of the Heavens. The Celestial Pole—yourself being First Observer—is over your head, and called the Zenith. The Axis of the Observer, or Movable Positions, is the line which includes your own person, and passes downwards through the centre of the Earth.

The Axis of the System of the Heavens, of which the Ecliptic is the Great Circle, is of course perpendicular to the plane of that Great Circle. It makes an angle with the Earth's Axis of 23½ degrees, and the place of the North Pole of this System, the only one ever visible to us, will be found on the Celestial Globe in the Constellation *Draco*, the Dragon, at the point where the Winter half of the Solstitial Colure cuts the Arctic Circle. As no very bright star is near the North Ecliptic Pole, it is not easy to learn its *exact* place when you look at the Heavens with the naked eye. But you can attain a good idea of its position by considering that the Solstitial Colure intersects the Equinoctial Colure (whose position you know) at the North Pole of the Heavens; or simply the North Pole. The Ecliptic Pole is nearer to the North Pole by 7° than either *Megrez* or *Caph*, and it is towards the same part of the Heavens as is the bright star Lyra. It is of great importance that you make yourself familiar with the Ecliptic Poles and Axis. Point towards its Poles, and your arms will be in the line of its Axis.

On the Terrestrial Globe, learn the two Polar Circles. What is each called? What is their distance in degrees from the Equator? What oceans does each pass through? what continents? what countries? What difference is there between the two Polar Circles in regard to the quantity of land and water through which each passes?

CHAPTER V.

The Nature of the Sphere resumed.—Vertical Circles.—Points of the Compass.—North and South.—The Prime Vertical not an East and West Line, except at the Equator.—Definitions.

1. The original idea of a Sphere, as given by mathematicians, is, that it is a figure generated by revolving a semicircle about its diameter, which thus becomes an Axis. From this definition it is evident, that the whole surface of a Sphere may be regarded as a series of semicircles;—that any two of these on opposite sides of the Axis so meeting as to be in one and the same plane, the circumference of that plane constitutes a complete Circle,—and that this Circle will be a Great Circle of the Sphere: and hence, that there may be formed a system of Great Circles of any desired number, having a common Axis, and meeting in its Poles.

2. Such are all Vertical Circles, the Terrestrial having the Line of the Observer as their common Axis, and meeting at its Poles—viz., the Upper and Lower Vertex—and the Celestial having for their Axis the same Line of the Observer, extended to the Heavens, and meeting at its Celestial Poles, the Zenith and the Nadir.

Chapter V.—1. What is the original idea of a Sphere? What is evident from this definition?—2. What is the common Axis of all Vertical Circles? What are the two Poles of all Terrestrial Vertical Circles? What of Celestial Vertical Circles? (*Draw on the blackboard a system of Vertical Circles.*) Do Vertical Circles belong to the Permanent or Movable Positions? How does this appear?

3. The Line of the Observer and the Upper and Lower Vertex being the Axis and Poles of Movable Positions, to these, therefore, belong all Vertical Circles, the *Prime Vertical* being that which passes through the points East and West. The *Great Circle of this Axis*, is the HORIZON; any other Great Circle cutting this at right angles and passing through its Poles, is its Secondary. *Every Vertical Circle is, therefore, a Secondary to the Horizon.*

4. Vertical Circles are of importance in the Celestial Sphere, as upon them is measured the position, which every heavenly body occupies, with respect to the First Observer. When the Zenith, Nadir, Horizon, Vertical Circle, &c., are mentioned, the place of an Observer expressed or understood is always presupposed.

5. The ALTITUDE *of a Heavenly Body is its number of degrees from the Horizon, measured by an arc of a Vertical Circle.* The ZENITH DISTANCE is the complement of the Arc of Altitude. The *Angles of Altitude and of Zenith Distance*, are at the common centre of the two Spheres, and measured on arcs of Vertical Circles. The AZIMUTH of the body, must also be ascertained before its exact position at any specified time and place can be known. For if merely its altitude is mentioned, its position might be anywhere on a Circle of the same altitude parallel to the Horizon. The Azimuth decides where on such a Circle the body is; it being the measure of its distance from the points North and South, either as taken on the Horizon from the Vertical Circle which passes through the heavenly body, or measured on any parallel to the Horizon in which it is found. The AMPLITUDE of a heavenly body is the number of degrees of its rising and setting from the points East and West.

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3. What on the Earth and in the Heavens is the Great Circle of the Axis of Movable Positions? What are Vertical Circles in respect to the Horizon, and why?—4. Why are Vertical Circles of importance in Astronomy? In what cases are we to remember that the location of a First Observer is presupposed?—5. What is the Altitude of a heavenly body? its Zenith distance? What is said of the Angles of Altitude and Zenith distance? What is the Azimuth of a heavenly body? the Amplitude?

6. These definitions all belong to the Movable Positions; since without a supposed located Observer they have no significancy. *General remarks* may, however, apply to any observer situated on a certain parallel of latitude or longitude. . . . To show the reality of the distinction made between Permanent and Movable Positions, compare the terms *latitude* and *altitude.* Fifty degrees of latitude, is the *positive* expression of a certain distance from a known, natural, determinate, and unchangeable position; but fifty degrees of altitude—what is it? Why, it is fifty degrees above the Horizon. But what is the Horizon? Nothing, without an Observer. The place of the Observer, or Upper Vertex, is its first element on the Earth, and the Zenith of the Observer its first element in the Heavens. Then since Altitude is nothing without the Horizon, and the Horizon is nothing without an Observer—Altitude and other similar terms are nullities, except as they relate to the located Observer.

7. There are four CARDINAL POINTS of the Compass, East, West, North, and South, marked E. W. N. S. on the accompanying diagram (*see Fig.* 9). They are placed on the wooden Horizon of both Globes, each being divided into four equal arcs of 90°. They are subdivided by the points Northeast, Northwest, Southeast, Southwest, making arcs of 45° with the Cardinal Points. These arcs are subdivided into two equal arcs of 22½° each, by the points North-northeast, East-northeast, East-southeast, and so on, as may be seen by the Globes, or the diagram (*Fig.* 9).

8. These 16 points (*see Fig.* 9), taken together, divide the circle of the Horizon into 16 equal parts of 22½° each. The *Mariner's Compass* is an instrument, adjusted to guide the mariner on the deep—having suspended on a

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6. To what do the preceding definitions belong, and why? For what purpose, and how are Altitude and Latitude compared?—7. What are the Cardinal Points of the Compass? What is the first subdivision? the second?—8. Into how many parts do these divide the Horizon? What is the Magnetic Needle? the Mariner's Compass?

Fig. 9.—Points of the Compass. Terrestrial, Vertical Circles, and Almacantars.

pivot within it the MAGNETIC NEEDLE—a piece of magnetized iron always pointing to the North Pole. The compass has each of the arcs of $22\frac{1}{2}°$ subdivided, and hence instead of 16, it has 32 points. Our artificial Globes have upon the inner rim of the Horizon, the same division of 32 points of the Compass. But, Geographical and Astronomical descriptions seldom need greater exactness than may be obtained by 16 points.

9. Concerning the Points of the Compass, no little confusion exists in books and definitions. To see clearly the nature of the difficulty, let the Terrestrial Globe be rectified, say for New York. What from that city is the farthest

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8. Where may you find 32 points of the Compass?

point which is due North? If you answer me from the definitions of almost any book of Astronomical Geography, or even from Webster's Dictionary, you will say, that it is the place where the Meridian of the Observer at New York cuts his northern Horizon at 90° distance. Examine the Globe and see if this is so. What do you find in the place thus described? It is the country between Siberia and Mongolia, near to the lake Baikal; the nearest city of which to the point named, is Irkutsk. Here, then, is the question, is Irkutsk due North from New York? If balloons were so improved that a traveller could go 90° on the North and South Vertical Circle, through the North Pole to Irkutsk, would his whole course be North in going to that place?

10. This brings forward another question to be first answered. Is there to any Observer on the Earth, a place farther North than the North Pole? for if you say that going a due North course would carry the traveller the whole distance from New York to Irkutsk, then you assert, that to every person in North Latitude, there is (since Latitude equals the elevation of the Pole) a point North of the North Pole by a number of degrees, equal to his Latitude; and of course to all those in South Latitude, there is a point, the same distance South of the South Pole. But this is absurd. The Poles of the Earth are its extreme North and South points. For, the Meridian of every Observer in North Latitude is by definition South towards the Sun at noon, and North in the opposite direction, and the reverse to all those in South Latitude. And as this is the case with every Meridian on the Earth;—it is as much so with that of Irkutsk, as with that of New York. The North Pole is, then, the extreme North point of the Earth; and it follows, that if, in a balloon or any other way, any person could go direct from

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9. What is the farthest point which is due North from New York? How does your author state the question?—10. What further question is thus brought forward? If we should say that a person might travel North all the way from New York to Irkutsk, to what absurd conclusion would it lead? What are, then, the Earth's extreme North and South points?

New York to Irkutsk, his course would be North only until he arrived at the Pole, and thence from the Pole to Irkutsk it would be South.

11. Nor is it merely with respect to the points North and South, that definitions disagree with facts; for in no case, except when the Observer is located on the Equator, will the places on his Terrestrial Prime Vertical, as it descends to his Rational Horizon, be in reality East and West from his position. If he lives on the Equator, the plane of his Prime Vertical will coincide with that Great Circle, and all the places upon it will keep an equal distance from each Pole; and no line can be an East and West line, unless all the places upon it are. For the Poles are the extremes of North and South, and all Meridians are North and South lines; and hence no line can be an East and West line which does not cross every Meridian at right angles, and at equal distances from both Poles. No lines but the Equator and its parallels of latitude do this; and as no parallel of latitude is a Great Circle, and the Equator is, it follows that the Prime Vertical of no Observer on the Earth can coincide with an East and West line, except the inhabitant of the Equator. It follows, also, that all lines of latitude are due East and West courses.

12. For illustration, we will place the Observer of New York at the Upper Vertex, and see where his Prime Vertical will cut his Rational Horizon. Of course it will be at the intersection of the Equator with the Horizon; for that is always the point East, whichever Pole you elevate, and for whatever latitude. Here we find Lower Guinea, an equatorial country, which no one will say is in an East course from New York. On the contrary, all must

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10. How, then, is the question to be decided concerning the Point of Compass followed in going on a direct line from New York to Irkutsk?—11. In what case will the Observer's Prime Vertical indicate, as it descends to his Rational Horizon, a true East and West course? How may it be proved, that but in one case will the Prime Vertical show (at the distance of the Rational Horizon) a true East and West direction? What, besides the Equator, are due East and West lines?—12. What illustration is given?

see that it cannot be so, since the Vertical Circle, which is the direct course from New York to that place, cuts all the Meridians, which it passes at oblique angles, going farther and farther from the North Pole, until at the Horizon its distance has increased 40°, a number just equal to the latitude of New York.

13. A direct line, or the shortest distance between any two places on a Globe, is by definition, an arc of a Great Circle. Since lines of latitude are never Great Circles, it follows, then, that a due East and West course between places on the same latitude is not the shortest, except on the Equator. The greater the distance from the Equator, the more that navigator would lose by making needless way, who should follow a line of latitude to reach a distant place upon the same parallel.

14. To make this clear, observe where the line of W. Latitude 40° crosses the Pacific Ocean between America and the islands of Asia. Take the quadrant of altitude and lay it from the extreme points direct from coast to coast, and you see at once what a bend the navigator must make, and how much way he must lose, should he sail from one of these points to the other on the line of latitude 40°. If you take in, the same number of miles nearer the Equator, the difference will be less; if nearer the Pole, greater.

15. Since all lines of longitude are arcs of Great Circles, the shortest distance between any two places North and South will be found by keeping on the same Meridian. The line on which the navigator sails, between any two places oblique to the Cardinal Points, is called a *Rhumb Line*.

16. The principle, that on a Globe, the shortest distance between any two places lies in an arc of a Great Circle, is useful to the student of Astronomical Geography as well as to the navigator, and the simplest plan in our

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13. What is the shortest distance between any two places? When may a due East and West line be the shortest course, and when not?—14. Show a case upon the Globe which will illustrate the principle.—15. What is said of keeping a due North or South course? What is the navigator's oblique line called?

case, and perhaps in that of the navigator, might be, to make an arc of a Vertical Circle, by putting one of the places in the Upper Vertex, and by carrying the quadrant of altitude from the Zenith to the Horizon, so as to intercept the other. The number of degrees' distance will be shown by the intercepted arc, which, multiplied by 69, will show the number of English miles.*

17. Vertical Circles would, if the Earth were a plane stretched out like a map on Mercator's projection, truly indicate the points of Compass in every latitude; *and so far as the Observer's Sensible Horizon is a plane tangent to the earth*, so far, and no farther, *will Vertical Circles truly indicate all his points of Compass on its surface.*

18. In the light of this subject we see the indispensable necessity of distinguishing the Permanent from the Movable Positions. Especially must this distinction be borne in mind as we look at night upon the Northern Heavens. There the two systems are almost entirely distinct; and indeed, as we have seen, in one case they are opposite: the same line, which referred to the Movable System is North, being found, as regards the Permanent, to be South.

EXERCISES.

The Axes and Poles of our three Systems being determined, let us now look to the visible heavens, and see what there we can find respecting their three Great Circles. And here our subject, so perfectly simple in the beginning, begins to grow somewhat complicated. For we are to consider, not only that each of these three Great Circles has the centre of its plane cut at right angles by its Axis, and that each is ever at 90° distance from its Poles, but, furthermore, how they intersect each other. The centre of the Earth is the common centre of the three. The connection of the System of the Earth with that of the Observer is regulated by the Observer's latitude, and is therefore

* The number is expressly sanctioned by Sir John Herschel.

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16. What is the best method of measuring places on the artificial Globe?—17. In what supposed case would Vertical Circles truly represent the points of Compass? In what real case do they rightly indicate those points?—18. What are the concluding remarks of the chapter?

not determinate. In the connection of the two other Systems with each other, both being Systems of Permanent Positions, they are regulated by the unvarying angle of inclination of the two Axes, which is 23½°. The two Great Circles, the Ecliptic and Equinoctial, of course intersect at the same angle. This angle is measured by a Great Circle of the Sphere, which, of all the Circles drawn upon the Celestial Globe, is the only one which is a common Secondary to both the Ecliptic and the Equinoctial. It is called the *Solstitial Colure*. It passes through both the Poles of the Earth and the Poles of the Ecliptic, and cuts both the Circles at the two opposite points where their distance from each other is the greatest.

We will again refer to our stars in the North, since they are the constant companions of our nights. We will, for convenience of language, divide the Circle of the two Colures each into two semicircles. The one passing through the *Summer Solstitial Point* (a visible Point in *Space* where the Sun appears at the *Time* of the Summer Solstice) we will call the Summer Colure, and the opposite, which passes through the *Winter Solstitial Point*, we will call the Winter Colure. The four Points where the Colures cut the Ecliptic are the *four Cardinal Points* of that Circle. They are each important locations, but the *Vernal Equinoctial Point* is that one of the four whose position should be first and most thoroughly impressed upon our minds. The Vernal half of the Equinoctial Colure passes through it. It is at the first degree of the *sign* Aries, but, as will be hereafter explained, in the *constellation* Pisces, 30° in the rear. It is on that half of the Colure through which *Caph* passes, and is twice as many degrees from Caph, as Caph is from the Pole.

Endeavor to identify the Constellation Pisces in the Heavens, as in it, is the VERNAL EQUINOCTIAL POINT. There are no remarkable stars in Pisces, but in the head of the Ram, *Aries*, the next Constellation in advance, there are two stars of the second magnitude, *Arietis* and *Mesartin*, which we may learn to distinguish. The next Constellation, Taurus, the Bull, is known to all, by the *Pleiades*, or Seven Stars. Another group in it is called the *Hyades;* and it contains the great star, *Aldebaran.*

On the Terrestrial Globe learn to give a general account of the Oceans and Continents, Seas, Great Bays, Islands, and Countries of the TORRID ZONE.

CHAPTER VI.

EQUINOCTIAL POINTS IN SPACE.—EQUINOXES IN TIME.—DEFINITIONS.—EARTH, DIURNAL ROTATION.

1. THE VERNAL EQUINOCTIAL POINT is of paramount importance. As we shall have frequent occasion to mention it, as also its opposite, the Autumnal Equinoctial Point, we shall sometimes abbreviate and call the first the Vernal Point, and the second the Autumnal Point; but we shall on no account call them Equinoxes, for there is an important distinction to be kept constantly in view: *the Equinoxes belong only to* TIME, *whereas the Equinoctial Points belong solely to* PLACE. They are the points where the Ecliptic intersects the Equinoctial Line, or Equinoctial—a name by which astronomers distinguish the Equator of the Heavens. The time of the year when the Sun appears in these Points, is the Equinoxes. The time when he is in the Vernal Point is the Vernal Equinox, and the time when he is in the Autumnal Point is the Autumnal Equinox; but the places, we repeat, where the Sun is at these times are the Equinoctial Points, and may be seen in the visible Heavens. Though these two Points thus far require a common definition, yet the Vernal Point, being that from which Celestial reckoning begins, is of superior importance. In Time, also, although the two Equinoxes are alike in respect, that when the Sun is in either, there is "equal night," yet the Vernal being at the beginning of the year, takes precedence of the Autumnal.

2. The DECLINATION *of a Heavenly Body is its dis-*

CHAPTER VI.—1. What one Point in the Heavens is of paramount importance? What distinction is there between Equinoxes and Equinoctial Points? Which Point in *Space* takes precedence, and why? Which Point in *Time* takes precedence, the Vernal Equinox or the Autumnal Equinox, and why?

tance North or South from the Equinoctial, measured on any Secondary—commonly the Vernal half of the Equinoctial Colure. This is essentially the same definition as Terrestrial Latitude, but in Astronomy *the Latitude of any Heavenly Body is its distance (not from the Equinoctial) but the* ECLIPTIC. The *Longitude of any Heavenly Body is its distance from that Secondary of the Ecliptic which passes through the first degree of Aries, measured on the Ecliptic.* When the distance from the same point —that is, the first of Aries—is measured on the Equinoctial, it is called *Right Ascension.* Both Longitude and Right Ascension are reckoned in the order of the signs from West to East, quite round to the same point—*i. e.*, from 0 to 360°. This point, so often mentioned as the first of Aries, is the same as the Vernal Equinoctial Point. This determinate and important point in Space is the place in the Ecliptic in which the Sun is seen on the 20th of March. The Astronomical year begins at the moment of noon on that day, it being the Vernal Equinox.

3. Young learners, finding not the same simplicity of measurement in the Celestial as in the Terrestrial Sphere, are naturally inclined to inquire why Latitude and Longitude, reckoned from the Equinoctial and from a fixed Secondary, might not have fully answered the purpose in Astronomy as well as in Geography. There are reasons why to the Astronomer the Ecliptic must be the circle from which to reckon distances in the Heavens; and of course if Celestial Latitude is reckoned from the Ecliptic, Celestial Longitude must be reckoned from a Secondary of the Ecliptic; and that one is chosen in which the Sun appears at the time when the Astronomical year begins.

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2. What is the Declination of a Heavenly Body? What definition of Geography is this essentially like? What is Celestial Longitude? What besides is reckoned from the same point? In what order is Longitude and Right Ascension reckoned? How far round the two Great Circles on which each is reckoned? What is further said of the Vernal Equinoctial Point and the Vernal Equinox?—3. What inquiry is here naturally suggested to the learner? What reply is made to this question?

4. But after Celestial Latitude and Longitude had been thus established, would not Declination and Right Ascension have been spared? We answer, they could not; for Astronomical Geography indispensably requires a Celestial measure answering to Geographical Latitude; and such is Declination. The necessity of this will be fully apparent as we proceed; and since this was necessary, a corresponding measure on a Secondary of the Equinoctial was of course necessary also. The first Secondary of the Equinoctial, which is that where the Sun is when the Astronomical year begins, is the Vernal Colure; and from that Right Ascension, answering to Terrestrial Longitude, as before stated, is reckoned.

5. But why, the student who reads without examining the Celestial Globe, may ask, why, since the Sun is at the commencement of the Astronomical year in the first Secondaries both of the Ecliptic and the Equinoctial, why are not these the same? and since Right Ascension and Celestial Longitude are both reckoned from the same Point (the Vernal Equinoctial Point) round the whole 360° to the same Point again, why are they not the same? Because, as the Ecliptic, with its principal Secondary the First of Aries, intersects at this Point the Equinoctial with its principal Secondary, the Vernal Colure; yet, going from this Point, these four Circles diverge—the two Primaries at an angle of 23½°, and the two Secondaries, of course, at the same angle. All Circles of Celestial Longitude being at right angles to the Ecliptic, meet in its Poles, and all Circles of Right Ascension being at right angles with the Equinoctial, meet in its Poles—*i. e.*, the Poles of the Earth. No Circle of Celestial Longitude is coincident with Right Ascension, except the Solstitial Colure.

6. Circles imagined to be drawn around the Observer's place, as a centre, are called ALMACANTAR CIRCLES. The

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4. What query here concerns Declination and Right Ascension? How is this query answered?—5. Examine the Celestial Globe, and explain in what respect Celestial Longitude and Right Ascension are alike, and in what respects they differ?—6. What is said of Almacantar Circles, both Terrestrial and Celestial?

Upper Vertex is, therefore, the Centre or Pole of Terrestrial Almacantars, as is the Zenith of the Celestial. They belong, of course, to the Movable Positions. They are sometimes called Azimuth Circles, and Circles of Altitude. By this designation they belong solely to the Celestial Sphere; but we shall take the liberty to transfer them, by the name of Almacantars, or Almacantar Circles, to the Terrestrial Sphere, as we there need them in an important Geographical problem. They have heretofore been used only to measure the Heavens in degrees; but we intend to use them for the practical purpose of measuring the Earth in miles.

7. Having in view this design, we are especially desirous that our learners should fully understand these Circles. If we should fancy an immense pair of compasses to have one foot placed at the Zenith, and the other revolved, taking in 30° of any Vertical Circle, a Celestial Almacantar Circle would be produced, cutting every possible Vertical Circle at 30° from the Zenith, and of course 60° from the Horizon. If the compasses, then, sweep another Circle with 60°, a second Almacantar Circle would be formed, cutting all Vertical Circles at 60° from the Zenith, and of course at 30° from the Horizon. Every heavenly body on the first drawn Circle would have 60° of *Altitude* and 30° of *Zenith Distance*, and all those on the second would have 30° of Altitude and 60° of Zenith Distance.

8. Again: suppose these great compasses, or dividers, brought down to the size of the Earth, and the stationary foot being placed at the Upper Vertex, two imaginary circles should be drawn, dividing the system of Terrestrial Vertical Circles in the same manner at 30° and 60°. Then these, with the Horizon, would make three equal gradations of distance from the Observer.

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6. To which of the Positions, Permanent or Movable, do they belong? What other appellations are used respecting them? What use does the author design to make of Terrestrial Almacantars?—7. What supposition is made still further to illustrate Almacantar Circles, beginning with those of the Heavens?—8. Make a similar supposition to illustrate Terrestrial Almacantars?

9. In Astronomy, the points East and West refer to the order of the Twelve Signs of the Ecliptic, which are numbered from West to East. This is the course of the Earth in her orbit, and of the Sun in the Ecliptic. If any heavenly body moves in this direction, its course is said to be *direct;* if it does not move, *stationary;* if it moves contrary to the order of the Signs, *retrograde.* But, says the young student, do I not see all the Heavenly Bodies moving every day from East to West? Are *their* motions retrograde? If not, what are? No; their motions are not all retrograde. Unless they are moving with respect to each other, they are regarded as eternally at rest. Thus with respect to the fixed stars, notwithstanding they *appear* with the whole Heavens to revolve once in 24 hours about the Earth from East to West. Their apparent Western course is caused by the real motion of the Earth on its Axis in the contrary direction. But it is the motion of the bodies of the Solar System, regarded in reference to the fixed stars, to which the terms, direct, stationary, and retrograde, are applied.

10. The motions of those Planets whose Orbits are exterior to that of the Earth, and which are therefore called the Exterior Planets, are always direct. That of the Interior Planets, Mercury and Venus, would always appear direct if seen from the *heliocentric* position—that is, from the Sun; but when seen from the *geocentric* position—that is, from the Earth—they are direct only when the Planets are beyond the Sun. When moving between the Earth and the Sun, their motion is retrograde; and when either advancing or retreating they are on the sides of

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6. What is to be understood by the terms East and West, as used in Astronomy? Explain the terms direct, stationary, and retrograde. What inquiries may here present themselves to a young student? What reply does your author make?—10. What is here said concerning the motions of the Exterior Planets and of the Interior Planets? What position would a fancied Observer, standing on the Sun, be said to occupy? What position is that of the Observer on the Earth said to be? (In Greek, *Helios* is the Sun, and *ge* the Earth.)

their Orbits where tangents from the Earth would meet them, they appear for a time *stationary*.

11. By the Earth's diurnal motion, the extended plane of the Horizon of each Observer is constantly moving forward in the order of the Signs from East to West, and Man, the Observer, supposes, in the mean time, that the whole Universe is moving in an opposite direction. He no more apprehends the truth, that the Sun is stationary, and he is moving, than does some child, upon a fast-sailing vessel, at night, that the object which flies so swiftly past him, is in reality a light-house on the shore. Were there a thousand light-houses, the illusion would but be increased by the dazzling brightness of the objects. And so with Man. Not only does the Sun fly past him, but the Moon and all the Stars.

12. To obtain, by the use of the Terrestrial Globe and a stationary lamp, a distinct view of the manner in which we are affected by a diurnal revolution of the Earth, we should not merely wheel the Globe about its Axis within the Horizon, but we should, after choosing the location of ourselves as First Observers, and bringing our place to the Upper Vertex, revolve the Globe *with* its frame, so as to keep ourselves in the same relative position with regard to the Horizon during the whole revolution. Our place will thus continue to appear to us the Upper Vertex,—our Horizon being everywhere 90° distant.

13. Let us fancy our position to be somewhere on the Equator, and suppose our time to be six o'clock in the MORNING. (*See Fig.* 10.) The Sun's disk is now cut by our Eastern Horizon, and thus he appears to us to be rising as we begin our diurnal revolution. As the Earth moves, it carries us towards the East, making the whole Celestial Sphere appear to move, as if it revolved on the same Axis as the Earth, but in a contrary direction. Hence,

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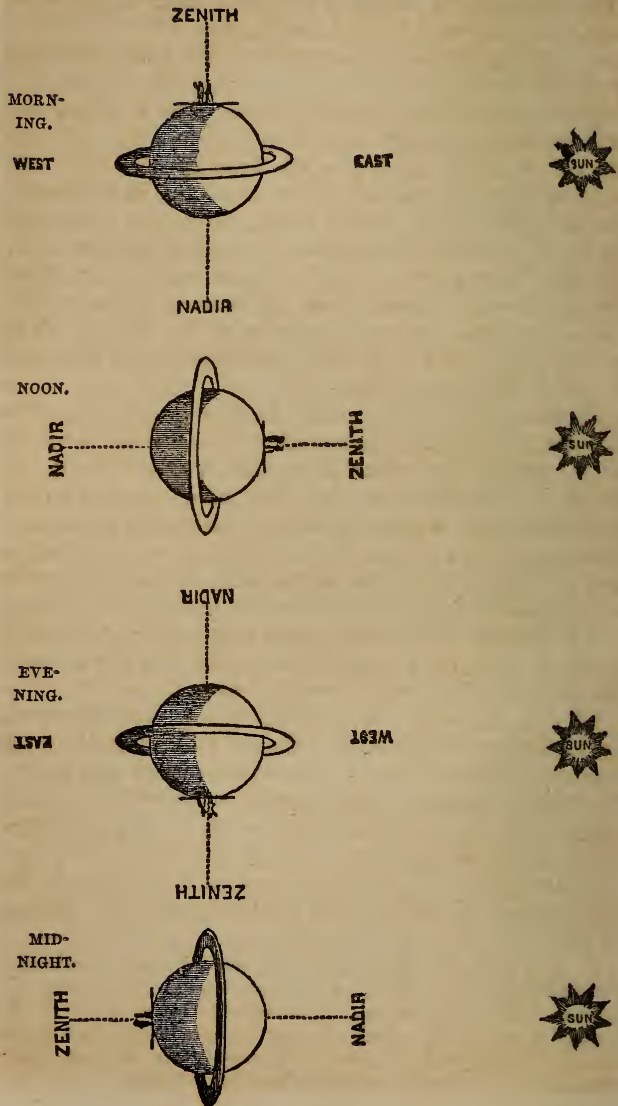
11. How is the fact illustrated, that the Sun being stationary, yet appears to the Observer to move?—12. How should we proceed in obtaining an idea from the Terrestrial Globe of the manner in which we are affected by a diurnal revolution of the Earth?—13. Draw on the blackboard, from *Fig.* 10 the representation of "Morning," and describe from the text.

Fig. 10.—Diurnal Rotation.



while the artificial Terrestrial Globe has its true motion round its Axis from West to East, the artificial Celestial Globe should be turned, as the Heavens *appear to move* from East to West.

14. And as we have moved from West to East, how will our Horizon have *appeared* to move with regard to the Sun? As we move towards the Sun in going to the East, our Horizon—keeping always at 90° distant from us —will sink beneath;—that glorious body always keeping the same place—so that when we have moved an hour, the Sun will be an hour high, and our time will be seven o'clock in the morning. When we have moved two hours, the Sun will be two hours above our Horizon; or, rather, that will have sunk two hours beneath it, and our time will be eight o'clock, A. M.* When we have moved six hours, we shall have gone through one quarter of our Circle of daily motion, and the Sun will have appeared to move the same part of his circuit through the Heavens; our Horizon in the East having proceeded 90° from him, and that in the West having advanced 90° towards him, he is now in our Zenith, and it is NOON; and we being under the Equator, are in the very centre of the blaze of day.

15. But the Earth still keeps turning on her Axis. No moment of idleness ever overtakes her. As we move, our Western Horizon comes nearer, and our Eastern goes farther from the Sun, while he appears to us to be going in a contrary direction, and declining towards the West. At the end of three hours, it is three o'clock, P. M. At the end of six hours, another quarter of a Circle is completed, and our Western Horizon now cuts the Sun's disk. He is setting, and it is EVENING.

16. But since our Zenith, our Sensible Terrestrial Horizon, and our Rational Celestial Horizon, have all gone

* A. M., *Ante-Meridian—i. e.*, before Noon; P. M., *Post-Meridian*, after Noon.

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14. In the same manner draw the figure and describe the change from Morning to Noon.—15. Draw and describe in like manner the change from Noon to Evening.

with us—since our feet have been always downwards towards the centre of the Earth, and our heads always upwards from that centre—we have not naturally the idea that we have moved at all; but while in reality we have been going East from the Sun, the Sun seems to have moved West from us. From sundown to MIDNIGHT we have moved through another quarter of our daily Circle. Our heads pointed successively, as we moved, towards various constellations of beautiful stars. When our clock, which still to our view keeps its upright position, shall strike twelve, our heads will point in a direction the opposite of that in which they were at noon, but our Zenith has still kept over our heads, and our Horizon been around us. We are still attracted to the earth, just as we were then, and are not sensible that we have moved at all; but we have only fancied that since Noon the Sun has declined from the Zenith to the Western Horizon, and the stars moved from the Eastern Horizon 90° to the Meridian.

17. From Midnight to MORNING we now move during another six hours; but we still occupy the Observer's place in the vertex of the Upper Hemisphere, and we fancy, as we are turning towards the Sun, that the stars of the Zenith are descending towards their setting in the West. As the Eastern edge of the Horizon is turning towards the bright "Eye of the World," we begin to enjoy his warmth and dawning light; the mountain tops are illumined, and at length, at six o'clock in the morning, we behold

"The Powerful king of day, rejoicing in the East."

18. We are now at the same point at which we began our diurnal revolution. Having been on the Equator, we have moved nearly 25,000 miles,—the greatest measure of the Earth's circumference. But since we have changed neither our place on the Earth, nor our Zenith, we have

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16. From Evening to Midnight.—17. From Midnight to Morning again.—18. How many miles must we, as Observers, have moved in a day? Why, in making this Circuit, have we been insensible to any motion of our own?

ever kept our conceit that the middle of the Earth is where we are, and the top of the Heavens directly over our own heads. We have not been sensible that we have moved, although we have gone more than a thousand miles an hour; but we have fancied that the Sun and stars have all been occupied with making immense circuits for our especial benefit, and to save our little Earth the trouble of turning upon its axis.

EXERCISES.

It is our object, as fast as possible, to enable our pupils, as they look out upon the stars, to be able to locate them from observing the map of the real heavens, as they can a city, as they look upon the map of the world. An acquisition, so novel for a young person to make, and so delightfully preparing the way for future acquisitions in Astronomy, cannot be made at once; but if our learners will patiently follow our course, we hope to conduct them to this point.

In the methods of describing the positions of the heavenly bodies by latitude and longitude, reckoned from and on the Ecliptic and its half-secondary, the first of Aries, because the Ecliptic does not coincide with the Equinoctial, Celestial latitude and longitude do not, as we have seen, coincide with Terrestrial. But Declination and Right Ascension do, in the Celestial Sphere, coincide with Terrestrial latitude and longitude; being reckoned from and on the Equinoctial and its half-secondary, the Vernal Colure. Right Ascension differs from Longitude, in going from West to East, not half way only, but quite round the Circle.

It is to Declination and Right Ascension that we shall now give our attention. Let us remember, as we look out upon the starry heavens, that they inclose the "terrestrial ball" on which we stand. Extend your left hand northward and upward towards the North Pole (for the Astronomer looks to the East), and your right in the opposite direction, towards the South Pole, tending by as many degrees as your North Pole is above, to a point below your Horizon. Then conceive that the Equinoctial goes quite round the Earth, though only half of it can at once be seen above your Horizon.

Next endeavor to conceive of the four semicircular Colures, or two Circles secondary to the Equinoctial, and crossing each other at right angles in the Poles—each divided into two parts. Think how these Colures are making four spherical right angles at the North Pole, extending South and separating in four directions—

keeping, of course, 90° apart—crossing the Equinoctial at right angles—then beginning to converge until they meet at the South Pole, in the same manner as at the North. If you find this difficult from the mere examination of the Heavens, study the Celestial Globe.

You know that from the Equinoctial to the Pole is 90°, and you have begun to learn to measure distances in the Heavens by the eye. Then, knowing where are the Equinoctial and the Poles, you will more and more learn to decide by the eye about the degree of distance North or South from that Circle. This is understood as Declination. But for Right Ascension, study the four Colures. The one through which Caph passes has no Right Ascension; but it is that Meridian from which Right Ascension is reckoned. Then go a quarter round (90°) from West to East, and there is the Summer Colure, having 90° of Right Ascension. Then the Autumnal Colure, with 180°. Then comes the Winter Colure, 270°; and, lastly, the whole Circle is completed at the same Vernal Colure from which the reckoning begins. On the East side of this Colure is 0°; on the West side is 360°. With these Circles and numbers remembered, the intelligent student will be able to judge, with general correctness, of the Declination and Right Ascension of any heavenly body; and further exercises will improve him, whenever he pursues them, either on the Globe or on the face of the sky.

What is the Declination and Right Ascension of Megrez? of Arcturus? of Capella? of Procyon? of Sirius? of Spica Virginis? of Caph? of Cor Leonis, or the Lion's Heart?

On the Terrestrial Globe, study the Northern Temperate Zone. What portions or divisions of water, oceans, seas, bays, and gulfs, does it contain? What divisions of land, continents, countries, and islands, and what great cities, are in this Zone?

CHAPTER VII.

Signs of the Ecliptic.—Retrocession of the Equinoctial Points caused by the Precession of the Equinoxes.—Annual Revolution of the Earth in her Orbit.—Apparent Motion of the Sun in the Ecliptic illustrated by a Father's Expedient to teach his Son.

1. With the two systems, which we have denominated those of the Earth and the Observer, we have in connection, as we must recollect, a third, whose primary element being the Ecliptic, we have denominated it the

System of the Heavens. The names of the twelve Constellations of the Zodiac (a belt of 16° broad, through which the Sun passes in his apparent annual course), with the Signs appended which bear the same names, are contained in the following table:

The 1st Sign is ARIES, ♈, or the Ram; which Sign the Sun enters MARCH 20th.
The 2d Sign is Taurus, ♉, or the Bull; which Sign the Sun enters April 20th.
The third Sign is Gemini, ♊, the Twins; which Sign the Sun enters May 21st.
The fourth Sign is CANCER, ♋, the Crab; which Sign the Sun enters JUNE 21st.
The fifth Sign is Leo, ♌, the Lion; which Sign the Sun enters July 23d.
The sixth Sign is Virgo, ♍, the Virgin; which Sign the Sun enters August 23d.
The seventh Sign is LIBRA, ♎, the Balance; which Sign the Sun enters SEPTEMBER 23d.
The 8th Sign is Scorpio, ♏, the Scorpion; which Sign the Sun enters October 23d.
The 9th Sign is Sagittarius, ♐, the Archer; which Sign the Sun enters November 22d.
The 10th Sign is CAPRICORNUS, ♑, the Goat; which Sign the Sun enters DECEMBER 22d.
The 11th Sign is Aquarius, ♒, the Waterman; which Sign the Sun enters January 20th.
The twelfth Sign is Pisces, ♓, the Fishes; which Sign the Sun enters February 19th.

2. The 360 degrees of the Ecliptic were thus divided into twelve equal parts of 30° each, and these twelve Signs were adopted corresponding in name to the twelve Constellations, each having its peculiar emblem. Thus, in the time of Hipparchus, B. C. 130 years, the Signs and

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CHAPTER VII.—1. What third system is found in our science in connection with those of the Earth and the Observer? Mention the names of the twelve Constellations of the Zodiac. What is the Zodiac? (*Make on the blackboard the twelve Signs.*) Mention the months and days of the month when the Sun enters Aries, Cancer, Libra, and Capricornus.—2. Are the Signs and Constellations of the same name now together? When were they together? While there has been a Precession in Time, what has there been in Space?

Constellations were going on together; but now, by *the Precession of the Equinoxes*, there has been a *Retrocession of the Equinoctial Points;* so that the Signs are 30° behind the Constellations; and in the Heavens, at the Vernal Equinoctial Point, where together was the first Sign and the first Constellation, we now find the first Sign (♈), Aries, and the twelfth Constellation, Pisces.

3. This subject has been, as we conceive, perplexed by a lack of precision in language, arising from a want of proper distinctions. The Equinoxes (equal-nights), it will be recollected, belong to Time, and the Equinoctial Points to Space—they being the places where the Sun appears at the time of the Equinoxes. By the advance of the time of the Equinoxes a few minutes every year, the place where the Sun had appeared in the Ecliptic is not quite reached. But this place must be in the Equinoctial; and thus it happens that while there is a *Precession* of the Equinoxes, there is a movement of the Ecliptic upon the Equinoctial, and a corresponding *Retrocession* of the Equinoctial Points, which, in 2000 years, has amounted to 30°.

4. Of course the Pole of the Ecliptic has the same motion, with respect to the Pole of the Earth, as the two Great Circles of the same systems have; and so also must all the Circles connected with each. Any degree of Celestial Longitude will not, therefore, indicate the same position of the same stars now as formerly.

5. The grand phenomena of the daily apparent motion of all the heavenly bodies, in consequence of the Earth's rotation on her axis, is so striking and sublime, that it dazzles our vision, and hinders our perceiving at first, what is in itself more vast—the yearly motion of our planets. The annual path which the Earth describes in moving around the Sun we term simply the EARTH'S ORBIT. In form it is an *ellipse*, though not varying greatly from a circle. An ellipse has a longer and a shorter diameter,

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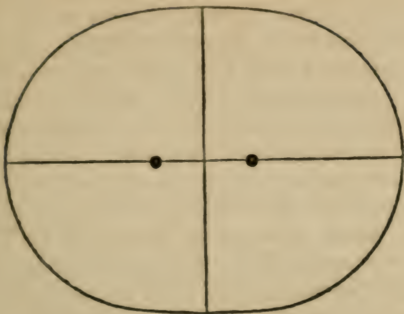
3. How is the term Equinoxes used? Explain how Time precedes and Space retrocedes.—4. What is said of the Poles of the Ecliptic?—5. What is said of the Earth's annual path around the Sun? What is an ellipse?

Fig. 11.



and two *foci*, in one of which is the Sun's place. The Earth's Orbit is sometimes, but, as we maintain, improperly called the Ecliptic. The word ecliptic is not from *ellipse*, but from the Greek word *ekliptos*, to *eclipse*, since all eclipses observed on the Earth are seen in this Circle. The *Ecliptic is the circle of the Sun's apparent annual path in the Heavens;* or it is that circuit which, to an Observer upon the Earth, the Sun, though at rest, appears, as the Earth moves to describe, as if moving in an opposite direction, upon the concave surface of the starry Heavens. The *plane of the Ecliptic coincides with the plane of the Earth's Orbit, as far as the latter extends.* But while the *Earth's Orbit is a limited ellipse*, the *Ecliptic* is an *unlimited Great Circle of the Celestial Sphere*, reaching far beyond the Earth's annual path.

6. The Ecliptic is the principal Great Circle of the Celestial Sphere: the latitude of the heavenly bodies is, therefore, reckoned from it. The circle on the Terrestrial Globe, called the Ecliptic, may be defined as the circle of the intersection of the Earth's surface with the common plane of the Ecliptic and the Earth's Orbit.*

* No little confusion exists in works on Astronomical Geog-

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5. Why is it improper to call the Earth's Orbit the Ecliptic? What is the Ecliptic? In what respect do the Ecliptic and the Earth's Orbit coincide?—6. What is reckoned from the Ecliptic, and why? How may the Circle on the Terrestrial Globe, called the Ecliptic, be defined?

7. We once heard a learner say: "I see that there is a diurnal motion of the heavenly bodies to be accounted for; but in regard to an annual revolution, one day seems to me like another; and I do not see any evidence that there is a yearly motion." We may, however, be convinced, by observation, that there is a circuit made in the Heavens, which is completed in a year. Indeed, it is from its completion that we obtain the idea of a year. If we take some specified hour in the evening, as nine o'clock, and observe some one star, as Aldebaran in Taurus, we shall find it changing its position relatively to the Sun at the rate of 30° each month. Or if we keep our attention fixed to our Celestial Meridian, at some one hour when the stars are visible, we shall perceive in the course of the year that all the Constellations—not only those of the Zodiac, but all in our visible Heavens—will (advancing from the East) come each in its turn to the Meridian; and this proves that a yearly revolution of the Sun in reference to the fixed stars, either real or apparent, does actually take place.

8. The knowledge gained by Astronomy of the motions of the heavenly bodies, makes it certain that it is not the Sun which really moves through this vast circuit of the Ecliptic, but that our own planet, by changing her place as she moves through her comparatively little orbit, makes the Sun *appear* thus to move. Hereafter, should

raphy from the indiscriminate use of the terms *Ecliptic* and *Earth's Orbit*. And the confusion becomes worse confounded when the signs which solely belong to a Great Circle of the Heavens are placed upon an Artificial *Terrestrial* Globe for learners. To the young mind, the Earth seems tasked to carry her annual journey on her back, with all the Constellations of the Zodiac. Mr. Townsend, the author of an ingenious "Mechanical Zodiac," seems to have had a just appreciation of this abuse of the human understanding, when he says, "The subject is to most minds *an inextricable confusion*."

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7. What was said by a learner? But how may we know from observation that a yearly revolution of the Sun, either apparent or real, does actually take place?—8. Is the Sun's motion real or only apparent? What causes the Sun to appear to move?

you study the glorious science of Astronomy, you will receive full evidence of the truth of this great fact. But how, you ask, *can* the real motion of the Earth round the Sun in an ellipse make the Sun appear to move in a great circle around the Earth, and through these immeasurably distant groups of fixed stars?

9. Here is a little picture* of a small island, in a lake surrounded on all sides by various objects. The mansion in the centre is the residence of Mr. Teachwell. This gentleman's young son, Charles, was much troubled because he could not understand how the Sun, standing still in the Heavens, should, by the Earth's moving around him, seem to make a yearly circuit through the twelve Constellations of the Zodiac.

10. The father having become, by previous industry and economy, a man of wealth and leisure, thought that his time and money would be well spent in encouraging his son's good desires after knowledge. So he caused to be erected, in the little rocky island, something like a great Solar-Lamp, to represent the Sun. He lights it, and then at the hour of twilight takes his son into a boat, and directs him to give no attention to the motion of the boat, but to keep his eyes constantly fixed on the mock-sun and the objects beyond. He then rows him quietly round the island, making his course, not in a circle, but in an ellipse.

11. Charles lends his whole mind to the subject, and not thinking of the motion of the boat, perceives that as he sails around, the mock-sun appears to him to move, but in a direction contrary to his own; and, as he keeps in view the objects beyond, the lamp-sun appears to pass directly over them. From his first position near the foot

* See Fig. 8. In the figure, the boat containing Mr. T. and his son is represented in three different positions. Their boat is called the Earth-boat. Another, called the Moon-boat (hereafter to be noticed), is put down, at the first and third position of the Earth-boat.

9-10. What arrangements were made by a father to enlighten his son?—11. How did the youth profit by his father's endeavors to instruct him?

Fig. 3.

of the stairs (*see Fig.* 3, *a*), he sees the lamp as if it were in the statue opposite; and as he moves, it is apparently going round the circuit the same way,* seeming to go towards, and then over, the mansion, and thence to the summer-house, and so on until, when he had completed his little voyage round the mimic-sun, that had also made a complete circle, and come to the same point where it was when he set out.† He then perfectly understood that by the illusion of his sight the lamp-sun had appeared to him to describe a perfect and very large circle, though he had sailed around it, in a small ellipse. When our young voyager was sailing between the mansion and the island-sun, its luminous track seemed to pass over a distant mountain; but to his vision the track was as near as when, in the opposite part of its course, it apparently passed over the mansion.

12. Mr. Teachwell next aided Charles to form a circle on paper, making twelve equal parts of 30° each, and then to divide the objects all around the lake, over which the track of their sun had seemed to pass, into twelve corresponding parts. These Charles named, according to the example of the ancients, as the constellations of his little Ecliptic. The first he called the constellation Statue, the second the constellation Mansion, the third Summer-House, and so on. The father and son at many a twilight hour repeated their little voyage, sometimes to clear up one point and sometimes another. On one evening the subject was to show the youthful learner how sailing in an ellipse, with the mock-sun in one of the foci, the apparent time of the Sun's passing through some constellations would be greater than in others, though the motion

* That is, it apparently goes over the objects in the same succession.

† Only a quarter of this circuit appears on the picture. More than 90° cannot well be taken in by the eye at once.

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11. How did the boy make out a little Ecliptic, with its signs, for his mock-sun?—12. What use could be made of the twelve signs of his little zodiac through which his mimic ecliptic passed?

was equable. Another point which was made clear was—how, since the Sun, hiding the stars, is never seen among them, can we know that he is in a certain constellation? Referring to the place of the little Ecliptic, Mr. Teachwell carried Charles around the circuit, with his back to the sun. Seeing what constellation his own little earth-boat was in, he could know that of the sun, because it was always in the opposite sign in the Ecliptic.

13. One evening, after our little traveller had become quite familiar with the idea that his own real motion produced an apparent motion in an imaginary line made by a mock-sun through objects which, though at different distances, all seemed at the same, his father took him in the boat when the hour was later, and there was no light except what proceeded from the lamp, which was made very brilliant. Then as he rowed his son around the little island, he made him turn on his feet round and round the same way that he was rowing him. This was to represent the Earth's daily motion on her Axis, while at the same time she is carried around the Sun. His father told him to imagine that his head was the Earth, and his eyes the Observer's. The centre of his head would, for these Observers, be downwards, and, away from the centre, upwards. Thus he comprehended how the annual and diurnal motions go on together, the one not interfering with the other.

EXERCISES.

In determining the place in the Heavens of the *Autumnal Equinoctial Point*, we will again begin by looking to the Northern sky, and there we shall never fail to find our familiar friend, the Dipper, whose two foremost stars, the Pointers, will unerringly indicate the Polar Star, Cynosura. Taking, in our eye, Caph, Cynosura, and Megrez, and following on in that direction, about

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13. How did the father of our little traveller cause him to illustrate the union of the Earth's annual and diurnal motions?

as far as from Caph to Megrez, 60° there, the Autumnal Colure cuts at their common intersection both the Ecliptic and the Equator; and this point of intersection is the place of the *Autumnal Equinoctial Point.* The *time* when the sun is in it is the *Autumnal Equinox.* In the days of Hipparchus, this Equinoctial Point was in the constellation Libra, the Balance; but now, by the *Precession* of the Equinoxes in *time*, this Equinoctial Point has, in *space*, *retroceded* 30°, and is in Virgo, the Virgin. Observe the stars in this constellation, especially four, which form an imperfect square near the Autumnal Point, and also the beautiful star of the first magnitude, *Spica Virginis*, or the Virgin's Blade of Corn, as you may observe on the Celestial Globe, she is represented as having in her hand. Hipparchus, 128 years before Christ, described the position of this star. Its change in regard to the Equinoctial Point is the foundation of the certain knowledge which astronomers possess of the Precession of the Equinoxes. Spica Virginis is now on the Ecliptic 15° from the *Autumnal Point* which it is our object so to locate in the Heavens, that we shall always know where to look for it.

The *Summer Solstitial Point* is found on the Celestial Globe, where the Summer Colure intersects the Ecliptic. Study the arrangement of the stars on this part of the Globe, in reference to this Point, and you will find near it some of the brightest in the Heavens. Place the Summer Point on the Celestial Globe in the Zenith, by bringing it to the Meridian, and elevating the Pole 23½°. Then, with the Quadrant of Altitude, measure the degrees of distance, and mark the direction of the following stars from the same point, viz.:—*Capella*, in Auriga, the Wagoner; *Castor and Pollux*, in Gemini, the Twins; *Procyon*, in Canis Minor, the Little Dog; *Betelgeuse*, in Orion; and *Aldebaran*, in Taurus. All these are stars of the first magnitude; and in no other equal part of the sky can so many be found.

On the Terrestrial Globe, study the Southern Temperate Zone, and learn what are its Oceans and Continents (and what parts of the same); what its Countries, great Rivers, and great Cities; and compare it with the Northern Temperate Zone, in respect to the quantity of land and of water in each.

CHAPTER VIII.

TIME AND SPACE.—PERIODICITY.—SECONDARIES OF THE EQUATOR. —TERRESTRIAL GLOBE MADE FOR THE LONDON OBSERVER.— 24 SEMICIRCLES MEASURING THE EQUATOR INTO 24 EQUAL PARTS OF 15° EACH. THIS UNIT IN SPACE EQUAL TO AN HOUR IN TIME.—TERRESTRIAL LONGITUDE; HOW RECKONED; HOW CALCULATED.—CIRCUMPOLAR STARS.

1. THAT TIME and SPACE shall mutually measure each other, is an appointment of the wise Author of Nature. This appears by what some writers term *Periodicity.* That is, certain circuits are accomplished over determinate spaces, in the planetary system, in certain fixed and invariable times. Of this the Earth, both in her annual and diurnal motions, the Moon, and the planets, all furnish examples.

2. In our three systems, their Great Circles—viz., the Equator, the Ecliptic, and the Horizon—have each their Secondaries. The Secondaries of the Horizon we have already noticed under the head of Vertical Circles. We come now to speak of the *Secondaries of the Equator*—an important branch of Astronomical Geography. These Secondaries have a two-fold character, each circle referring both to *Space*, or Place, and to *Time;* and it is in this double capacity that they are placed on the Terrestrial Globe, and shown in the accompanying diagram.

3. This Globe is arranged for a located Observer, and for a specified day of the year, and hour of the day. The place of the First Observer is London. The Meridian

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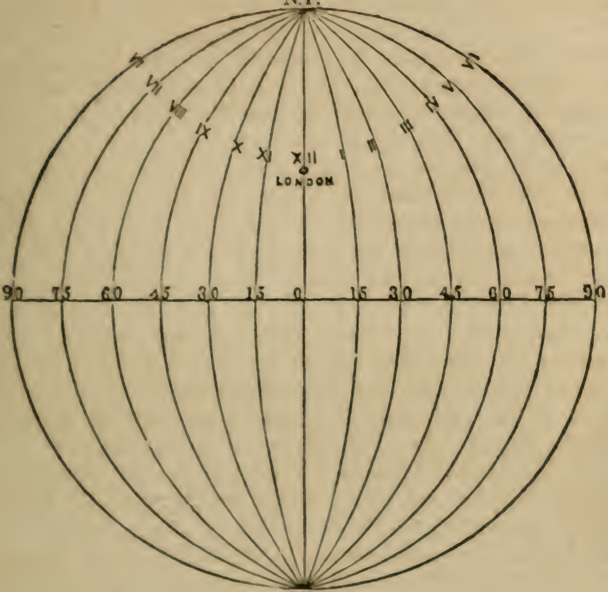
CHAPTER VIII.—1. How does it appear to be the design of the Author of nature that Space and Time shall mutually measure each other?—2. In the three systems before mentioned, what are the Great Circles? What adjuncts to these are here mentioned? What, as belonging to the Horizon? What is said of the Secondaries of the Equator as to their two-fold character? (*Draw and describe the diagram.*)

Fig. 12.

N.P.



S.P.

from which Longitude is reckoned on this Globe passes through that city. That circumstance alone would not, however, fix the Observer at London, since any other place on the same Meridian might have been his residence; but we know that it is from London or Greenwich that Longitude is most commonly reckoned, and there is not on the earth any other large city on this Meridian. According to the Globe, the Observer is at the moment of the beginning of the Astronomical Year, which is at XII o'clock at noon on the 20th of March.

4. This appears by the Celestial Circles, the Ecliptic,

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3. For what is the ordinary Terrestrial Globe arranged? Why do we suppose that the First Observer is to be located at London? What time must be that of the Observer? When does the Astronomical Year begin?

and the two Colures, which are brought down for this occasion, and marked on this Earth-Globe. Their position on the Globe suits this Meridian, and no other; and it suits this Meridian at no other time. In four minutes, the Vernal Equinoctial Colure, here coinciding with the Meridian of London, will, by the Earth's diurnal motion towards the East, have apparently passed a degree to the West,—in an hour 15°. But the Vernal Colure is here coincident with the Observer's Meridian, and this common circle, composed of both, cuts both the Ecliptic and the Equator in the first degree of the sign Aries, at the Vernal Equinoctial Point. This coincidence happens to the London Observer only on the first day of the Astronomical Year, which, although the civil day commences at midnight, begins at XII at noon, and the Time-Circle around the Pole shows that this is now the hour of the Observer, for whom, at this special moment of the year and day, this Globe is expressly made.*

5. The twelve Secondary Circles of the Equator, as relating to *Space*, are called *Meridians* or *Lines of Longitude;* as relating to *Time*, *Horary* or *Hour Circles.* On the Equator (or equal divider of Space) they are marked with figures for the Longitude, or measurement of place and distance; but on the Time-Circle, near the Pole, by Roman letters, indicating the 24 hours of the day. Both as Meridians and Hour-Circles, it is more convenient to consider each Secondary as divided into two Semicircles at the Poles. When one Semicircle is above, and the

* This Globe *could not* be made in this respect to suit all times and all Observers, but must, if these three Celestial Circles are placed on it at all, have a located Observer and a specified time. But great is the perplexity to teachers and scholars which they have caused.

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4. How does it appear that our London Observer must be at the beginning of his Astronomical Year? At what hour commences the day as known in law, or the civil day?—5. How are the twelve Secondary Circles of the Equator named, as relating to Space? how as relating to Time? How are they distinguished in their two-fold capacity by the numbering on the Globe and in the diagram? How is it most convenient to divide them at the Poles?

other below the Horizon, the upper is called the Superior and the lower the Inferior Meridian.

6. The grand invariable UNIT OF TIME is ONE ROTATION of the Earth about its axis. There is no reason to believe that if the time occupied by the Earth in making a diurnal revolution as measured by the return to some fixed star in the Meridian, could be determined by the nicest time-keeper, that there would, in a thousand years, be found the variation of the thousandth part of a second. In the observations of 2000 years, not the slightest deviation from perfect uniformity has been discovered. This Unit is termed a Day. Its division into 24 equal parts, called Hours, appears to have been arbitrary, yet it is made with consummate skill and judgment, and it has come down to us from the earliest antiquity.

7. By the uniform daily motion of the Earth around its axis, every individual on its surface is carried around in a perfect circle. These circles, greatest at the Equator, gradually grow less, although not, on account of the Earth's convexity, by equal gradations, until at length they find their vanishing points in the Poles. But each circle has its 360°, and these 360° are in every circle to be divided into 24 equal parts of 15° each, since each 24th part of the space is in each to be passed over, in one-twenty-fourth of the time.

8. Twenty-four Meridian Semicircles, uniting at the Poles, and dividing the Earth into twenty-four equal parts, will each contain $\frac{1}{24}$th of 360°, which is 15°. The Sun, then, in his apparent daily course, passes in one hour over 15° of Longitude. Since one hour is 60 minutes, and in 60 minutes, by the Earth's rotation, the Observer passes over 15,° he will pass over one degree of Space in just four minutes of Time.

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6. What is the grand invariable Unit of Time? What is said of its invariability? What is this Unit called? How divided?—7. What consequence of the Earth's daily uniform motion is here noticed? What is the same in all the circles, whether great or small?—8. By what calculation does it appear that the Sun, in his apparent daily course, passes over 15° in an hour? And how many degrees in a minute, and why?

9. To say that the Sun, in his apparent course, has moved over 15° of Longitude, is to say that he has been moving one hour in Time. To say that he has been moving two hours, is to say that he has moved over twice 15, or 30° of Longitude. Indeed, it is not uncommon to use the one expression for the other. Thus, instead of saying that St. Petersburg is 30° E. Longitude from London, it might be said St. Petersburg is two hours east from London.

10. As the Earth's rotatory motion is from West to East, so must the hours be marked on the Time-Circle. Observe this on the Globe. Our Observer at London has XII on his Meridian. Those whose Meridian has already passed from his Meridian 15°, have now I o'clock, P. M., while those who have gone on till their Meridian is 30° East from London, have at this moment their time at II o'clock; those whose Meridian is 90° East, have VI; and those who have gone half round the circle (180°), have midnight. But to those whose Meridian is in the rear of that of London, if 15°, then an hour must elapse before it is noon with them; if 30°, then two hours—that is, it is with them X o'clock, A. M. Philadelphia is 75° (which is five hours) West of London; wherefore it must be five hours before the Meridian of Philadelphia will have so revolved as to be where that of London now is, and it is there VII, A. M. Thus, universally, places East have earlier hours, and those West, later hours, than the located Observer, wherever he may be, whether at London or any other place.

11. Turning your mind from the Globe, consider a real Observer at London, having over his head at noon the Vernal Colure, and inquire what will be his position as the Earth revolves on its axis. His Meridian, as we have said, will have gone 15° to the East of the Vernal Colure,

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9. What remarks are here made concerning the language of Time and Space?—10. How does your author here explain the hours marked on the Time-Circle of the Terrestrial Globe? With whom will it be X o'clock, A. M., when it is noon at London? With whom will it be VII o'clock, A. M.? With whom will it be I o'clock, A. M.?

as his Eastern Horizon has turned an hour away from, and his Western Horizon approached an hour nearer to, the Sun; and with him it will then be I o'clock, P.M. As his East continues to recede from, and his West to approach towards, the Sun, when six hours have passed and 90° gone over, his Meridian will then coincide with the Summer Colure: at midnight it will be in the Autumnal Colure, and the Vernal will then be in the Meridian of his Antipodes; and in the morning, at VI o'clock, his Meridian will coincide with the Winter Colure.

12. As noon returns, will this Observer's Meridian again be in the Vernal Colure? Not precisely; it will have come to it, and gone nearly a degree beyond, for the Earth has been moving from West to East during a day, over the 365th part of the year-circle, by which the Sun in his apparent annual course will have gone forward that space in the Ecliptic; and the Earth, after making a complete revolution, must continue to revolve about four minutes longer, before the Sun's place will be in the Meridian of the London Observer; and the Vernal Colure will thus be left about one degree to the West.

13. Let the student now examine the Globe, and he will find the hours at the Time-Circle marked Eastward with the small hours I, II, &c., following XII. What means this? Simply, that this Globe suits the London Observer just so long as he keeps to his hour XII; but let the Earth rotate on her axis, and he goes from that place at the rate of 1° for four minutes, and 15° for an hour. His Meridian is no longer under the Vernal Colure, and will, before it comes under it again, sweep, with its extended plane, over every part of the Heavens. . . The four Colures are the principal Hour Circles, dividing the circles of Time and Space into quarters of 90° and six hours each.

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11. What will be the position of an Observer at London as the Earth revolves on her axis?—12. As noon returns with our London Observer, has he the Vernal Colure in his Meridian?—13. What further proof that this globe is made for this Observer, at this time? What would the extended plane of the Observer's Meridian sweep over during one diurnal revolution? What are the four principal Meridians and Hour-Circles?

14. Terrestrial Longitude is reckoned East and West, 180° each way from the First Meridian, until the two calculations, each amounting to 180°, meet at the opposite half of that circle. But here arises a confusion which sometimes obliges Geographers to reckon on beyond the 180°. For example, the Longitude of the Eastern Continent from Greenwich must be stated as extending from 17° West to 190° East. For if we say that it extends from 17° to 170° West Longitude, we then describe just that portion of the Earth where the Eastern Continent is not. It is, therefore, maintained by some, that Terrestrial Longitude should, like Celestial, be reckoned from the fixed Meridian East, quite round the whole 360° of the circle.

15. When, by the united labors of Astronomers and Geographers, the invariable identity of 15° Space in Longitude, and one hour of the day in Time, was ascertained, then the key was discovered by which unknown Longitudes could be found. Suppose a navigator, sailing on the Atlantic from London, wishes to find how many degrees he has proceeded West from the Meridian of that place. He ascertains by the Sun that it is noon. His *chronometer*—for that is the name given to the carefully-adjusted time-keeper made for navigators—shows that it is two o'clock at London. Then he knows that he is in Longitude West 30° from London.

16. But suppose some accident should damage his chronometer, so that he loses the London time; or suppose he is on a very long voyage, and in a matter so important as, learning his exact position, he is afraid to trust it, since man's work cannot be, like that of the Almighty, unerringly perfect. He wants, then, to find means of reference to the celestial bodies, by which he can gain the true London time. Various methods have

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14. How is Terrestrial Longitude reckoned? What difficulty occurs from this mode of reckoning?—15. What is the key to finding unknown Longitudes? Suppose a navigator sailing West from London wishes to find how many degrees he has proceeded?—16. If on a long voyage, what fears might he reasonably entertain?

been adopted. The moon's appearances have been, of late, most resorted to. Jupiter's satellites, as little as it was to have been expected that those distant moons would ever do us any good, have yet been especially useful in this way. At what moment an eclipse of a satellite will appear, both where he is and in London, a nautical almanac will show. Our navigator watches for it with his telescope, sees it, and accordingly corrects his chronometer for the exact London time. When he compares this with his own time, and finds their difference, he knows his Longitude.

17. In regard to Terrestrial Longitude, there is no natural determinate first Meridian; nor have the learned in Astronomical Geography yet done the world the service to agree upon one; but in different nations the Meridian of each respective capital has been made by Astronomers the First Meridian, or that of the First Observer. This has given to Terrestrial Longitude a certain degree of dependence on the position of the Observer, while in other respects it cannot be changed by that position. In most of our maps and globes, the First Observer is, however, supposed to be located at London, or very near it, at Greenwich, where is an observatory fitted up with telescopes, and all other necessary instruments and conveniences for Astronomical observations. The Meridian of London is sometimes called the XII o'clock Hour-Circle.

18. CIRCUMPOLAR STARS (a phrase without any definite meaning until the position of the Observer is ascertained) are those stars which any Observer sees revolve perpetually around the Elevated Pole without ever setting. Since the elevation of the Pole equals the Latitude of the Observer, those stars which have the same number of degrees' distance from the Pole, will, in their lower culmination, touch the Observer's Northern Horizon; and

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16. By what means might he correct his London time?—17. What is said of a First Terrestrial Meridian?—18. What is said of the phrase, "Circumpolar Stars?" What stars are designated by this expression?

those which are nearer will describe round the Pole, *Circles of Perpetual Apparition*; and the stars which describe these circles are to that Observer, *Circumpolar Stars.*

Heavenly bodies are at their highest, or *culminating point*, when they come to the Meridian. The Circumpolar Stars come twice to the Meridian in each revolution, and are said to have an Upper and a Lower Culmination. Those stars around the depressed Pole, which never rise, are said to describe *Circles of Perpetual Occultation.* The Polar Star itself has a revolution round the exact place of the Pole, from which it is distant about a degree and a half. But this distance is so small, that for ordinary purposes it is considered as stationary, and marking the place of the North Pole in the Heavens.

19. The ANALEMMA on the Terrestrial Globe is a diagram placed in some vacant spot of its surface, extending through the Torrid Zone, and divided into months and days, corresponding to the SUN'S DECLINATION, or distance in the Ecliptic, from the Equinoctial, which for every day in the year may there be found. The month and day of the month being given—the Declination, at the time may be found; or the Declination North or South being given, the time when the Sun is in that Declination can be ascertained, as well as the sign and degree of the Ecliptic.

EXERCISES.

Many problems of great interest, which may be worked out by the Globes, require us to know the Sun's place in the Ecliptic at a certain time. Find by the Analemma where he is at the day in which you now are. This will show his Declination, and by tracing at the same distance from the Equator round the Globe, you can see over whose heads he is to-day vertical.

If we were perfectly possessed of the Uranography of the Circumpolar Stars, we could make them (having the knowledge

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18. What is said of Culminating Points? What are Circles of Perpetual Apparition? of Perpetual Occultation?—19. What is said of the Polar Star? What is the Analemma and its use?

of the Sun's present place in the Ecliptic) a kind of clock by which we could give, in general terms, the time of night. If the Sun is in the Vernal Equinox, and we see *Megrez* at its Upper Culmination, or in our Meridian, we know it is Midnight. If Megrez wants 45° of reaching the Upper Culminating Point, then it is 9 o'clock, P. M.

Learn from the Celestial Globe the principal Constellations which, in your Latitude, belong to the Circumpolar Stars; and learn them with reference to the Four Semicircular Colures and to their Right Ascension:—1. Those extending from the Vernal Colure to the Summer Colure—*i. e.*, from 0° to 90°; 2. Those from the Summer Colure to the Autumnal Colure—*i. e.*, from 90° to 180°; 3. Those from the Autumnal Colure to the Winter Colure—*i. e.*, from 180° to 270°; and 4. Those from the Winter Colure round to the Vernal Point from which the calculation began—*i. e.*, from 270° to 360°.

On the Terrestrial Globe, give your attention to the two Frigid Zones—*i. e.*, to the Northern, which lies between the Arctic Circle and the North Pole, and the Southern lying between the Antartic Circle and the South Pole. What difference do you find between them as to the land contained in each?

Suppose that a navigator is sailing in N. Lat. 28°. He finds when it is 6 o'clock, A. M., with him, it is noon at London. What will be his Longitude, and where is he located? He is a quarter of a circle of time, and of course a quarter of the Earth's circumference, or 90°, from London. And since the Earth turns Easterly, he will go on from 6 o'clock in the morning towards noon. His Longitude is, therefore, 90° West of London, and his position is near New Orleans, in the Gulf of Mexico, with the muddy current of the "Father of Waters" around him.

CHAPTER IX.

Terrestrial Almacantar Circles,—how used to divide the Earth into Six Belts; being an easy Method of obtaining a General Knowledge of the Distances of all Places on the Earth's Surface from our own Position.

1. Having, in the exercises on the Terrestrial Globe, endeavored, in the first place, to lead our students to connect all places on the Earth's surface with the Permanent Positions, the Equator, its parallels, and the Zones which they include, we would now aid them in making a second and subsequent arrangement in reference to that useful law of our nature, by which every person must not only regard his own position as immediately under the crest of the sky, but also as constituting the very centre of the world in which his field of activity lies. By this law, man, in order to make his knowledge of Astronomical Geography useful, must connect it with himself. It is well to know the distance from each other of cities and countries; but their distance from himself is a great item of general information, indispensable to the man of science or of business.

2. We offer here an easy method of obtaining a general view of all terrestrial distances, by dividing the Earth's semi-circumference from our own position in the Upper Vertex to the Lower Vertex, or the position of our Antipodes into six Belts, or Zones, by five Almacantar Circles, of which the Rational Horizon is the third or central. (*See Fig.* 2.)

3. Reckoning the mean circumference of the Earth at

Chapter IX.—1. What principles of our nature are here referred to as important to be regarded in education?—2. What method of obtaining a general view of all terrestrial distances from our own position is here developed?

24,840 miles,* the half of that circumference, as measured on the great circles of the system of Terrestrial Verticals which find their Poles in the Upper and Lower Vertex, will be 12,420 miles. This half will be equally divided by our Horizon, to which these Verticals are secondaries, and from either the Upper or Lower Vertex to it the distance will be one quarter of the Earth's circumference—6,210 miles. This distance we subdivided by two Almacantar Circles, cutting the 90° between the Horizon and the Upper and Lower Vertices into three equal parts of 30° each. If 30° be multiplied by 69, the number of statute miles in a degree, the product will be 2,070, which is the same number as will be obtained by dividing 6,210 into three equal parts.

4. The width of each of the six equal Belts, or Zones, into which we divide the Earth, is therefore 2,070 miles. Our place may easily be comprehended by reference to Fig. 2, a little map of the world in which we have supposed ourselves located in the city of New York. The Almacantars are in dotted lines, two around New York as the Upper Vertex, and within the Horizon, and two around the Lower Vertex, and beyond the Horizon. The Lower Vertex, or opposite extremity of the Observer's Line from New York, being in the Indian Ocean, South-

* This is only 16 miles less than the estimate made on Sir John Herschel's number of miles in the Earth's mean diameter, which is 7,912. Most authors, however, continue to speak of the Earth's axis as 8,000 miles, and of the number of statute miles in a degree as 69½, which is too much, even on the supposition that the Earth's circumference were 2,500 miles, which it is not. 69 is the number sanctioned by Sir John Herschel, and it exactly coincides with the numbers we have given; for 360° × 69 m. = 24,840 miles, the half of which, or the semi-circumference, is 12,420 miles.

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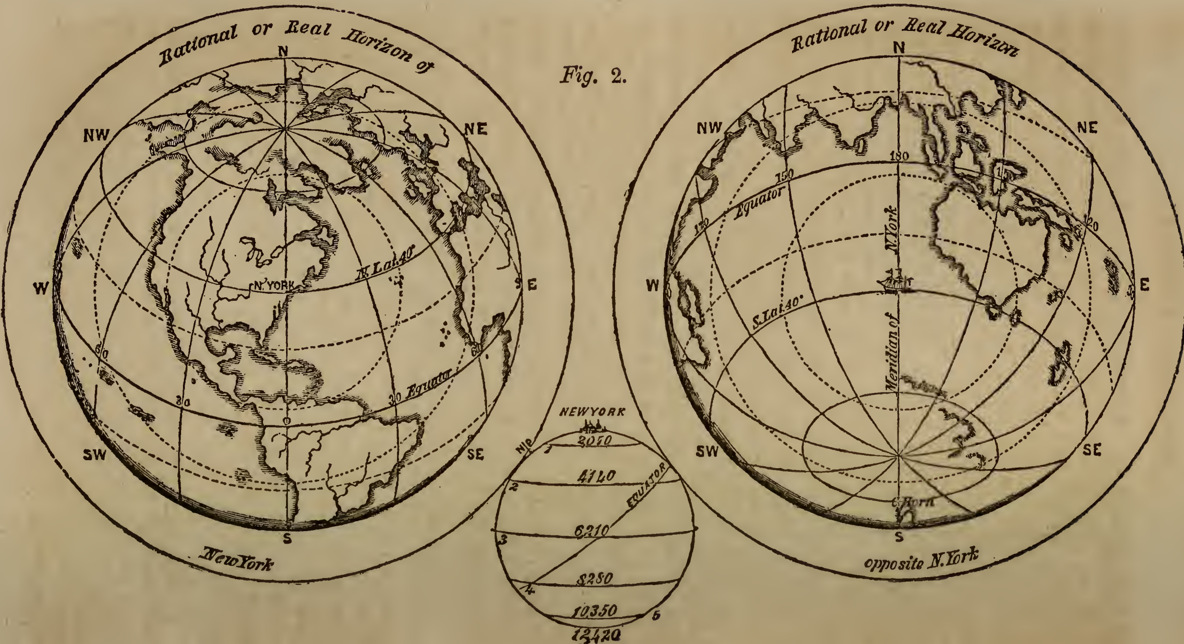
3. Draw on the blackboard a circle. Make the Line of the Observer or Axis of Movable Positions. Divide this Axis into six equal parts, by points, and draw through these points lines to the surface at right angles to the axis. These will divide the Globe into the six Zones mentioned. Place at each dividing line the number indicated, and explain the diagram.—4. What is the width of each Zone?

Fig. 2.


Rational or Real Horizon of
New York
N
NE
E
SE
S
SW
W
NW
N. YORK
N. Lat. 40°
Equator
Rational or Real Horizon
opposite N. York
180
150
120
Equator
S. Lat. 40°
Meridian of N. York
C. Horn
NEW YORK
2070
4140
6210
8280
10350
12420
EQUATOR

West of New Holland, where is no land, a ship is there placed, and its passengers are our Antipodes. From this little sketch of the Earth, small as it is, we can, by means of our Almacantars and easily-remembered numbers, derive a general view of the distances of all places on the Earth's surface from ourselves. A simple piece of mechanism might easily be made,* containing the two Almacantar Circles, to divide the Hemisphere, as described: or otherwise these circles of 30° and 60° radius might be measured round the Vertices by revolving the quadrant of altitude. The circle nearest our own position we term the first; that next, second; the Horizon, third; the next below it, fourth; the one next the Antipodes, fifth; and the sixth position is made by the Lower Vertex, or place of our Antipodes.

5. The five Almacantars are numbered from the Upper Vertex. All places on the First are from the Observer's position 2,070 miles; those on the Second twice that distance, or 4,140 miles; those on the Third, or Horizon, three times that number, or 6,210 miles. This is a quarter of the Earth's circumference, and it is exactly the number that 90° multiplied by 69 miles will produce.

6. Should we now reverse the Globe, and, for the purpose of calculation, put the Lower Vertex in the place of the Upper, our two Almacantars would enable us to measure the remaining half of the Earth. The circle next the Horizon is the Fourth Almacantar, and its distance from our position will be found by adding the increment 2,070 to the distance of the Third, or Horizon, and it is 8,280 miles.

7. The remaining Almacantar, nearest our opposite Vertex, is the Fifth; and its distance is found by adding the same increment of increase to the next preceding,

* At the suggestion of the author, Mr. Merriam, of Troy, is preparing the Almacantar Circles for his globes.

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4. From what point do we name the Almacantar Circles? What do we find at the Sixth Position?—5. How do the numbers increase as we go from our own position to the Horizon?—6–7. How as we go on through the lower Hemisphere to our Antipodes? What can you say of that point of the Earth?

and it is from our position 10,350 miles. Adding the same, we find the distance of the Sixth and last Position to be half the circumference, 12,420 miles. This is the completion of our plan, and it brings us to the place of our Antipodes—if, by the presence of a vessel at sea, we happen to have any. This is the only place on the Earth's surface, and it is but a point, which is thus remote from ourselves. Whatever people may be there, they have their feet opposite to ours, and that is the reason of their appellation—Antipodes.* They are on the opposite half of our Meridian, as many degrees from the South Pole as we are from the North.

8. Intermediate, then, between the Upper and Lower Vertex, we have five Almacantar Circles, of which the Horizon is one, dividing the circumference of the Earth into *six equal distances from the Observer*, so arranged as to be easily measured. For if we choose to throw away smaller numbers, and consider the Earth's circumference as 24,000 miles, then the First Distance will be 2000, and the increment of increase 2000; so that the

First Distance will be	....	2,000 miles.
Second " "	....	4,000 "
Third " "	....	6,000 "
Fourth " "	....	8,000 "
Fifth " "	....	10,000 "
Sixth " "	....	12,000 "

9. This is the more easily recollected, as the number of the thousands is the double of the number of the Distances. The thousands go from two to twelve, and the Distances from one to six. If greater accuracy is required, we have but to recollect that 70 is to be added to the First Distance, 2×70 to the Second, 3×70 to the Third, 4×70 to the Fourth, 5×70 to the Fifth, 6×70 to the Sixth.

* Anti-podes—opposite feet, from *podes*, the Greek word for feet, and *anti*, opposite.

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8. Recapitulate so as to be perfect in your recollection.—9. How can we show that these numbers are very easy to be recollected?

10. The Zones around the Upper and Lower Vertices are small, compared with the others. The two which are adjacent to the Horizon are much the largest of the six; and the two remaining ones are intermediate in size as in position.

Putting these surfaces into square miles, the *First* and *Sixth Zones*—those surrounding the Upper and Lower Vertices, and the least in extent—each contains 13,166,363 square miles; the *Second* and *Fifth*, or intermediates, each contain 35,996,171; and the *Third* and *Fourth*, or those adjacent to the Horizon, and the largest, each contain 49,168,761. To recapitulate:

The First and Sixth, each contain	..	13,166,363	square miles.
The Second and Fifth,	" ..	35,996,171	"
The Third and Fourth,	" ..	49,168,761*	"

If we add the three given numbers, we shall have one-half the square miles on the surface of the Earth. Multiplying this result by two, we obtain as a product the whole number. The square miles on the surface of the Earth are, therefore, by this computation, 196,662,590. Adding the two upper and smaller numbers, and subtracting them from the third and larger, we find that the sum of the two upper numbers equals the lower with only the small difference of 6227 square miles, which multiplied by two, is 12,454,—a fraction of the whole number (nearly two hundred millions),—so very small, that it may be thrown away. We shall then have the general rule that 60°—viz., 30° each side of any great circle of a Sphere—contains half the surface of that Sphere.

* This Problem of the number of square miles in each of the six Belts was worked out by Professor John A. Nichols, of the Free Academy, New York. As the first element of the calculation, he assumed the length of the Earth's diameter to be as given by Sir John Herschel, 7912 miles.

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10. How do these six Zones compare in size? How many square miles have the two largest? How many have the two smallest? the two intermediate? How many has the Earth? What rule is here mentioned, and how is it obtained?

EXERCISES.

When, in looking upon the starry Heavens, we reflect that Astronomers know and name every star which we can distinguish by the eye, and many which we cannot, it gives us a sublime idea of the powers of man, as well as of the works of God. When the stars were arranged into constellations, a work was done for Uranography, as has been already noticed, similar to what was done for Geography when the land was divided and the countries received names; and when the principal stars received names, it was as when great cities were thus designated. But there still remained a vast number of stars of which there was no distinctive appellation, much to the annoyance of Astronomers.

M. Beyer, a German, of Suabia, found a method of remedying this difficulty, very simple to those who know the letters of the Greek alphabet, which are—

		Name.	Sound.			Name.	Sound
Α	α	Alpha	a	Ν	ν	Nu	n
Β	β ϐ	Beta	b	Ξ	ξ	Xi	x
Γ	γ	Gamma	g	Ο	ο	Omicron	o *short*
Δ	δ	Delta	d	Π	π	Pi	p
Ε	ε	Epsilon	e *short*	Ρ	ρ ϱ	Rho	r
Ζ	ζ ϛ	Zeta	z	Σ	σ ς	Sigma	s
Η	η	Eta	e *long*	Τ	τ	Tau	t
Θ	ϑ θ	Theta	th	Υ	υ	Upsilon	u
Ι	ι	Iota	i	Φ	φ	Phi	ph
Κ	κ	Kappa	k	Χ	χ	Chi	ch
Λ	λ	Lambda	l	Ψ	ψ	Psi	ps
Μ	μ	Mu	m	Ω	ω	Omega	o *long*

In every constellation stars of the first magnitude are designated by α, those of the second by β, those of the third by γ, and so on. When the stars in any constellation are so numerous as to exhaust the letters of the Greek alphabet, Roman letters are then employed.

If the two Almacantars mentioned be placed upon the Upper Hemisphere of the Celestial Globe, the Observer's Zenith being placed in its true position (the time of the year and the day given), it will be a beautiful problem to find the principal stars upon them—especially those on the Upper Almacantar, they being at 30° distance from our Zenith at the moment specified.

What is the Declination and Right Ascension of the star of the first magnitude *Antares*, in the Scorpion's Heart? of *Fomalhaut*, in the mouth of the Southern Fish? of *Altair*, in Aquila, the Eagle? Declination and Right Ascension, it will be recollected describe these stars in respect to their nearness or distance from the Equinoctial and its principal secondary, the Vernal Colure.

From the Terrestrial Globe, according to the preceding chapter, learn what countries, seas, islands, and large cities lie on the first Almacantar Circle, 30° or 2070 miles from your own position. As the Geographer is supposed to stand with his face to the North, begin at the North, trace towards the East, then South and West to the North again, and describe in that order what you find on this circle, and at that distance from your own position.

Learn in the same manner all the various divisions of land and water, islands and cities, which the second Almacantar Circle passes over, and remember that the distance of these various objects from yourself is 4140 miles.

These recitations may, according to the ambition and intelligence of the pupils, contain more or less information. The ambitious and able-minded will include in their recitations not only all we have mentioned, but the passage of the circle over mountain-ranges and celebrated peaks, and tell what great rivers it crosses.

In studying by these five Almacantars, remember that the nearer are the places to your own position, the more minute should be your knowledge of them.

CHAPTER X.

CHANGES OF THE SEASONS, AND THE CAUSES.

1. THE way is now prepared for us to understand the cause of the CHANGE of the SEASONS, *which is the annual motion of the Earth in its Orbit, with its* AXIS *inclined to the* COMMON PLANE *of that Orbit and the Ecliptic.* The inclination of the Axis of our planet to that plane is, as we have seen, $66\frac{1}{2}°$—the complement of the angle, $23\frac{1}{2}°$, or that angle which the Earth's axis makes with the axis of the Ecliptic. This angle $23\frac{1}{2}°$ is also the same which the plane mentioned makes with the plane

CHAPTER X.—1. What is the cause of the change of the Seasons? What is the inclination of the Earth's Axis, and to what plane? What is the angle made by the Axis of the Earth with the Axis of the Ecliptic?

of the Equator. Our subject thus leads us to begin the consideration of the *intersections* of the Spherical Systems, which will be more fully developed hereafter. We shall see, that upon the angle made by the axes of the systems, depends not only the changes of the seasons and the alternations of heat and cold, but the share which any observer or individual on the Earth will receive of each.

2. A part of our object is to understand the Globes. The Ecliptic and the two Colures—three circles which belong solely to the Celestial Sphere—are marked on the Terrestrial Globe, and the instructor can find on it nothing which explains how or why. This deficiency we endeavor to make up, according to the best of our power. As the three systems are spherical—that is, made up of spheres—the Earth's surface is a sphere concentric to the others, whether we conceive them to be little or much larger; and every axis of each must pass through the Earth's centre and also the plane of every great circle, which must divide the Earth into two equal parts.* The Ecliptic is a great circle, and the Colures are great circles, and we may conceive that their planes, dividing the Earth, leave their traces on the Earth's surface, where they intersect it in passing forth from the common centre to extend out every way to the Heavens: and so the maker or designer of the Artificial Terrestrial Globe has imagined; and he has thus marked these intersections on the Globe, calling them, as you perceive, the Ecliptic, the Solstitial Colure, and the Equinoctial Colure.

* See Fig. 1.

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1. To what does our subject lead us? What shall we be enabled to see?—2. What three great circles of the Celestial Sphere are marked on the Terrestrial Globes? Why do we call our three systems spherical? When a smaller Sphere has larger ones inclosing it, all having a common centre, what do we call them? Where must every Axis of each pass? Where must the plane of every great circle belonging to any of the concentric spheres pass? and how divide the Earth? Where may we imagine these planes to make circles? How, then, are we to suppose that the designer of the artificial Terrestrial Globe placed those three great circles upon it?

3. But even this definition is not correct, as already shown, except under definite circumstances of place and of time. To make it right, we must suppose the time to be the moment of the beginning of the astronomical year, at the noon of the Vernal Equinox, and the place somewhere on the meridian of London. At this time and place only, would the planes of the Ecliptic and of the Colures, if marked on the Terrestrial Sphere, where they intersect its surface, be as they appear on the Terrestrial Globe. For, 1st, take the same time and a different place, and they would be wrong. Take New York, for example, at the opening of the astronomical year, which is the noon of that city on the 20th of March (the day of the Vernal Equinox), and then the line of the Vernal Colure should be made to intersect at New York instead of London; and the Ecliptic and Solstitial Colure must be correspondently moved. Or, 2d, let it be London at the noon of the Summer Solstice, and the Summer Colure instead of the Vernal must then pass through London. In truth, it seems to us, explain it as we may, the height of absurdity to fasten on to the Terrestrial Globe these great circles, belonging solely to the Celestial Sphere, and within which, the Earth turns daily, bringing them successively under each Meridian, and over each observer's head, every day of the year.

4. We will now begin our illustration of the definitions given of the cause of the change of Seasons, by placing this line of intersection (called the Ecliptic) within and parallel to the wooden Horizon of the Terrestrial Globe, which, for the time being, we suppose to be a section of the common plane of the Earth's Orbit and the Ecliptic. This plane, we know, is extending indefinitely, but always keeping the same direction with respect to the Axis of the Earth. The table on which the Globe stands is a

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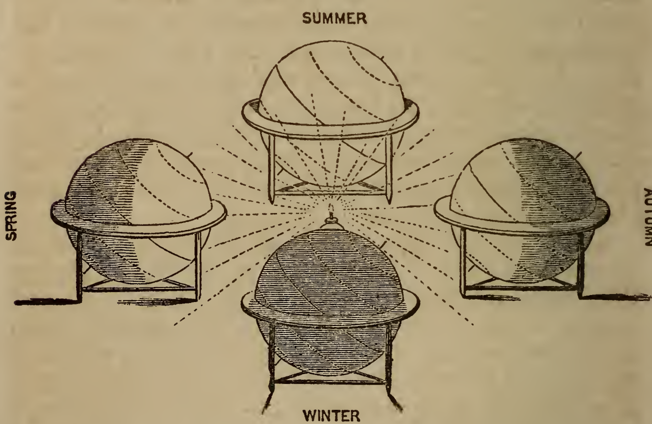
3. How far is this definition correct? What time and place is presupposed? Suppose we take the same time and a different place? Suppose we take the same place and a different time? What is your author's opinion of placing the Ecliptic and Colures on the artificial Terrestrial Globe?—4. Explain the step first to be taken in our illustration of the Seasons?

plane parallel to our assumed imaginary plane of the Earth's Orbit, which, of course, always passes through the Earth's centre. . . . We will further prepare for our experiment by closing the window-shutters and lighting this small lamp. We have prepared it for the occasion, and it is of such a height that its centre is in the same plane as the centres of the Earth and of the wooden Horizon, which are both in the plane of the Earth's Orbit. We are not now to be observers in a *geocentric* position—that is, on the Earth's surface, attending to mere appearances—but we must imagine ourselves to occupy a *heliocentric* position ; that is, to be looking out from the Sun, and understanding things as they are. But whenever the apparent motion of the Sun is described, we must come back to our geocentric position.

Fig. 13.



5. Now, we will move the Globe around the lamp in a manner to explain how the annual revolution of the Earth, with this inclination of the Axis, causes the succession of the four seasons. We must fancy this wooden plane to be nothing but an imaginary one, and of course obstruct-

4. What farther preparations are indicated for the experiment to be made? What is a geocentric position?—heliocentric?

ing no view, and casting no shadow; and we must bear in mind that light falling on a Globe from one direction, will shine over just half its surface, and no more.

6. We place the Globe in this first of its four positions (*see Fig.* 13), so that it represents the Earth at the time of the Vernal Equinox, when the Sun enters the First of Aries. This, we must recollect, is the *sign*, and not the constellation Aries; since, on account of the Precession of the Equinoxes, the Sun is now in the constellation Pisces. The Sun at the moment, as the lamp on our Globe, shines equally to both Poles. The days and nights are equal all over the Earth, and with us in the northern Hemisphere it is SPRING.

7. We will now slowly trace a quarter of the Earth's imaginary Orbit, which is the line made by the centre of the Globe as we move it around our poor substitute for the glorious Sun; and the direction in which the Earth moves through her whole revolution is, by definition in astronomy, from west to east. As the Earth moves from its Spring to its SUMMER position, the Sun apparently passes from the *sign* Aries through Taurus and Gemini to the first degree of Cancer, which it enters on the 22d of June. The *constellations* through which the Sun appears to move at the same time are Pisces, Aries, and Taurus, to Gemini. The Sun has at this time his greatest northern declination, or distance from the Equinoctial, and after appearing to stand for a few days in this *Summer Solstitial Point*, he turns again in his apparent course towards the South. It is supposed that the ancients gave the name of the Crab to the constellation which the Sun was in before its change by the Precession of the Equinoxes; because the crab moves both backwards and for-

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5. How is the movement of the Globe round the lamp to be made?—6. How is the Globe first to be placed? What are we here to understand by the First of Aries? How does the Sun's light at this time affect the Earth?—7. Describe the Sun's apparent course as the Earth moves in her Orbit from the Vernal Equinox to the Summer Solstice? After the Sun arrives at the Solstitial Point, what does he then? What is said of the name of the constellation Cancer?

wards; and the Sun from this point goes back to the Equator.

8. But, as we move our Globe, we must keep in mind our main object—which is, to observe how the rays of light and heat affect it, as it moves. In going from the Spring to the Summer position, keeping the axis always in the same direction, the North Pole becomes wholly enlightened, and the South Pole sinks into shade; and when we have reached the Solstitial Point, this northern polar light will extend beyond the Pole 23½ degrees, and the southern polar darkness will do the same. But they have now both reached their extreme limit.

9. We will again remove our Globe in its orbit another quarter, from the Summer to the AUTUMNAL position. During the removal, the Sun in the Ecliptic will appear to move through the signs Cancer, Leo, and Virgo, and through the constellations Gemini, Cancer, and Leo to Virgo. He enters the sign Libra on the 23d of September. The constellation Libra, the Balance, from which this sign was originally named, is supposed to have received its appellation in early ages, because the Sun, when in this constellation, gives an equal or *balanced* light and heat to all parts of the world. This is the *Autumnal Equinox*, when again the Sun has no declination, but is in the Equator of the Heavens, and, as our apparatus shows us, his light shines equally to both Poles.

10. We will now carry our Globe through the third quarter of its circuit, from its Autumnal to its WINTER position; the Sun meanwhile passing through the signs Virgo, Libra, and Scorpio, to the first degree of Capricornus, when he is in our *Winter Solstice*, having 23½ de-

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8. What is the manner in which the rays of light and heat affect the Earth as it moves from the Spring to the Summer position?—9. While the Earth moves from the Summer to the Autumnal position, how will the Sun appear to move both with respect to the signs and the constellations? When does the Sun enter the sign Libra? What is said of this name? What is this time?—10. While the Earth moves from the Autumual to the Winter position, where does the Sun appear in respect to the signs and constellations?

grees of Southern Declination. During this quarter of the Earth's motion, the light has been receding from the North Pole and leaving it in darkness; and, of course, as the Sun always shines on half the Globe, his rays have in the same degree shone on the Earth beyond the South Pole. It has proceeded $23\frac{1}{2}$ degrees, which is, of course, the limit of this southern light and northern darkness.

11. The Sun, when he moves from this *Winter Solstitial Point*, will return in his apparent course to the Vernal Point in the Equinoctial, when again his rays will fall direct on the Equator of the Earth. We will now move our Globe through this last of the four quarters of its little Orbit, from Winter to Spring. The signs through which the Sun will move are Capricornus, Aquarius, and Pisces; the constellations falling one behind are Sagittarius, Capricornus, and Aquarius, leaving him to begin, as before, the next astronomical year, with the first degree of the sign Aries, and in the first of the constellation Pisces.

12. Concerning this awkward discrepancy of the signs with the constellations of the same name, Sir John Herschel says: "The *signs* are purely technical subdivisions of the Ecliptic, commencing with the actual Equinox, and are not to be confounded with the constellations so called and sometimes so symbolized. The constellations of the Zodiac, as they now stand arranged on the Ecliptic, are all a full sign in advance* or anticipation of their symbolic cognomens, thereon marked." To avoid this source of misunderstanding, the ordinary reckoning of celestial longitude by degrees, from 0° to 360°, will, he asserts, be substituted; and the names, Aries, Virgo, &c., be restricted to the constellations properly so called. At

* In advance, as respects time, at the Equinoxes.

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10. How does the Sun's light at this time affect the Earth?—11. While the Earth moves from the Winter Solstice to the Vernal Point, through what signs and constellations will the Sun appear to move? How will, at this time, the Sun's light and heat affect the Earth?—12. What says Sir John Herschel concerning this awkward discrepancy between the signs and constellations?

present, however, when it is said the Sun is in a certain degree of Aries, Libra, &c., we are to understand the *signs* of that name, and not the constellations.

13. The contemplation of the Seasons in all their variety of usefulness and beauty, lifts up our hearts in adoration of the Wisdom, the Power, and the Goodness which thus adapts all parts of nature to each other and to man; and we recognize in them the hand of a BENEFICENT FATHER who loves to please, as well as to preserve his children. Well does Thomson, the harmonious poet of the "Seasons," exclaim:

> "Mysterious round! what skill, what force divine,
> Deep felt in these appear! a simple train,
> Yet so delightful mix'd, with such kind art,
> Such beauty and beneficence combined;
> Shade, unperceived, so softening into shade,
> And all so forming an harmonious whole;
> That as they still succeed they ravish still.
> But wandering oft, with brute unconscious gaze,
> Man marks not THEE, marks not the mighty hand,
> That ever busy, wheels the silent sphere;
> Works in the secret deep; shoots, steaming, thence
> The fair profusion that o'erspreads the Spring;
> Flings from the sun direct the flaming day;
> Feeds every creature; hurls the tempest forth;
> And as on earth this grateful change revolves,
> With transport touches all the springs of life."

EXERCISES.

In all our attempts to give instruction on great astronomical subjects, we are liable, by our illustrations, while we afford light and truth, to introduce some error and confusion along with it. In moving our terrestrial globe around our mock-sun, we show how the revolving motion with the inclined axis produces the change of the seasons. But the student will find his mind confused on account of the direction of the plane of the Ecliptic and Earth's orbit, and it will be but by slow degrees that he will be able to acquire clear ideas on this complicated subject.

The Ecliptic is determinate in space, else the Sun would not, as the Earth, year after year, goes round him, be seen always passing in his apparent Ecliptic-path through the same groups of stars. But to Observers on every side of the Globe, each supposing that over his own head is up, and the contrary down, the

Ecliptic seems to each one to have a different direction. This is also, in degree, the case with the Equinoctial, but its changes are much more easily understood, since to every observer it always crosses the Horizon in the points east and west, while the Ecliptic varies perpetually during the 24 hours, by the Earth's diurnal motion.

Let us look out upon the stars, and endeavor to conceive where in *our* Heavens is now the Ecliptic. Suppose we are looking upon the sky at midnight on the 20th of March. The Sun is in the Vernal Point, and since it is midnight, he is in the Meridian of our Nadir. In our Meridian is, at this moment, the Autumnal Point, having 180° Right Ascension. The Autumnal Colure, of course, coincides with one Meridian. The Winter Colure is East 90°, which makes its Right Ascension 270°. The Summer Colure, in the west, is in the rear, having 90° of Right Ascension. Where, then, is the Ecliptic Pole? and where is that semicircle of the Ecliptic which is now in our view? Elevate, as before directed, the Pole of the Celestial Globe a number of degrees equal to your latitude, and bring the Autumnal Point to your Meridian. But at the same time study the starry Heavens. The Ecliptic Pole, as both will inform you, is on the Winter Colure 23½° South from the Pole of the Earth. The great circle of this Pole at 90° distance is the Ecliptic itself. Keep this in mind, and at all times when you can see the stars, it will be a key to the momently changing position of the Ecliptic in the Heavens. For this great circle being 90° from its Pole, which is 23½° South of the Earth's Pole and on the Winter Colure, then the Ecliptic itself must, on that Colure, be 23½° South of the Equator, and at its greatest Southern declination, or its greatest possible distance from our Zenith. Then of consequence, too, the Summer Solstitial Point will be 23½° North of the Equator and nearest our Zenith, on the Summer Colure. Then of the four Cardinal Points of the Ecliptic, the two Equinoctial and the two Solstitial Points, there will now be—1st, the Autumnal Point in your Meridian, where it crosses the Equator, and, 2d, the Winter Point, a little below your Horizon, south of east; 3d, the Summer Point in the opposite Heavens is north of west, and, on account of the Earth's convexity, a little above your Horizon. So that the actual position of that half of the Ecliptic now in your view sweeps across the sky from E. S. E. to W. N. W. Examine the subject by the Celestial Globe.

It will be a useful exercise on that Globe to find answers to questions like the following: What is the direction from the North Pole, at any given place and hour, of the North Pole of the Ecliptic? Describe how the visible half of the circle of the Ecliptic is situated at the same time and place.

On the Terrestrial Globe, proceed to learn the division of the Earth's surface by Almacantar Circles. Trace the Third Almacantar (the Rational Horizon), and as this is so much the largest Circle, it will be well to divide it by the points of Compass, as expressed by the Horizon What seas and lands do you find on the Third Almacantar from your own position in its passage from north to east? from east to south? from south to west? Bear it constantly in mind that all these places are distant from you 6,210 miles. If you forget the odd numbers—in your recitation you may say about 6,000 miles, or more than 6,000 miles—but it will be easy to calculate them by merely remembering the number 70 to be added to the thousands, multiplied by the number of the Almacantar Circle as reckoned from your position.

CHAPTER XI.

Permanent Positions arising from the Intersections of the Systems of the Earth and Heavens.—The Tropics and the Polar Circles.—Different Planets have their Axes at Different Degrees of Obliquity.—The Five Zones.

1. The Tropics, the Polar Circles, and the Zones are Permanent Positions belonging to the System of the Earth. They are all parallels to the Equator; but the Tropics and Polar Circles, which fix the location of the five Zones, are not, like ordinary parallels of latitude, to be drawn at pleasure anywhere between the Equator and the Poles. They have by nature determinate positions, and these are derived from Intersections between the System of the Earth and the System of the Heavens. These two Systems belonging to the Permanent Positions, their Intersections will also be the same.

2. We must be careful to understand the Systems as they exist singly—each by itself; and their Intersections will then be less difficult. In any two Spherical Systems,

Chapter XI.—1. In what respects are the Tropics and Polar Circles like ordinary lines of latitude? and in what respects are they different? What are the places of these four circles derived from? How may we know that they are Permanent Positions?—2. Of what two Spherical Systems are we now to consider the Intersections?

as has been shown, *as is the angle made by the Intersection of their axes, so will be the angles of their great circles and of all parallels to the great circles.* The axes make with each other, in the two Systems mentioned, an angle of 23½°, and so do their great circles, the Ecliptic and the Equinoctial. The same angles will also be made by the similar parallels—viz., those of celestial latitude and declination. But in regard to the angles made by the *Secondaries* of the great circles, the convexity of the Sphere in all the Secondaries but one, will cause the angle of Intersection to vary. That one Secondary of each of the Systems mentioned, is that which, in the System of the Heavens, passes through the first degree of the signs Aries and Libra, and that which, in the System of the Earth, passes through the same Points, and is called the Equinoctial Colure. These two Secondaries cut each other at 23½°, the common angle of intersection. They are the only Secondaries which make an angle so large; but the angles grow less and less, until, with the two Secondaries at right angles at the Poles (in each System) to the two already mentioned, the angle entirely disappears, and the last-named Secondaries coincide—viz., that Secondary of the Ecliptic passing through the first of Cancer and Capricorn, with that of the Equinoctial passing through the Solstitial Points, and called the Solstitial Colure.

3. To recapitulate: The first of Aries and Libra intersects the Equinoctial Colure at an angle of 23½ degrees, while the Solstitial Colure coincides with the first of Cancer and Capricorn; and of the intervening Secondaries of each System—viz., in the System of the Heavens, the

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2. Suppose the Axes of any two Systems make a certain angle of intersection, what similar parts will make the same? In the two systems under consideration, what is the angle of the intersection of their axes? What other similar parts will make similar angles? But what can you say concerning the Secondaries of the Great Circles of any two intersecting Systems? What in the two Systems mentioned are the two Secondaries which intersect at the common angle of 23½°? Which are the two Secondaries that coincide? What can you say of the intermediate Secondaries of each System?

Secondaries of Celestial Longitude, and in the System of the Earth, the Secondaries of Right Ascension, make angles which go from 0° at the Solstitial Colure to $23\frac{1}{2}$° at the Equinoctial. So that at the Solstitial Colure, Celestial Longitude and Right Ascension coincide throughout the common circle, but they vary elsewhere, except at the angle of their Intersections. Let these Intersections be verified by tracing them on the Celestial Globe.

4. An arc of the Solstitial Colure intercepted between the Ecliptic and the Equinoctial, is the greatest possible distance between them, and is the measure of the angle of their intersection. An arc of the same Colure and of the same extent, measures the distance of the two North Poles of each System; and also the distance between their two South Poles. This arc is the measure of the angle made by the Intersection of the Axes. The two Equinoctial and the two Solstitial Points are sometimes called the *Four Cardinal Points of the Ecliptic;* the Vernal Point being the Zero (0°), or initial point of both Celestial Longitude and Right Ascension. As in time we go from Spring to Summer, so the Summer Solstitial Point, tracing in the Ecliptic from west to east, is 90° east from the Vernal Point. Autumn follows, and the Autumnal Point is 180° next west in the order of the signs; and the Winter Point has 270°, and these degrees are both of Celestial Longitude and Right Ascension. Then from Winter to Spring is 90° more, which will complete the 360° of the Circle.

5. In asserting that the Intersections of the Permanent Positions are Permanent, it is proper to mention that there is a slight change in them, going on constantly, though

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3. This subject being of importance, you may recapitulate the manner of intersection of the Secondaries of the System of the Earth with the System of the Heavens.—4. What arc measures the angle of intersection of the Ecliptic and the Equinoctial—of the distance of the North Celestial Pole of the Earth and that of the Ecliptic? What are the Four Cardinal Points of the Ecliptic? What degrees both of Celestial Longitude and Right Ascension, and what seasons of the year, commence with each of these four Points?

very slowly, as may hereafter be understood in considering the subject of the Retrocession of the Equinoctial Points. This gives rise to some of the most intricate calculations of Astronomy. For all the important purposes of Astronomical Geography, however, these intersections may be considered as producing *Permanent* Positions. They will never, in any case, fall under those definitions to which we have applied the term Movable—viz., such as depend on the changeful place of the human Observer. Nothing in either of these Systems is thereby affected. The Intersections of the Observer's System with either of the two Permanent Systems will produce Movable Positions.

6. Although the Axis of each System is its fundamental position, yet it is not always the first-found element. In the Terrestrial, we may safely presume that the Equator, receiving the Sun's vertical rays at the time when the days and nights are equal over the whole world, was the first-found element of the System. The Axes and Poles are, of course, known when the Great Circle is known, since the Axis must cut its plane at right angles, and the Poles be 90° distant. Of the Celestial System, also, the first-found element was doubtless its Great Circle, the Ecliptic; where the Sun, "the King of Day," apparently walks his annual majestic round through the constellations. In like manner, when the Intersections are arranged, as on the Celestial Globe, into one Compound System, although the angle of the Axes, 23½°, is the first or leading angle, yet that first noticed will

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5. What exception is there to the rule that the Intersections of the two Permanent Systems are Permanent? What Positions will be produced by Intersections of the Observer's (or the Movable) System with either of the two Permanent?—6. What difference is here noticed between a *fundamental* and a *first discovered element* of a Spherical System, and what is the fundamental element of each System? What do we presume was the first-found element of the Earth's System? The Great Circle of a System being given, how are the Axis and Poles known? What do we presume to have been the first-found element of the System of the Heavens? What angle in the combined Systems of the Earth and Heavens is the leading angle? and why?

necessarily be the angle $66\frac{1}{2}°$, or the angle of the Axis with the common plane of the Earth's orbit and the Ecliptic, which is the complement of the first angle, $23\frac{1}{2}°$. For *it is the coincidence of the Earth's orbit with the plane of the Ecliptic which constitutes the necessary connection between the two Systems.*

7. We will now consider how the Intersections of these two Systems give rise to the Polar Circles and the Tropics. If we suppose the Axis of the Ecliptic to be revolved from the centre at an angle of $23\frac{1}{2}°$ about the Axis of the Earth, it would mark upon the Earth's surface the Polar Circles. That around the North Pole is called the *Arctic Circle*, and that around the South Pole the *Antarctic.* The Sun, in his connection with the Celestial System, has his centre cut by the plane of the Ecliptic, and his central vertical ray always passing towards the centre of the Earth, in the same plane. His extreme rays then falling on just half the Earth, will always extend to the Poles of the Ecliptic, and no farther.

8. Now, the Poles of the Ecliptic are in the Solstitial Colure, which crosses the Equinoctial Colure at right angles in the Earth's Celestial Poles; while the Equinoctial Colure crosses the Equator at the Equinoctial Points. The Solstitial Colure, therefore, crosses the Ecliptic at the two opposite points where its distance from the Equator is the greatest, and where the Sun is at the time of the Solstices, and which therefore forms a limit to that portion of the Earth where the Sun's vertical rays fall. *The two Tropics are drawn through these Solstitial Points, and made parallel to the Equator*, of course at the dis-

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6. But what is naturally the first noticed? What constitutes the necessary connection between the two Permanent Systems? What are the degrees of each of the angles mentioned, and what are their relations to each other?—7. How, from the Intersections of the two Systems, are the Polar Circles produced? What are they called? From what circumstances concerning the Sun is it apparent that he is always shining just as far as to the Poles of the Ecliptic and no farther?—8. What is here said of the Solstitial Colure? what of the Equinoctial? Where, then, are the two Tropics drawn, and what is said of the names by which they are distinguished?

tance of $23\frac{1}{2}°$. When they received their names, the constellation Cancer was at the Northern Solstitial Point, and that of Capricorn at the Southern, and from these constellations they were called the Tropics of Cancer and of Capricorn.

9. The angle of obliquity which the Axis of any planet makes at its Intersection with the plane of its Orbit, is, as we have seen in our chapter on the Seasons, of great significancy. The Earth's Axis is, as we have already noticed in this chapter, oblique to the plane of its Orbit by an angle of $66\frac{1}{2}°$. If we place the Axis of the globe perpendicular to this plane (which, for this purpose, we will still fancy the wooden Horizon to be), the Equator would then coincide with the plane of the Ecliptic. The revolution of the Earth around the Sun would, in this case, cause no change of Seasons; for the Sun, as we may see by moving this Globe as before around a lamp, would at all times in the year shine equally upon the whole Earth, and the days and nights would everywhere, and always, be equal. This is supposed to be nearly the position of the Axis of Jupiter. The dwellers of that planet, who, on account of their greater distance from the Sun, have much less light and heat than ourselves, have not the same succession of seasons. Yet their planet, being so large, a great surface is spread out before the Sun, like a vast plane, and will thus intercept his rays almost vertically over a large part of its surface.

10. If the Axis of a planet should be coincident with, or lie in the plane of its Orbit, it would, at the period of its Equinoxes, in this, as in every other case, have the Sun's light direct upon the Equator, and shining equally to both its Poles; then, coinciding with those of the Ecliptic, its days and nights would be equal. But if, as before, we remove the Globe from the Vernal to the north Summer station, we shall see how very rapidly the season must be changed, till at the Summer Solstice the Sun's

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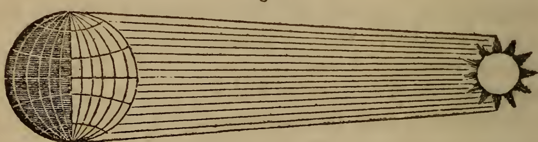
9. Suppose the Axis of any planet is at right angles to the plane of its Orbit? What planet is nearly in this case?—10. Suppose the Axis of any planet should lie in the plane of its Orbit?

rays would fall direct upon the North Pole—the whole northern Hemisphere be enlightened, and the whole southern in darkness. This is an imaginary case. No known planet has its Axis parallel to its Orbit. It implies changes so great and rapid, that no animal or vegetable known to us could endure them.

11. We recognize the goodness and wisdom of God in inclining the Axis of the Earth, so as to accommodate the creatures which he has made to inhabit it. Mars has his Axis inclined to the plane of his Orbit 30°, Saturn (distinguished for his bright rings) at an angle of 29°, and Uranus probably at the large angle of 46°. If these and other circumstances vary the climates of the different planets, the inexhaustible wisdom of the Almighty will doubtless have suited the planets to their inhabitants, or the inhabitants to their planets.

12. Every place on the Earth's surface lying between the Tropics, has the Sun's direct rays shining upon it twice each year. At the Tropics he is vertical only once a year,—in the Northern, at the Summer Solstice, and in

Fig. 14.



the Southern, at the Winter Solstice. From the convexity of the Earth, the climate is hottest where the Sun's rays are direct.* This belt of the Earth's surface between the Tropics is called the Torrid Zone, and is 47° broad.

* Let Fig. 14 be drawn large. Compare the number of rays falling near the Equator and the Poles.

10. Do we know of any planet in this case? What consequences would follow?—11. What is the position of the Axis of Mars? of Saturn? of Uranus? For what is Saturn distinguished? Do we recognize wisdom and goodness in the arrangements by which the Almighty has prepared man for a planet whose Axis is inclined as ours is? And suppose other planets do vary, what may we conclude concerning their inhabitants?—12. Where is the Torrid Zone, and what is its breadth?

In vegetable productions, the Torrid Zone shows the fertilizing power of the Sun's rays. Here

> "Blossoms and fruits together rise,
> And the whole year in gay confusion lies."

But man was made for labor, and in this Zone, as he needs little shelter or clothing, and his food grows spontaneously, he is but too often an indolent, unlettered savage.

13. The two FRIGID ZONES are around the Poles, and included within the Polar Circles. They enjoy too little of the Sun's influence to afford the necessary productions to sustain man's life, or to warm and expand the air, so as to afford him a healthy respiration and a comfortable home. The island of Spitzbergen, within ten degrees of the North Pole, inhabited by a few Russian fishermen, is the extreme northern limit of human habitation. Captain Parry penetrated, in one of his late voyages, to latitude 82° 45′ north. But it is at great risk of human life that these high latitudes are ever visited. Our own day furnishes an example, in Sir John Franklin, of a bold navigator, whose life, and that of his associates, has doubtless fallen a sacrifice to the temerity of attempting to penetrate those forbidden regions of ice and snow. Both England and America, moved by the solicitations of his wife, the noble Lady Franklin, have vainly sent out expeditions to search for him in the Arctic seas of the American continent, where the last traces of him were found.

14. The two Zones lying between the Tropics and Polar Circles, are called the NORTHERN and SOUTHERN TEMPERATE ZONES. These Zones are the most healthy and desirable habitations of the human race. Living as

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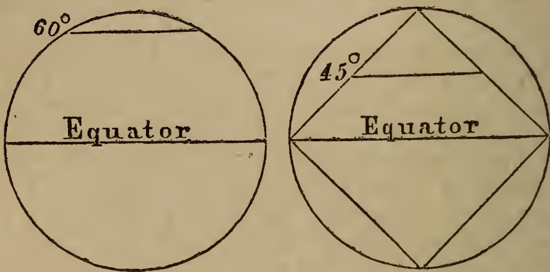
12. If you multiply its breadth in degrees by 69, what number of *miles* in breadth will you find the Torrid Zone to be? What circumstance distinguishes this Zone from all the rest of the Earth?—13. What is here said of the Frigid Zones? What example has recently been given of the danger of braving the rigors of the Frigid Zone?—14. What is said of the Temperate Zones?

we do near the middle of the Northern Temperate, we can, in degree, judge for ourselves concerning their climate and productions. If the Earth were in form like two solid cones meeting at the base, its size would diminish in exact proportion to its Equatorial distance; the circle of latitude 45°, the middle of the Temperate Zone,

Fig. 15.



would then be half the length of the Equator; but, from the globular form of the Earth, the circle of latitude, which is half the extent of the Equator, is the parallel 60°. Of course each degree of longitude at the latitude 60° is one-half the width of a degree at the Equator; and since a degree on the Equator is 60 geographical or 69 statute miles, a degree there will be 30 geographical or $34\frac{1}{2}$ statute miles.

15. In taking a general view of the surface of the Earth, we are at once struck with some singular coincidences of conformation in the great divisions of land in the eastern and western continents. Each continent comes to a point in the Southern Temperate Zone; each has a large number of fertile islands lying in the Torrid Zone; each spreads to its greatest width in the Northern Tem-

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14. What is said concerning the place on the Earth where a circle of latitude is just half the Equator in extent? What, then, does a degree of longitude measure in Latitude 60°?—15. In studying the Terrestrial Globe, what remarkable coincidences shall we find?

perate; and each extends its northern outskirts into the Frigid.

16. Of the five Zones, although the Torrid is the largest, yet the Northern Temperate Zone is historically and geographically the most remarkable. In this alone, there is on the Earth's surface more land than water. In one of the Zones,—the Southern Frigid,—there is no habitable land known, and in another,—the Northern Frigid,—there is very little. In the Southern Temperate and Torrid Zones, the surface covered by water is more than double that occupied by land. It is in the Northern Temperate Zone, and in the heart of the greatest continent of the Earth, that the first vestiges of the human race are found; and there the Saviour of mankind made his advent. In this Zone have been located all the great empires known to history. But now, on the western continent, extending from ocean to ocean, has been planted a Republic, whose career has been providentially blessed, and whose government is the most just and equal of any yet known to man. May the Almighty grant to its inhabitants the wisdom and virtue to sustain its noble institutions, and to recommend them to the world.

EXERCISES.

Since the Meridians or lines of Longitude are all great circles, and Latitude is measured in all its degrees from 0° to 90° on some one of these, a degree of Latitude is always the same, and may be estimated in statute miles at 69 miles to a degree. But the degrees of Longitude, beginning at the Equator, and reckoning each way, diminish, on account of the spherical form of the Earth, to their vanishing point, the Poles.

The following table, which we recommend should be committed to memory, will show the number of statute miles contained in a degree of Longitude in every tenth degree of Latitude. The geographical mile is one-sixtieth part of a degree (or corresponds with a minute) on a great circle, and is larger than the statute mile in the ratio of 60 to 69:

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16. What general comparison may be made concerning the five Zones, geographically and historically?

Degrees of Latitude.	Statute Miles.
On the Equator	69
10	68
20	65
30	60
40	53
50	44
60	34½
70	23½
80	12
90	0

It is important to gain a distinct idea, both on the Globe and in the Heavens, of that semicircle of the *First Secondary of the Ecliptic* from which Celestial Longitude is reckoned. Passing from one Pole of the Ecliptic to the other, it cuts the Ecliptic at right angles at the first degree of Aries, and it is called by Astronomers the *First of Aries.* The Point where it cuts the Ecliptic is that so often referred to—the Vernal Equinoctial Point. It here intersects, as we have seen in the preceding chapter, both the Equinoctial and its principal Secondary, the Equinoctial Colure; the latter at an angle of 23½°. We hope our students have already a distinct idea of the Vernal Point; and will now remember that it is here where the Equinoctial and its principal Secondary meets the Ecliptic and its principal Secondary, and from which Longitude is reckoned on the Ecliptic from its Secondary, the First of Aries, and Right Ascension from the Equinoctial, or its principal Secondary, the Vernal Colure. This makes the Vernal Equinoctial Point the most important Point in the Heavens for us to understand, as to its exact position, except the North Celestial Pole. Having found in the Heavens this Point, extend your eye over 90° direct to the Pole of the Ecliptic, and the line your eye will follow is that of the First of Aries. Observe from the Celestial Globe, that Latitude and Right Ascension are the same at the Equinoctial Points, but diverge as Latitude and Declination increase, and are finally at an angle of 23½°, as measured by the arc of the Solstitial Colure, in which both the Ecliptic Pole and that of the Equinoctial are found.

On the Terrestrial Globe, learn the parts of the Earth through which the Fourth and Fifth Almacantar Circles pass; review their distance from your own position, the Upper Vertex, and pay special attention to learning from the Globe the exact location of your Antipodes. If they are in a ship at sea, what is their position with regard to the nearest large country and islands, and what is their latitude and longitude? What is their distance in degrees and miles from yourself?

CHAPTER XII.

THE INTERSECTION OF SPHERICAL SYSTEMS.—THAT OF THE EARTH WITH THAT OF THE OBSERVER.—EIGHT CENTRAL ANGLES OF THE INTERSECTING SPHERES.—LATITUDE AND LONGITUDE THE FOUNDATION OF GEOGRAPHY.—OF NAVIGATION.—MEANS OF FINDING LATITUDE.

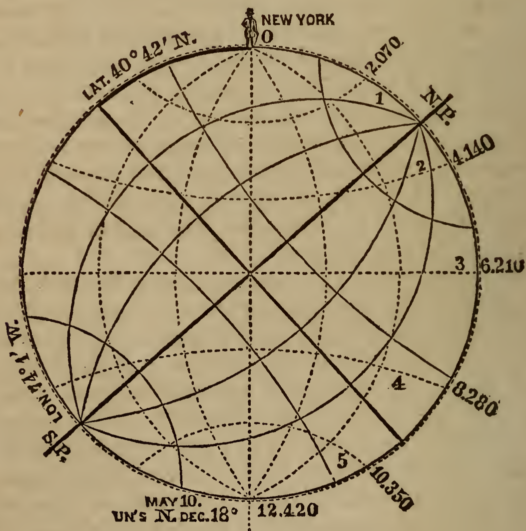
1. IN the INTERSECTION of one Spherical System with another there must be at their common centre eight angles; unless either their Axes coincide, or mutually, the Axis of the one System coincides with the plane of the Great Circle of the other; in which cases there will be four angles at the centre, of 90° each. In all other cases, the intersection of the simple elements of two Spherical Systems—viz., their Axes and Great Circles—will produce *eight angles at the centre, whereof four will be equal to the angle made by the Axes, and four will be equal to the complement of that angle.*

2. For proof, inspect the accompanying figure, by which is represented the Intersection of the Observer's Movable System of Positions, with the Permanent Positions of the System of the Earth; the former being distinguished by dotted lines. At the centre are eight angles. The two Axes—the Earth's and the Observer's Line—make the angle which is measured by the arc extending from the Observer's place, or Upper Vertex, to the North Pole. To this its opposite vertical angle, measured on the arc extending from the South Pole to the Nadir, is equal. The two vertically opposite angles (of course equal to each

CHAPTER XII.—1. What angles in all, except the cases mentioned, are produced at the centre by the Intersection of one Spherical System with another?—2. Draw on the blackboard the outer circle of the figure with the two Axes and the profile of the planes of the Great Circles, and explain the figure as far as regards the four first-named angles.

other), made by the intersections of the two Great Circles, are equal to the two first. For suppose the Spheres so placed together that the Axes should coincide with each other, then the planes of the Great Circles must coincide also; but if the Axes are so moved as to make angles at the centre, then the plane of each Great Circle must move with its Axis, and just as many degrees. So that the two vertical angles made at the centre by the planes of the Great Circles will be equal to the two, which may be termed Axial, and the four angles are therefore equal each to each. Of course the arcs which subtend them are equal also.

Fig. 16.



3. Although it is more systematic to begin with the Intersection of the Axes and Great Circles, yet in forming this union of two Systems into one, it is an angle made by the Axis of the one System with the plane of the

2. What proves that they are equal each to each?

Great Circle of the other, which is the first-found and leading element. That is *the angle made by the Observer's Line with the plane of the Equator*, or the ANGLE OF THE OBSERVER'S LATITUDE. The arc which measures it on the Terrestrial Sphere which he inhabits is his LATITUDE. We have in the figure distinguished the arc of the Latitude by a heavier line.

4. In the diagram, we locate our Observer at New York, in Latitude 40° 42′. The arc 40° 42′ which measures the angle of Latitude, measures, of course, its opposite vertical angle, subtended by the arc extending from the Nadir to the Equator. Equal to the angle of the Latitude, also, is that of the elevation of the North Pole above the Horizon, and its opposite vertical, that of the depression of the South Pole. For suppose the two Systems so brought together that the Axis of one—viz., the Observer's Line—shall coincide with the plane of the Great Circle of the other—viz., the Equator—then will there be also, since all the angles are right angles, the mutual coincidence of the other Axis and Great Circle—viz., the Axis of the Earth with the plane of the Horizon.

5. If, then, the Observer's Line shall move any number of degrees, as by the Observer's going north of the Equator, that Great Circle will apparently recede towards the south; and since its Pole is always distant 90°, as the Equator sinks towards the south, the North Pole will rise above the Horizon, degree for degree. If the Observer, then, is 40° 42′ north of the Equator, the same will be the arc of the altitude of the North Pole, and also of its opposite vertical angle, the depression of the south.

6. The angle of Latitude and its opposite—the angle of the elevation of the North Pole and its opposite—are therefore four angles, all equal to the angle of Latitude,

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3. Describe the angle which is practically the elementary or first-found angle in this System—composed by the combination of two Systems.—4. Describe the diagram in reference to the location of the Observer, and the angle and arc of his Latitude.—5. What proves the equality of the altitude of the North Pole to the Latitude?—6. How are four angles proved to be equal each to each?

and of course equal each to each. By reference to the figure, it is seen that each quarter of the circle has one of these four angles of 40° 42′, and one of the remaining four, each of which must therefore be an angle of 49° 18′, the angles of 40° 42′ and those of 49° 18′ being complements each to each. These eight angles at the centre take up as their subtenses the whole 360° of the circle.

7. Terrestrial Latitude and Longitude, in some respects, admit of a common description. They are imaginary circles which cross each other at right angles, and when reckoned in degrees and minutes, they together exactly define the situation of any place on the Earth's surface. By means of the position of the heavenly bodies, they are ascertained with exactness by instruments made for the purpose. The Latitude and Longitude of any newly discovered point on the Earth's surface can thus be determined, and its name set in its true place upon maps and globes.

8. On the sea-coast, the correct situation of the principal capes, bays, and promontories being thus ascertained, and the noble science of mathematics lending its aid, the boundaries of the sea and land are made out, and exhibited in their true positions. Geography, that most familiarly useful of all the sciences, is thus, by means of Latitude and Longitude, settled on a firm foundation ; and is no longer, as in ancient days, involved in darkness and obscurity. . . The Baron Humboldt says, it is Columbus to whom the world at large is indebted for the knowledge of the great truth that the Earth is a globe. Many are the navigators who have followed in his track, discovering new islands in the deep, which, being correctly marked on maps and globes, can now at pleasure be visited again, and their products be exchanged for those of other lands, for the benefit of all.

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6. What, according to the location of the Observer in the figure, must be the degrees and minutes of each of the eight angles and their corresponding Arcs? Suppose the Observer's Latitude was 10° N., what would then be the number of degrees of each of the eight angles?—7. In what respects do Latitude and Longitude admit of a common description?—8. Describe the manner in which Geography, as a science, is based and settled on the foundation of Latitude and Longitude.

9. Thus the great art of NAVIGATION, by which the ocean-barrier has been converted into a broad highway of nations, owes its usefulness to Latitude and Longitude. The mariner has his charts and maps—made out on a great scale, with not only all the coasts and harbors which he may wish to visit laid down exactly in degrees and minutes, but he has all those objects which would endanger his safety, such as rocks and shoals, marked down also.

10. From the former part of the preceding lesson, we may learn what various methods may be devised, by measurements of the heavenly bodies, to ascertain the Latitude of our Position; for since four of the eight angles of the combined Systems are ever above our Horizon, if means can be found of measuring any one of these four angles (celestially the same as if measured terrestrially), we shall have found our Latitude, either directly or indirectly. If we could measure the Sun's altitude as he comes to the Meridian at either of the Equinoxes, that would be the *complement* of our Latitude;—his Zenith distance will then be the Latitude itself. If it is the Summer Solstice, the Sun will be nearer to us when in our Meridian than is the Equator, by 23½°, which must therefore be added to the Zenith distance, to obtain our Latitude;—if at the Winter Solstice, the same must be subtracted; and we must, in the same manner, for lesser items of northern or southern declination, add or subtract, as the case may be.

11. By measuring the altitude of the Polar Star, we obtain the measure of an angle equal to that of our latitude; by measuring its Zenith distance, an arc equal to our co-latitude. This is regarded by many as quite

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9. In what manner is Navigation indebted to Latitude and Longitude?—10. What principles have we learned concerning the eight angles which may show what various methods can be taken to obtain from the Celestial Sphere a knowledge of Terrestrial Latitude? When will the Sun's altitude be the measure of the co-latitude? What then is the arc of his Zenith distance? What must be done at the Solstices to find the Latitude by the Sun's position? At other times, besides the Equinoxes and the Solstices, when must the Sun's declination be added, and when subtracted, from his Zenith distance?

the best method of ascertaining Latitude. Or suppose you have some bright star on your Meridian, as the upper one of the three which compose the belt of Orion, and you know that this star is upon the Equator, then if you measure the arc from this to your Zenith, it will be your Latitude. If you measure on the Meridian the distance of the star to the southern Horizon, you will then have measured the arc of your co-latitude. These facts show the great practical importance of the science of which we treat.

EXERCISES

On the Celestial Globe review, as you have time, the following Constellations and single Stars, and observe their positions in the Heavens:

CONSTELLATIONS AND PRINCIPAL STARS OF THE ZODIAC.

Names of the Constellations.	Names of the Principal Stars and their Magnitudes.
1. Aries, the Ram.	Arietis, 2d magnitude.
2. TAURUS, the Bull.	*Aldebaran*,1. Group { *Hyades.* *Pleiades.*
3. Gemini, the Twins.	*Castor*, 1; *Pollux*, 1.
4. Cancer, the Crab.	Acubens, 3.
5. Leo, the Lion.	*Regulus*, 1; *Denebola*, 1.
6. Virgo, the Virgin.	*Spica Virginis*, 1.
7. Libra, the Balance.	Zubeneschamale, 2.
8. Scorpio, the Scorpion.	*Antares*, 1.
9. Sagittarius, the Archer.	} The largest Stars in these are of the 3d magnitude.
10. Capricornus, the Goat.	
11. Aquarius, the Water-bearer.	
12. Pisces, the Fishes.	

PRINCIPAL NORTHERN CONSTELLATIONS.

Names of the Principal Northern Constellations.	Names of the Principal Stars and their Magnitudes.
URSA MINOR, the Little Bear.	*Cynosura*, the Pole Star.
URSA MAJOR, the Great Bear.	{ *Dubhe*, 1; *Alioth*, 2; Benetnasch, 2; Mizar, *Megrez*, Phad, Merak.
DRACO, the Dragon.	Rastaben, 2.

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11. What is regarded by many as the best method of finding Latitude? How might the Meridian altitude of a fixed star determine Latitude?

Names of the Principal Northern Constellations.	Names of the Principal Stars and their Magnitudes.
CASSIOPEIA, the Lady in her Chair.	Schedir, 3; *Caph*, 3.
Camelopardalis, the Camelopard.	
CYGNUS, the Swan.	Deneb, 2.
Lynx.	
Lacerta, the Lizard.	
Auriga, the Wagoner.	*Capella*, 1.
Perseus et Caput Medusæ, Perseus and the Head of Medusa.	Algenib, 2; Algol, 2.
Andromeda.	*Alpherat*, 2.
LYRA, the Harp.	Vega, or *Lyra*, 1.
Hercules.	
Corona Borealis, the Northern Crown.	Alphecca, 2.
Boötes, the Herdsman.	*Arcturus*, 1.
Coma Berenices, Berenices' Hair.	
Aquila, the Eagle.	Altair, 1.
Pegasus, the Flying Horse.	Markab, 2; Scheat, 2.

PRINCIPAL SOUTHERN STARS.

Names of the Principal Southern Constellations.	Names of the Principal Stars and their Magnitudes.
Cetus, the Whale.	Menkar, 2.
Eridanus, the River Po.	Achernar, 1.
ORION.	*Rigel*, 1; *Betelguese*, 1.
CANIS MAJOR, the Great Dog.	*Sirius*, 1.
Canis Minor, the Little Dog.	*Procyon*, 1.
Hydra, the Water-serpent.	Cor. Hydra, 1.
CRUX, the Cross.	
Piscis Australis, the Southern Fish.	Fomalhaut, 1.
Argo Navis, the Ship Argo.	Canopus, 1.

On the Terrestrial Globe learn to give a general account of the principal states, cities, large waters, rivers, mountains, and islands which lie within your first Almacantar Circle; or within the distance of 2,070 miles from your own position. These places being nearest your own position, their situations should be the most minutely understood.

CHAPTER XIII.

GREAT CIRCLES CAN, BY THEIR PLANES, BE TRANSFERRED FROM ONE SPHERE TO ANOTHER.—SMALLER CIRCLES CANNOT.—OBSERVER'S LINE AND AN IMAGINED RAY OF SOLID LIGHT MADE MEDIUMS FOR TRANSFERRING CIRCLES OF LATITUDE AND OF DAILY MOTION.—COMPARATIVE LENGTH OF DAYS AND NIGHTS. —RIGHT SPHERE.—PARALLEL SPHERE.

1. OUR next subject will be the Connection of Circles of Daily Motion with Latitude, and the different Lengths which the Days and Nights have at different times in the year, and in different Latitudes. This subject has a relation to that of the Seasons; but from its importance, and its complicated nature, it demands a separate consideration,—to which the investigations of the preceding chapters lead the way.

2. There is, we are aware, a confusion in the minds of learners respecting the correspondence of the smaller circles in the two Spheres of the Earth and Heavens. They are apt to fancy that these circles on the Earth must, like the Equator and other Great Circles, each have its plane extending to the Heavens, there to mark its corresponding circle. But this is impossible.

3. The centre of the Earth is the common centre of the two concentric Spheres. Every Great Circle of the Terrestrial Sphere cutting this centre, and dividing the Earth into Hemispheres, may have its plane extended so as to cut the Heavens proportionally, dividing the Celestial Sphere also into Hemispheres. In the same manner will the plane of any Great Circle of the Heavens divide the Earth. But this is not the case with smaller circles.

CHAPTER XIII.—1. How does the author state the subject?—2. What supposition of learners is here asserted to be an impossibility?—3. How may Great Circles be transferred from one Sphere to the other, dividing each proportionally?

Their planes, as extended from the Earth to the Heavens, will cut the Celestial Sphere, but not proportionally.

4. Indeed, if the planes of smaller circles, parallel to Great Circles on the Earth, should be extended to the vast distance of the Celestial Sphere, they would then coincide with the plane of their Great Circle,—the small space between them vanishing in the distance. Thus the plane of the sensible Horizon, tangent to the Earth, and at the distance of its whole semidiameter, coincides, when extended to the Heavens, with that of the Rational Horizon. Much more would this happen, should the planes of parallel Almacantar Circles be extended, since they cannot be so far from the Rational Horizon as is the tangent plane of the Sensible. In the same manner, if a plane tangent to the Earth, at the North Pole, were extended to the Heavens, it would there coincide with the plane of the Equator. Much more, then, would the planes of all circles of Latitude, which are of course nearer to the Equator, coincide with the Equinoctial should they be extended to the Celestial Sphere.

5. By similar reasoning, it may be shown, that no plane of a circle of the Heavens, which is not a Great Circle, can be supposed to cut the Earth. Take, for example, the Equinoctial, whose plane (it being a Great Circle) intersects the Earth's centre and marks on its surface the Equator. No Celestial Circle parallel to the Equinoctial would have its plane touch the Earth at all, if its distance from the Equinoctial exceeded 4,000 miles, the Earth's semidiameter; but it would pass at right angles to the Earth's extended axis, either north or south of the Terrestrial Poles; so that it is evident that in the Intersection of two Spheres, the planes of smaller circles in the one being extended to the other, do not, like the planes of Great Circles, produce circles corresponding to

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4. Suppose smaller circles of the Earth should have their planes extended to the Heavens: How would it be with the plane of the Horizon, and of those of its smaller parallel circles? with the Equator and its parallels?—5. Can the smaller circles of the Celestial Sphere be transferred by the extension of their planes to the Terrestrial?

themselves. But the Circles of Daily Motion made by the Sun, and other Heavenly bodies, are, except when they are in the Equinoctial, smaller circles, and yet they have their proportional circles on the Earth, and these are parallels of latitude. The Tropics, and the Polar Circles, too, as placed on Maps and Globes, have their counterparts in the Heavens.

6. We want, then, to find mediums which, extending from the one Sphere to the other, shall mark corresponding circles. These can be found; but they will be straight lines, and not planes. We consider parallels of latitude, as originating on the Earth and extending to the Heavens, but Circles of Daily Motion, as originating in the Heavens, and extending to the Earth. The Line of the Observer meeting with the plane of the Equator, at the common centre of the two Spheres, makes the angle of the Observer's Latitude.* As the Earth revolves once on its Axis, the extremity of the Line, the Observer's Zenith, would describe in the Heavens a circle there proportionate to his parallel of Terrestrial Latitude. Suppose the Observer's Latitude to be 20°: the circle thus described in the Heavens would be 20° from the Equinoctial; and thus would be transferred a smaller circle from the Earth to the Heavens.

7. *The apparent path which the Sun, or any other heavenly body, describes in moving through the Heavens during one rotation of the Earth on its Axis, is its Celestial Circle of Daily Motion for that day.* In order to obtain a correspondent Terrestrial Circle, let us conceive as coming from the centre of the heavenly body a ray of solid light (since light moves in straight lines), of

* That is, meeting with *a straight line* drawn from the Earth's centre to the Meridian, *on the plane of the Equinoctial.*

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5. Do corresponding smaller circles exist, however, on the two Spheres?—6. How can we find an imaginary line which, proceeding from the Earth, may be supposed to mark the smaller circle of the Observer's Latitude on the Celestial Sphere, as the Earth revolves on her axis?—7. How may we fancy a line which, coming from the Celestial Sphere, shall mark on the Terrestrial, as it daily revolves, any heavenly body's Circle of Daily Motion?

sufficient density and force to penetrate to the Earth's centre. This line of light, where it intersects the Earth's surface, would mark, as the Earth revolved on its axis, the Terrestrial Circle of the Daily Motion of the heavenly body from which it proceeded. The Terrestrial Circle thus described upon the Earth's surface, would be that over which the vertical ray of the body describing it would on that day fall.

8. Any fixed star, shooting its central ray of solid light to the Earth, would thus mark its line of daily motion, which would be invariable, since both the stars and the direction of the Earth's axis are fixed. Owing to the immense distance of the fixed stars, they appear in the same places when viewed from opposite parts of the Earth's orbit. By the Earth's annual motion, however, they appear to describe a yearly circuit, though their Circle of Daily Motion is the same. But the Sun, as we have seen in the chapter on the Seasons, having his apparent yearly motion in a circle in which one solstice is 23½° north of the Equinoctial, and the opposite 23½° south, traverses twice in a year 47°, from one Solstitial Point to the other.

9. So that, except for a few days at the Solstices, the Sun's Circles of Daily Motion, unlike those of the Stars, will, on each successive day, be in a different part of the Heavens, and over a different part of the Earth. The Sun has six months' time to traverse the 47°, from the Winter to the Summer Point, and six to return; that is, three months in which to make 23½° distance, which is nearly 8° in a month, or about 16 minutes a day. His course is, therefore, like a huge spiral screw, whose threads are close to each other.

10. The Sun is vertical at noon to any Observer when his Circle of Daily Motion equals in declination the

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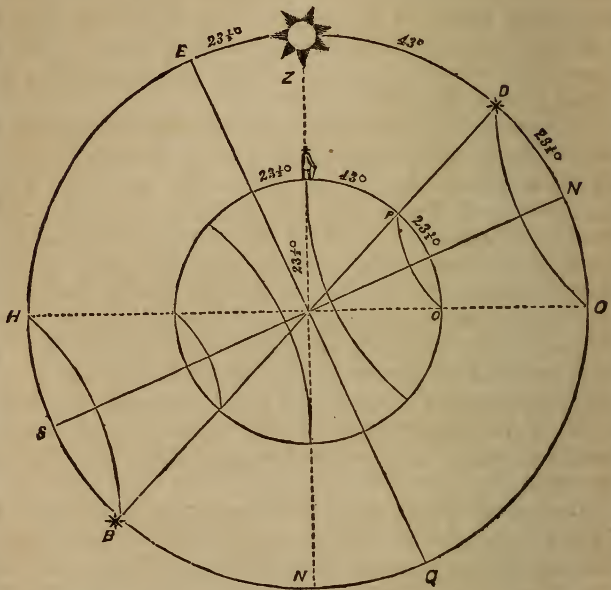
7. What would the circle described be in regard to the heavenly body whose central ray describes it?—8. What is here remarked of the Circles of Daily Motion of the Fixed Stars? In what respect do the Sun's Circles of Daily Motion differ from those of the Fixed Stars?—9. Describe the Sun's Circles of Daily Motion during a year.

Observer's Latitude, and at no other time. The accompanying figure represents an Observer whose latitude is

Fig. 17.



23½° north, having on the day of the Summer Solstice the Sun in the Solstitial Point, on his Meridian. A Ray of Light supposed to proceed from the centre of the Sun will coincide at this day with the Line of the Observer; and these two lines being, by a revolution of the Earth on its axis, made to describe correspondent circles on the two Spheres—the Observer's Zenith in the Heavens, and the Sun's central ray on the Earth—there will be circles both of the Observer's latitude 23½°, and of the Sun's

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10. Draw the figure and explain from the blackboard how the imagined central ray of the Sun's light has marks on the Terrestrial Circle of the Sun's Daily Motion, or his vertical course over the Earth at a specified day—viz., the 21st of June.

declination on the 21st of June; and in this case these lines will coincide, and the Observer must on that day have the Meridian Sun in his Zenith. And to every Observer in this latitude, this will be the case, and to no other; for in no other part of the Earth on this day will the Sun's Circle of Daily Motion be identical with the Observer's Latitude.

11. To show how our imagined ray of solid light will apply to the circles described by those heavenly bodies, which are far from the Equinoctial, let us take a star D, in the Celestial Sphere, whose distance from the Zenith is 43°. This, added to the Observer's Latitude, would make its Northern Declination 66½°, and its Polar Distance 23½°. We will imagine our line of light passing through P to the centre. As the Earth revolves, the star describes a celestial circle from D to C, concave towards N, the North Pole of the Heavens. The line of light from its centre marks on the Earth's surface, as it rotates, the corresponding circle from P to O. This circle in the Heavens is the diurnal circle of the star at D, and its corresponding circle on the Earth's surface is that upon which its vertical rays daily fall; and since the position of the stars and the Earth's axis are both fixed, the vertical ray of this star would fall in the same manner perpetually, and would in this case forever mark upon the Earth the Arctic Circle.

12. The Polar Distance of the star at D is, as seen on the diagram, equal to the latitude of the Observer; and this star, we perceive, just touches his Horizon at its lower culmination. Wherefore, *when the Polar Distance of any star is equal to or less than the latitude of any place, if it be towards the elevated Pole, it never sets; if towards the depressed Pole, it never rises.* This may be seen on the diagram, by the star at B, the same distance from the

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11. Draw on the blackboard and describe the Circle of Daily Motion of a Star whose Zenith Distance is 43°, and its Northern Declination 23½°.—12. What must be the Polar Distance of a Star which, at its lower culmination, just touches your Horizon? What Stars in your latitude describe Circles of Perpetual Apparition? of Perpetual Occultation?

Southern Pole, as is the star at D from the Northern. Stars which never set describe *Circles of Perpetual Apparition*, and are *Circumpolar Stars;* those which never rise, describe *Circles of Perpetual Occultation.*

13. Every Observer has all his Circles of Daily Motion, except those of Perpetual Apparition and Occultation, cut by his Horizon into two parts, upper and lower. So far as the Sun's light is regarded, the upper is the *Diurnal* and the lower is the *Nocturnal* arc. Since the Sun's presence causes Day, and his absence Night, no arcs but such as he traces in the Heavens can, with the same propriety, be called Diurnal and Nocturnal. *When the days and nights are equal to any Observer, then his Horizon cuts the Sun's Circle of Daily Motion into two equal parts.* This can never be except at the Equinoxes, when it coincides with the Equator. The greater his distance from the Equator, the greater will be the difference between the Observer's *Diurnal* and *Nocturnal* Arcs, and the reverse.

14. This may be understood by *Fig.* 18, in which we see that the Horizon, H O, cuts into equal parts, E Q, the Equator, and into unequal parts the Circles of Daily Motion, D R F and A B C. In this diagram we give the Observer's Latitude at 40° north, the Sun's Declination at 20° south, and the hour, noon, when the Sun is on the Meridian. Our imagined line of solid light will, by the rotation of the Earth, mark on this day on its surface the Circle of the Sun's Daily Motion, A B C. As much shorter as is the arc A B than the arc B C, of which A B above the Horizon is the Diurnal, and B C below the Horizon the Nocturnal Arc, so much shorter will be the day of the Observer (under Z, the Zenith) than will be

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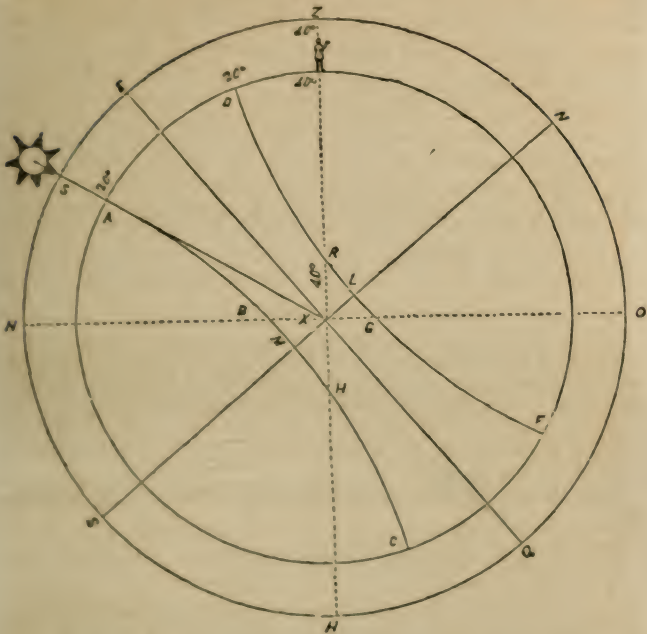
12. How is it with Stars near the South Pole which are equal to or less than your latitude?—13. How does your own Horizon, or that of any Observer, cut all his Circles of Daily Motion, except those of Perpetual Apparition and Occultation? To what are the terms Diurnal and Nocturnal Arcs applied? When the Observer has his days and nights equal, what occurs? Which has the greatest difference in the length of his days and nights, the Observer in 10° of latitude or in 20°?

Fig. 18.



his night. If the Sun had a Northern Declination of 20°, the same Observer would have had D R F as his Circle of Daily Motion. His days would then have been longer than his nights; and by the same difference, since D G and G F have the same difference as A B and B C.*

15. By inspection of the same figure, it is apparent, that in all latitudes the Observer's day and night will be equal, when the Equator coincides with the Sun's Circle

* Referring to the figure, the difference between the two diurnal arcs D G and A B will be seen to be L G + B M, or twice L G; since L G = B M.

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16. Draw on the blackboard and explain from the figure how our imagined line of solid light from the centre of the Sun would describe the Observer's Circle of Daily Motion (his latitude and the Sun's declination being given).

of Daily Motion—that is, at the Equinoxes; and that in all latitudes where the Sun's Circle of Daily Motion is nearer to the Observer than the Equinoctial, his days will be longer than his nights; but when it is farther, his days will be shorter than his nights. Although the Observer (*Fig.* 17) is only 23½° from the Equator, and the Sun is in his Zenith, so that he would cast no shadow to the north or south at noon, yet his diurnal is longer than his nocturnal arc, and his days are longer than his nights.

EXERCISES.

In order to educate the eye of the pupil to judge of distances in the Heavens, let him learn, and looking at the Heavens and pointing to the stars mentioned, say aloud or mentally:

From Merak to Dubhe is 5°.
From Dubhe to Megrez is 10°.
From Dubhe to Mizar, 20°.
From Dubhe to Benetnasch, the whole extent of the Dipper, 25°.
From Caph to the Pole Star, 30°.
From Lyra to the Pole Star, 5C°.
From Megrez to Caph, 60°.

Remark that the degrees mentioned are degrees of a great circle, not degrees like those of Celestial Longitude and Right Ascension, which diminish till they vanish at the North Pole and the Pole of the Ecliptic.

Remark, further: these distances, in some cases, lack a little of absolute correctness. Lyra has 38½° of northern declination, which makes its Polar distance 51½°. The distance of the Pole Star from the true Pole of the Heavens is about 1½° *towards* Caph. Now Caph is about 31½° from the true Pole, but is 30° from the Pole Star. Megrez has the same distance as Caph from the true Pole, but is a little farther from the Pole Star; and thus the distance from Megrez through Cynosura to Caph is a little more than 60°.

Lyra's position it is highly important to know. Our students, in learning our plan of studying the Heavens, will never be at a loss to remember the Vernal Colure on the Caph side of Cynosura, and the Autumnal Colure on the Megrez side of that Pole

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15. Suppose the Sun to have had the same degree of northern declension? Show from the figure the difference between the Diurnal and Nocturnal arcs. (Observe the note.)

Star; and then all know that the other, or Solstitial Circle of the Colures, crosses the Equinoctial Circle at Right Angles in the North Pole; but on which side of Caph is the Winter Colure? We wish to locate this, because in it is the Pole of the Ecliptic, one of the keys of the whole system of Uranography. Now, then, look for Lyra, that beautiful lonely star, the brightest of the northern host. Lyra is only 4° east of the Pole of the Ecliptic, and about 26° south. If Lyra is not to be seen—for being a little without our circle of perpetual apparition, it will, though rarely, be absent—you may then know that the Ecliptic Pole is beyond the Earth's Pole, and nearer the Northern Horizon. The Ecliptic Pole may also be discerned and located by the cluster of stars in Draco. Or you may say, since Winter is before Spring, I shall find the Winter Colure to the west of the Vernal.

On the Terrestrial Globe, describe the divisions of land and water on the Second Almacantar Zone of 2,070 miles breadth, recollecting that the distance of these places from your own is from 2,070 to 4,140 miles. What number of square miles do the first and second of these Almacantar Zones contain? See Chapter IX.

CHAPTER XIV.

SPHERES.—A RIGHT SPHERE; A PARALLEL SPHERE; AN OBLIQUE SPHERE.—THE ATMOSPHERE—NECESSARY TO MAN'S RESPIRATION; THAT IS, HIS LIFE.—AERIAL TIDES.—OCEANIC MOUNTAINS.

1. OF the Intersections of the Observer's System with that of the Earth, there are three different modes; producing, first, a RIGHT SPHERE; second, an OBLIQUE SPHERE; and, third, a PARALLEL SPHERE. Every inhabitant of the Earth lives in one of these three Spheres. Although nearly the whole population of the world reside in the Oblique Sphere, yet it is profitable to take the view here indicated, for the sake of better understanding the various positions of the Observer, and the effect

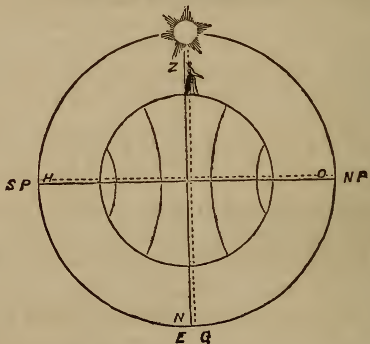
CHAPTER XIV.—1. Of what Systems does your author here speak? Of what three modes of their Intersection? What is remarked of the residence of mankind in regard to these Systems?

upon the influence of the Sun and the appearance of the heavenly bodies; for if, comparatively, few live on the Equator, and none at the Poles, yet the intermediate stations approximate in condition, according as they do in place, to the one or the other.

2. *When the Observer's System so intersects the Earth's, that, mutually, the axis of the one lies in the plane of the Great Circle of the other, his place is in a* Right Sphere. This is one of the two cases in which the central angles of the Intersection of the two Systems are four Right Angles. All the dwellers in this Sphere live on the Equator, and, of course, under the Equinoctial.

3. The accompanying figure shows the Observer in a Right Sphere. The dotted lines represent the Axis and

Fig. 19.—A Right Sphere.



Great Circle of his Movable Positions. They here coincide with the firm lines which represent the Permanent Positions of the Earth's System; the Axis of the Earth lying in the plane of the Horizon, and the Observer's Line in that of the Equator. This figure represents the

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1. Why, since mankind mostly live in one, is it worth while to pay attention to all of these three Spheres?—2. When is the Observer's place in a Right Sphere? Where are all the people who live in a Right Sphere?—3. Draw and explain the diagram of the Right Sphere, recollecting the use of the dotted lines.

Sun as being in the Zenith of the Observer. This determines the hour of the day to be noon, and the time of the year to be either the 20th of March or the 23d of September; since in those days only (the Equinoxes) is the Sun's circle of daily motion coincident with the Equator. But on either of these days the Sun's central meridian ray will coincide with the Observer's Line, and as the Earth rotates, that central ray will mark on the Earth the Equator, while the Zenith will describe in the Heavens the Equinoctial.

4. This is properly called the Observer's *Right* Sphere, because all his circles of daily motion, whether of the Sun or other heavenly bodies, ever make with his Horizon *right angles*. When the Earth's motion on its Axis shall carry the Observer from his noon position, as seen in the figure, his western Horizon will, like ours, rise to meet the Sun, while his eastern will recede; but its movement will be direct—not, as with us, oblique to the Meridians or Hour-Circles. If our Observer, in the figure, has now the Vernal Colure in his Meridian, then the entire circle of the Solstitial Colure will coincide with his Horizon, as will be seen by referring to the Globe. And every circle of daily motion being cut by this into equal Diurnal and Nocturnal Arcs, our Observer's days and nights must be always equal.

5. The Poles of the Earth lying in our Observer's Horizon—as his Meridian sweeps the starry Heavens, every constellation in its season will present itself to his view; whether its semicircle, like that of Orion on the Equator, be the largest possible, or whether it has diminished as it has receded towards the Poles, like that described by the Southern Cross or the Northern Bear. The Polar Star

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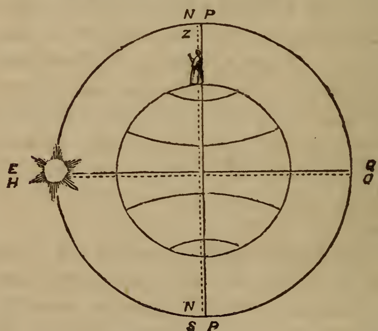
3. It being known that the Observer's place is on the Equator, what is to be inferred from the fact that the Sun is in his Zenith? —4. Why is it proper to call this a Right Sphere? If the Observer at the Equator moves from his noon position, what may be said of the movement of his Horizon? Suppose at the noon position the Vernal Colure is coincident with the Observer's Meridian, what will coincide with his Horizon?—5. What stars will be visible to this Observer?

Cynosura rests quiescent in the Northern Horizon, without a mate at the South, and this Observer has no Circumpolar Stars. The Observer on the Equator is in the only true position on the Earth's surface, with regard to the Points of Compass. Here alone the positions of the Movable System do not, in this respect, conflict with those of the Permanent.

6. The PARALLEL SPHERE constitutes the only remaining case where, in the Intersection of two Spherical Systems, there are four right angles at the centre. When the two Axes coincide, and also the planes of the two Great Circles—viz., the Observer's Line with the Axis of the Earth, and likewise the plane of the Equator with the plane of the Horizon—then the Sphere is said to be Parallel.

Fig. 20.—A Parallel Sphere.



7. We have represented the parallel Sphere in the accompanying diagram, where E Q, the Equator, is parallel with H O, the Horizon, and the Observer's Line with the Earth's Axis, as may be seen by the double line, one part dotted, which in our figures always represent Movable Positions. The Sun in the United Horizon and Equator

5. How do the Points of Compass appear to the inhabitant of the Equator?—6. What is said of the Parallel Sphere?—7. Draw the figure, and explain the position of the Observer in the Parallel Sphere.

indicates the time of the year to be one of the Equinoxes. Our Observer here is imaginary; for we know not that any actual human being has ever seen, what is nevertheless a demonstrated reality, the grand spectacle of the Heavens where all the stars of the Northern Hemisphere are, for six months, wheeling their perpetual circles of daily motion around the Polar Star, fixed in the Zenith; nor whether any one, after this long night, and after weeks of morning dawn, has seen the glorious Sun appearing in the Horizon—wheeling as he rises, and rising as he wheels—performing his circle of daily motion, so nearly parallel to the united Equator and Horizon, that in three months he is above them but $23\frac{1}{2}°$; then standing for a few days at the Summer Solstice, he winds down his immense spiral for another three months—till at the Autumnal Equinox he is again in the combined Great Circles of the Earth and the Observer: and then after an evening, where the Twilight lasts two months, that "Eye of the World" is again fully closed, and the firmament left to the cold brightness of the Moon and Stars, and the streaming coruscations of the Aurora Borealis.

8. The great length of the morning and evening Twilight in the Parallel Sphere, reminds us that we have not yet brought forward the important subject of the ATMOSPHERE, or AIR, which surrounds the Earth. After merely defining the Oblique Sphere, we will interrupt our present subject and proceed to its consideration. All cases of the intersections of the two Spheres—viz., of the Earth and the Observer—which do not produce right angles at the centre of the combined System, are OBLIQUE SPHERES; and these are all cases whereof the combined System has eight angles at the centre, as heretofore explained. As the Oblique Sphere comprehends the great variety of positions of the bulk of mankind who reside between the Equator and the Poles, we shall, though not immediately, resume this subject.

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7. What is said of the appearance of the Sun and other heavenly bodies in a Parallel Sphere?—8. When is the Sphere said to be *oblique?*

9. Both the heat and light of the Sun are modified in a manner greatly beneficial to man by the ATMOSPHERE or AIR, which surrounds the Earth, rising above it, to a height varying probably from 35 to 50 miles. The Atmosphere is the element in which Man exists by respiration. There must be lungs to breathe, and air to be breathed, else animal life does not begin; or having begun, it ceases. And there is no more important rule to direct us to use means for our physical well-being than this, that *the more perfect is breathing, the more vigorous is health; and the reverse.*

10. All animal life is thus sustained by Respiration,—a term which implies the existence of *atmospheric air*, and its reception by lungs. Animal heat is produced by the union of the oxygen contained in the *Air*, as it chemically combines, in the way of animal combustion, with the carbon of the blood; which is derived from the aliment—viz., the water and the food—taken at the stomach.

11. Animals are said to have a great quantity of breathing when they consume much Air. Birds have much breathing, and consequently great animal heat and a rapid circulation of the blood. Fishes, whose gills are imperfect lungs, which obtain no Air, except from the small quantity contained in water, have, on the contrary, so little animal heat, that they are called cold-blooded animals. They would not be animals at all unless they breathed. "Respiration," says the great naturalist, Cuvier, "is that which animalizes," or constitutes a being an animal.

12. The *atmosphere* is commonly defined as an *elastic fluid*. By its fluidity its particles move easily among themselves, and by its elasticity they may, by external

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9. What is here said of the Atmosphere? How does the importance of the Atmosphere in regard to man appear? What rule important to health and life is here laid down?—10. What is said of Respiration? Has animal heat any connection with the atmosphere?—11. When are animals said to have a great quantity of breathing? What difference is noticed between birds and fishes? Are there any animals which do not breathe?—12. How is the atmosphere defined?

pressure, be diminished in volume, and made more dense, and when that pressure is removed, spring again into large bulk. Heat expands and coldness condenses air; and hence the Sun's rays affect it. The atmosphere is also affected by Gravitation. Being adjacent to the Earth, its attraction keeps its particles from flying off into the regions of space. But the nearest particles gravitate most to the Earth, which makes them heavier. And this superior density is increased by the pressure of the superincumbent atmosphere: so that the density of the air is greatest at the surface, and rapidly diminishes as we ascend.

13. The whole weight of any assumed column of the atmosphere from the Earth upwards, is equal to a column of water of equal base, and of the altitude of $32\frac{1}{2}°$, or of a column of mercury of 29 inches. In Pumps and Hydraulic Machines, atmospheric pressure is taken off from a portion of the surface of water, while it remains on the surrounding fluid, and in Barometers from quicksilver. The result shows the comparative weight of the atmosphere; the water rising $32\frac{1}{2}$ feet, and the mercury 29.

14. The barometer, when taken to higher regions of the atmosphere, as to the tops of mountains, shows a diminution of the weight of the atmosphere; and travellers, in ascending heights, or going up in balloons, find themselves less and less able to breathe freely. In ascending 1,000 feet, the Air will have lost one-thirtieth of its weight, and in an ascent of 10,000 feet, one-third; of 18,000, one-half. Such heights are dangerous to beings formed to breathe the lower regions of the atmosphere,

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12. What is the consequence of its fluidity? of its elasticity? What effect have heat and coldness? Gravitation? What two causes operate to give a greater density to the layer of Air next the Earth's surface?—13. What is the weight of a column of the Atmosphere as compared with water? with quicksilver? How does this appear?—14. How is it proved that the weight of the Atmosphere diminishes as the distance from the Earth's medium surface diminishes? Is the Atmosphere far above the Earth found suitable for respiration? What is the height at which the Air loses one-thirtieth of its weight? one-third? one-half?

especially when the change is made suddenly; and in ascending still higher, a region will be found where the atmosphere is too rare to support flame or animal life.

15. Owing to the diurnal rotation of the Earth, the atmosphere is higher in the Equatorial regions than at the Poles, and is therefore, on its outer surface, still more spheroidical than the Earth itself, whose denser material would not, like air, readily yield to the operation of the causes of a form which is believed to be universal among the planets—that of the oblate spheroid.

16. Were the atmosphere to be free from all causes of the motion of its particles among each other, it would become unhealthy from stagnation. The same remark is applicable to WATER—that important element which, next to Air, is the object of man's most imperative necessity. Air and Water are in their nature connected, and being agitated together, as in storms of Wind and Rain, they mutually purify each other. Air, like Water, is also kept from stagnating by the attraction of the Sun and Moon, especially the latter; by means of which there are AERIAL TIDES. By the Tides, as will hereafter be explained, the whole of the particles of both the Air and the Water which surround the Globe are every day moved throughout their entire masses.

17. Water covers more than two-thirds of the surface of the Earth; but this proportion is none too large to give the greatest possible amount of arable land. For land not suitably watered, by running streams, by rains and dews, is nothing but a useless and hideous desert, without life, either animal or vegetable; and wherever these are interior parts of vast continents which cannot be watered—such deserts are found; as in the heart of Asia, Africa, and North America. The Ocean is the

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15. Where is the Atmosphere the highest? What do we suppose to be the form of the Atmosphere? What is believed to be the form of all the planets?—16. In what case would the Atmosphere become unhealthy? What is here said of Water? How do Air and Water mutually purify each other? What beneficial effect of the gravitation of the Sun and Moon is here noticed?—17. What proportion of the Earth's surface is covered by water?

grand reservoir of circulating waters. The Sun's heat raises them by evaporation, and the atmosphere receives and condenses their minute particles into clouds;—by its density bearing them up—by the agitation of its winds, scattering them in rain, hail, and snow upon the land. The clouds being especially attracted towards mountains, vast quantities fall there, so that on their highest summits fountain springs and deep lakes are kept supplied with water for the thousand streams which, flowing down the mountain sides, become confluent in the valleys, form rivers, and thus carry their waters back to the Ocean, to be again circulated over the land.

18. The bottom of the Ocean has the same variety of surface as the land. The tops of oceanic mountains appear as islands; and often mountain ranges are made visible by chains of islands which are connected with highlands or promontories of adjacent continents. Such are the Aleutian islands connected with the promontory of Alaska. The greatest depths of the Ocean yet sounded exceed the highest mountain eminences by about one-fifth; and there is reason to believe that its profoundest depths have not yet been sounded. So that it is probable that the depth of the water below its surface may be to the height of the land above the same, in about the proportion of the extent of the surface of the water to that of the land.*

* This opinion is sanctioned by the celebrated Lieut. MAURY, of Washington.

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17. What reason have we to suppose that this proportion of water is none too great for the good of man? Where have circulating waters their reservoir? By what are the waters of the Ocean raised? How do they become clouds? In what form do they fall to the Earth? Where is their fall most abundant? and how does this conduce to their perpetual circulation?—18. What is said of the form of the Ocean's bed? Where do the tops of Oceanic mountains appear? Where are seen ranges of Oceanic mountains continued from the land? What is said concerning the depth of the Ocean?

EXERCISES.

We hope our learners will by degrees acquire the power of so controlling their minds *as to make truth* in Astronomical Geography SEEM TRUTH. We know that we live not merely on an outstretched plane of land and water, with a blue dome above us, but upon a convex Globe, with an apparent concave sphere on every side, studded with stars. And we know that the circles concerning which we have been studying, and which belong to the two Permanent Systems, can only half of them appear to us at once. Let us, when we *see* what is above our Horizon, exercise our minds to locate, *in imagination,* their counterparts below.

After having prepared ourselves by the previous examination of the Globe, let us go forth and study the stars. Let us point with one hand to the North Pole, and keeping the two arms in the same straight line, point with the other hand to the South Pole. Point next to the North Ecliptic Pole, and then in the same manner to the South. We know that beyond the convex Earth, which is between us and the opposite Heavens, is the Concave Celestial Sphere, and we see it in fancy, if not in reality. Then, with your eye on the North Ecliptic Pole, point to it, and keeping your finger pointing the same distance from Cynosura ($23\frac{1}{2}°$), move it around that Polar Star, and you will have pointed out the Arctic Circle in the Heavens. Perhaps you already know from the Globe the stars through which it passes. You know of course that it is about 7°, nearly one-quarter of the distance nearer the Pole than are Caph and Megrez. Then turn to the South, and shutting your eyes, and thinking of the stars below, move your finger as if you traced out the Southern Polar Circle of the Heavens. The bright Southern Cross and the Centaur will perhaps seem to be where they are—a few degrees north of the Antarctic. Their circles of daily motion, you know, are circles of perpetual occultation, as those at the north are of perpetual apparition. Still they are in the Heavens beyond the Earth. There they have an actual existence in the celestial places towards which you point.

In the same manner follow over the face of the sky (first reviewing, if necessary, the Celestial Globe), and notice the principal constellations through which pass the Northern and the Southern Tropics, and lastly the Equator, carrying these circles around the Earth, by sight, above your Horizon, and by imagination beneath.

The Northern Tropic in the Latitude of New York is 15 hours above the Horizon and only 9 beneath. The Equator bends 40° north of your Nadir below the Horizon, as it does 40° south of your Zenith above. Of the remaining distance (50°), the Tropic of Cancer takes $23\frac{1}{2}°$; so that for the northern limit of that Tropic below the Horizon, you must point within 26½° of your Horizon's north.

From the Terrestrial Globe learn the third Almacantar Zone, extending from the 2d to the 3d Almacantar Circle, which is the Horizon—*i. e.*, that is, from 4,140 miles to 6,210 miles from your own position. Learn what are the great divisions of land and water, cities, islands, &c., noticing the points of compass in which they lie from yourself.

CHAPTER XV.

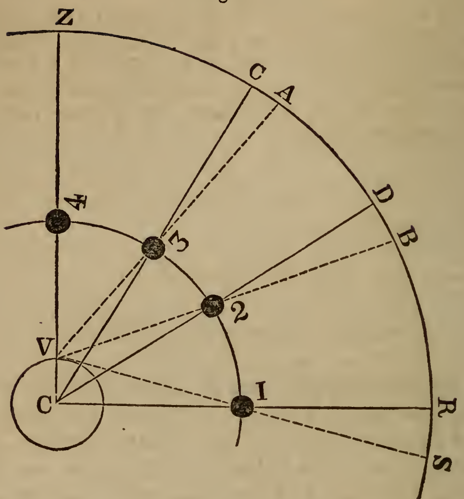
Parallax.—Refraction.—Reflection.

1. If all astronomers were to make their observations without regard to the convenience of each other, their labors would be comparatively useless. They, therefore, by common consent, all make their observations on celestial bodies as if from one and the same point; and that point is the centre of the Earth. But a heavenly body, viewed from the surface of the Earth, will appear in a position somewhat different from that which it would occupy if viewed from the centre. The first is called the *apparent*, the second the *true* place, and the difference is called the body's *Parallax*. If the body is seen in the Horizon, it is the *Horizontal Parallax;* if between the Horizon and the Zenith, the *Parallax of Altitude.*

2. In *Figure* 21, C is the centre of the Earth, V the Upper Vertex or place of the Observer; 4–1 is an arc of the Moon's Orbit of 90°, showing the Moon in four different stations, of which the first (1) is Horizontal, and the fourth (4) is Vertical; Z S is an arc of 90° of the Celestial Sphere. To an Observer at the centre, the Moon on the Horizon at 1—since vision is in straight lines—would

Chapter XV.—1. Why do astronomers, by common consent, make their observations from one and the same point, and what point is it? Explain what is meant by the apparent and the true place of a heavenly body and its Parallax. What is Horizontal Parallax? Parallax of Altitude?

Fig. 21.



appear in the Celestial Sphere at R, while to the Observer at the Upper Vertex, it would appear at S; lower than R by the arc R S. This arc is then the measure of the difference between the true and the apparent place of the Moon in the Horizon, and it is therefore *the arc of the Moon's Horizontal Parallax;* and the angle which this arc subtends, R 1 S, is *the Angle of the Moon's Horizontal Parallax.*

3. Between the Horizon and the Zenith, the heavenly bodies have a Parallax of Altitude diminishing as the altitude increases, until at length it vanishes in the Zenith. The parallactic angle and arc, when the Moon is in the second position, are less than in the first, smaller still in the third, and are nothing in the fourth; the Observers at the Centre and Upper Vertex having then the same line of vision. *The Horizontal Parallax of any heavenly body is, therefore, its greatest Parallax.*

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2. Draw on the blackboard and explain Fig. 21.—3. Where is Parallax the greatest?—How is Parallax affected by increase of Altitude?

4. The more remote from the Earth is any heavenly body, the less will be its Parallax. Suppose a planet, as Venus, to be at R, her Parallax will be less than that of the Moon at 1; for if we draw the line of vision from the Observer at the Upper Vertex to R, meeting that from the Observer at the centre (which of course lies in the plane of the Horizon), the angle V R C will be less than the angle V 1 C, and its opposite and equal angle (suppose the lines C R and V R continued) will be also less, and the corresponding parallactic arc also. In the same manner take points more and more remote, and the angle of Parallax continues to diminish, until it becomes quite imperceptible. The Moon's Horizontal Parallax is 57′ 1″.

5. The Moon being nearer than any other heavenly body, her Parallax is greater, and *the Moon's Horizontal Parallax affords the greatest possible parallactic angle.* This angle may be precisely determined, and *it becomes the medium through which the Moon's distance is known.* For in the triangle V 1 C the angle at 1 is equivalent to the parallactic angle. The angle at V being the angle made by the line of vision V 1 with the perpendicular V C, may be exactly measured; and since the angle at C is a right angle, the parallactic angle must be of so many degrees as that at V falls short of 90°, the three angles of a triangle being equal to two right angles or 180°. In this triangle the length of one side, V C, the semidiameter of the Earth is known to be 4,000 miles. The angles being known and the length of one side, the remaining sides can be found, and one of these sides, C 1, is the Moon's distance from the Earth, which is thus known to be 240,000 miles.

6. To the general rule that any heavenly body is as many degrees above the Horizon as its measure on a Vertical Circle would show, exception must be made on ac-

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4. What effect has increase of distance from the Earth on Parallax? Explain by the figure.—5. For what two reasons is the Moon's Horizontal Parallactic Angle the greatest possible? What important use is made of this angle? Explain on the figure the triangle V 1 C.—6. What is the general rule concerning the position of a heavenly body?

count of REFRACTION as well as Parallax. Refraction refers to the nature of light and the laws of vision.

7. We *see* by means of rays of light which ordinarily proceed in straight lines from the objects of vision to the eye. The eye sees those objects in the direction of the ray which last enters the eye, and at the distance of the length of the ray. Thus, in general, nature teaches us to regard the objects of sight in their real positions. But for wise ends the Creator has given to light the properties of Reflection and Refraction, by which its blessings are multiplied; although by their means objects appear out of their true places.

8. Light, in passing through certain transparent substances, such as glass, water, and air, has its rays bent. This bending of the rays of light, as they are coming to the eye from bodies which are seen through these transparent mediums, is termed *Refraction*. If you place a

Fig. 22.

staff obliquely in a vessel of clear water, it will appear bent, and the bottom of the staff nearer the upper surface

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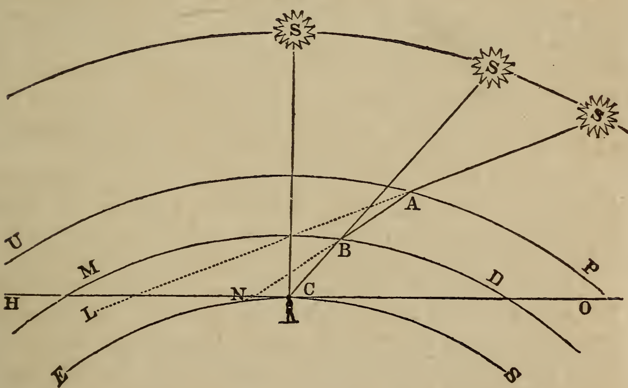
6. What exception is to be made? To what does Refraction refer?—7. By what means do we *see?* In what direction are objects seen? At what distance? By what properties of light do objects appear out of their true places? What good purpose is thus effected?—8. When is light said to be refracted? What illustration is given?

of the water than it really is. If you place the staff perpendicularly, there will be no refraction.

9. The more dense the medium, the greater the Refraction, and the reverse. Now, the atmosphere which surrounds the Earth is a transparent and slightly refracting medium ;—more and more dense as it comes nearer and nearer to the Earth. On account of this, all the heavenly bodies are seen by rays slightly bent downwards as they enter the atmosphere, and curving more and more as they proceed to the eye; so that they thus appear above their real places. The Sun is thus seen above the Horizon after its body is really below, which makes the day two or three minutes longer than the night. The angle of Refraction grows less and less as it approaches the Zenith, where it is nothing.

10. This is further illustrated by the appended figure,

Fig. 23.



in which E S represents a section of the Earth's surface, at the upper vertex of which stands our little Observer ; but here we have placed his feet somewhat lower than usual, because for our present purpose his eye must be in the

9. What is said of the atmosphere in reference to Refraction? How is the Sun's appearance affected by the Refractive power of the atmosphere?—10. Draw and explain Fig. 23.

plane of his Sensible Horizon, H O. Since rays of light are not bent by Refraction when they enter a denser medium perpendicularly, the Observer will see the Sun in his Zenith in his true place, by a ray of light which comes direct. But suppose the Sun to be in the station most distant from the Zenith of the three stations on the figure, he will see the Sun in this case above the true place, and as being in the station next above. For he sees him by a bent ray, and in the direction of the ray which last enters his eye. If there had been no atmosphere, the Observer would have seen the Sun by a ray which would have come direct from the Sun to his eye. Without refraction, the ray S A, by which he now sees it, would not have come to his eye, but would have passed above it and proceeded to L; or had it been only refracted at A as it entered the upper layer of the atmosphere, it would have passed to N; but by continued refractions it forms the curve S A B C, and this entering the eye in the direction B C, that direction is, by the laws of vision, followed by the Observer's eye to the distance of the object, and there the Sun appears above his true place. The arc on the Celestial Sphere between the true and the apparent place of a heavenly body is the arc of Refraction.

11. Thus we see that while Parallax lowers the true place of a heavenly body, Refraction elevates it. The astronomer must, therefore, in order to find the true place, subtract the arc of Refraction and add that of Parallax.

12. We have seen that Refraction, operating by certain properties of the atmosphere, has an effect to increase and prolong the light of the Sun. REFLECTION has perhaps still greater influence in multiplying the blessings which we derive from that king of terrestrial glory. It is by the Reflection of the Sun's light that all opake bodies are known to us by sight, that the Moon cheers us by her milder radiance, and Venus shines forth in beauty, the star both of the morning and the evening. But

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11. In what respect have Parallax and Refraction opposite effects?—12. What effects are produced by the Reflection of the Sun's rays?

especially for the mild dawn of the morning and the calm twilight of the evening are we indebted for the reflection of the Sun's light, as it falls upon the denser particles of the atmosphere below the Horizon. The last ray which, by the united powers of Reflection and Refraction, influences the sight of the Observer, comes from the SUN when he is 18° beneath it.* Twilight under the Equator continues an hour and twelve minutes; since 15° of space (it being a Right Sphere) equals an hour of time, and 3° equals 12 minutes. But as the Observer goes from the Equator towards the Poles, the Sun's line of daily motion becomes more and more oblique till, in latitude 49°, within 18° of the Polar Circle, twilight at the Summer Solstice continues all night. Since in a Parallel Sphere, the descending Sun is three months in reaching his lowest point, after going below the Horizon, which, as the Equator and Horizon are here coincident, is 23½°; then as 18 is to 23½ will be the proportion of that three months which will have twilight after the Sun descends and dawn before he rises.

EXERCISES.

Our last exercise was one in which we hope our learners took pleasure; and if so, it is evidence of improvement, for it was a bold lesson, and one on which we would not have ventured at first. But it is easier to learn whole circles than half ones, and incomparably more profitable. This you will more plainly see as you pursue Astronomical Geography. And who knows but you may yet travel South, stand on the Equator, and see all the stars alike to both Poles. Or perhaps you will advance into the centre of the Southern Hemisphere, and with your own eyes see the constellations there, making their perpetual circles, while those of the North will then have to be imagined. In

* The Quadrant of Altitude, when fastened to the Upper Vertex of the Terrestrial Globe, extends 18° below the Horizon to show the extent of twilight; so that in any latitude it is easy to find it.

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12. What is here said of twilight in a Right Sphere? in Lat. 49°? in a Parallel Sphere?

such a case of Southern residence, you would see some black spots of the sky looking almost as if the blue vault had apertures through which your eye penetrated into the profound abyss of immeasurable space. These spots, which are not yet understood, are called the *coal-sacks.* There is also to be seen in the Southern Heavens another unexplained phenomenon. It is a pyramid, faintly luminous, called the *Magellanic Light.*

Observe now in the Heavens and on the Celestial Globe the *Galaxy*, or Milky Way. It is an interesting part of the Celestial Sphere, and is especially considered as such, since the elder Herschel discovered by his great telescope, what has since been confirmed, that its cloudy white or milky appearance is the effect of an innumerable congeries of stars, too distant for our unaided vision separately to contemplate. This great Zone of the Heavens surrounds the Earth; but passing below our Horizon to the South into what is to us the region of perpetual occultation, we can never see its Southern portion, but we must imagine it. In studying the Milky Way on the Celestial Globe, let us consider it according to its general form, which is that of a great circle of the Celestial Sphere. Let us first find its extreme northern and southern parts. These will be found—the northern in Cassiopeia, near Caph, and the southern in the Southern Cross. Place these two points in the Northern and Southern Horizon of the Celestial Globe, and the general course of the Milky Way will then be nearly coincident with the Horizon. It will be seen that at its greatest (northern and southern) declination, it crosses the Equinoctial Colure (at the north the Vernal, and at the south the Autumnal); so, at its intersections with the Ecliptic and the Equator, it crosses the Solstitial Colure.

On the Terrestrial Globe, continue the study of the Almacantar Zones. Learn what lands, seas, great rivers, mountains, and cities the *Fourth* Almacantar Zone contains, and remember that their distance from your own position is from 6,210 miles to 8,280 miles. Which of the Almacantar Zones have an equal number of square miles?

CHAPTER XVI.

The Moon.—Its Poetic Influence.—Size.—Position.—Three Motions.— Orbit.— Selenography.— Nodes.— Gravitation.— Tides.—Light of the Moon.—Eclipses.

1. An infant who had just begun to utter single words, joyfully exclaimed, as he saw the full Moon rising, "Lamp! lamp!" The transport of the child was poetic. All poets love the Moon—especially when they are sad and sentimental. Thus Burns:

> "O thou pale Moon, that silent shines,
> While care-untroubled mortals sleep!
> Thou seest a wretch, who inly pines,
> And wanders here to wail and weep."

2. The great Milton, however, who never suffered himself, though utterly blind, to "bate a jot of heart or hope," thus describes the Moon, with the other heavenly bodies which bedeck the evening sky:

> "Now glowed the firmament
> With living sapphires; Hesperus, that led
> The starry host, rode brightest, till the Moon,
> Rising in clouded majesty, at length,
> Apparent queen, unveiled her peerless light,
> And o'er the dark her silver mantle threw."

3. By Hesperus is meant the planet Venus, the brightest star of the Heavens. This planet, nearer the Earth than any other, and having its orbit within the Earth's, is never seen far from the Sun. When she is in that part of her orbit where she rises before the Sun, she is called the Morning Star. The ancients supposed this

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Chapter XVI.—1. What is related to show that the appearance of the Moon naturally awakes poetic ideas? Of what class of poetic ideas is the extract from Burns, which you may repeat?—2. Of that from Milton, which may also be recited?—3. Give an account of the appearance of the planet Venus, and of the opinion of the ancients concerning it.

to be different from the Evening Star, and called it "Lucifer, son of the morning." When Venus is at that part of her orbit where she rises after the Sun, of course invisibly, she is seen as soon as the withdrawal of his rays will permit. She remains above the Horizon for some time after his setting, and is then called the EVENING STAR.

4. The diameter of the Moon is 2,160 miles, varying but little from that of the largest of the Asteroids. Forty-nine such bodies would be needed to make one of the bulk of the Earth;—to make one the bulk of the Sun, more than fifty millions. In surface, there is not the same difference. The Moon-Observer would see the Earth as we see the Moon, except 13 times larger, and full, when to us the Moon is new. It would wax and wane through all the phases, from new to full, and the reverse; and it would of course eclipse the Sun to the lunarians, as much more than the Moon does to us, as its surface is greater.

5. The Moon's mean distance from the Earth is 240,000 miles, while the Sun's is 95,000,000. Thus the Sun's distance exceeds the Moon's by nearly 400 times. But their apparent size is nearly equal, each showing upon the Celestial Sphere a mean diameter of a little more than half a degree. If bodies appeared less by distance, only in the *direct* ratio of the distance, the Sun would show immensely greater than the Moon; but the ratio in which objects diminish to the view as they recede, is in the compound ratio of *the square of the distance;* that is, if a body is three times the distance of another, the bulk of the two being equal, their apparent sizes will be as 1 to 9—since the square of 1 is one, and the square of 3 is nine. The apparent diameters of both the Sun and Moon are increased, when in or near

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4. What is the Moon's diameter? How much smaller is the Moon than the Earth? than the Sun? What is the difference in surface of the Moon and Earth? How would the Earth appear to an inhabitant of the Moon?—5. What is the mean distance of the Moon from the Earth? of the Sun? the comparative distance? What is their apparent size? What is said of the ratio by which bodies appear less as they recede from the eye?

the Horizon, by Refraction. Their horizontal diameters, from the same cause, appear elongated. In certain states of the atmosphere, its powers of refraction are so increased, that the Sun and Moon sometimes appear on the edge of the Horizon to be about a degree in breadth.

6. The Earth, as has been seen, has two motions—the Moon has *three:* one around the Earth, performed in about 27¼ days; one around the Sun, accompanying the Earth in her annual revolution; and another around her own axis, on which she rotates once in 27¼ days, the same time as her revolution round the Earth. By turning on her axis, she always keeps the same side towards the Earth. The fact that she does so, is known by observation, and can be accounted for only on the supposition that she revolves on her axis in exactly the same time as she moves around the Earth.

7. The period of 27¼ days is called *a sidereal month*, because it is the time of the Moon's passing from the meridian of any star until it return to the same meridian. But since the Earth is moving from west to east around the Sun, while the Moon is revolving around the Earth in the same direction—before the Moon, having set out from her conjunction with the Sun can come to the same point again, that is, to what is called *the change of the Moon*—she has to go on farther, to keep up with the Earth's course; so that from change to change—that is, from new Moon to new Moon again—is 29 d. 12 h. 44 m., which is called a *synodic month.*

8. The Moon's orbit is an ellipse, having the Earth in one of the foci. The *eccentricity* of the Moon's orbit, or the distance of either of the foci from the centre, is cal-

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5. How are the apparent diameters of the Sun and Moon increased? To what apparent size do they sometimes attain when on the Horizon?—6. What three motions has the Moon? What is said of her revolution on her own axis?—7. What is a sidereal month? What is the length of the synodical month? Why is it longer than the sidereal?—8. What is said of the Moon's orbit? What is its eccentricity? What is that of the Earth's orbit?

culated at 13,333 miles. The Moon, when in its *Perigee*,* or nearest station, must then be 26,666 miles nearer the Earth than when at its *Apogee*,* or farthest station. The eccentricity of the Earth's orbit is 1,618,000 miles; so that when she is at her *Perihelion*,* or nearest station to the Sun, she is 3,236,000 miles nearer than when in her farthest station, or *Aphelion*.*

9. *Selenography*,† or Lunar Geography, has been of late studied by means of the immense telescopes which the elder Herschel, and others since him, have brought into use. It has thus been shown that those cloudy appearances which children suppose to be the features of the "man in the Moon," are in reality deep valleys or the shadows of high mountains. Of these some have been discovered of the supposed height of nearly five miles. The principal are called by the names of celebrated astronomers. Mount Newton is marked at 23,830 feet. The elder Herschel discovered what he regarded as volcanoes in the Moon.

10. From the variations in her place and appearance, at some times being nearer the Equator, and some times many degrees to the north or the south, and then changing in apparent size from a faint crescent to the full round Moon, it is no wonder that with the unlearned the Earth's satellite has little reputation for consistency and stability; and that it should be said of capricious persons, that they are as changeful as the Moon. But in reality, though not in appearance, the Moon is as true to her ap-

* These four words are derived from the Greek. *Helios* is the Sun; *Gee*, the Earth; *Peri*, about or near; *Apo*, from, receding.

† Selenography, from *Selene*, the Greek word for Moon.

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8. What is the difference between Aphelion and Apogee? between Perihelion and Perigee? How much nearer to the Sun is the Earth in her Perihelion than in her Aphelion? How much nearer to the Earth is the Moon in her Perigee than in her Apogee?—9. What is said of Selenography? How has the "man in the Moon" been fairly put out of countenance? What is said of lunar mountains?—10. What is said of the changes in the Moon's place and appearance? How is it in reality?

pointed course as the Sun. The variations of the Moon's place in the Heavens may be understood by considering that the plane of the orbit in which she revolves around the Earth is nearly coincident with the common plane of the Earth's orbit and of the Ecliptic, making with it an angle of only about five degrees. The line of the intersection of the plane of the Moon's orbit with this common plane is called *the Line of the Nodes*,—the NODES themselves being the points of the intersection of the Moon's orbit with this plane. The Moon, then, in her revolution around the Earth, is always either in the Ecliptic, or at most having only about five degrees of celestial latitude. Add this to the $23\frac{1}{2}°$, the greatest declination of the Ecliptic, and it will give to the Moon a range of $28\frac{1}{2}°$ each side of the Equator, the double of which is 57°; so that the Moon's place in the Heavens ranges in an Oblique Sphere from south to north, on the Meridian nearly one-third of a Great Circle of the Upper Heavens. There will be, as you may perceive by examining the globes, a still greater number of degrees on the Horizon; and this excess will be the greater, in proportion as the Observer's latitude increases.* The Moon moves around the Earth in the order of the signs from west to east. So also move all the other satellites of the Solar System around their primaries.

11. Of all the laws by which the Almighty arranges and governs the material world, none which man has investigated are so sublime as those of GRAVITATION. It is these,

"Which but to guess, a Newton made immortal."

Gravitation is a term used to express that attraction which,

* For a continuation of this subject, see the exercises following this chapter.

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10. What two planes make an angle of about five degrees? What is the line of their intersection called? What are the Nodes? What is the part of the Heavens where the Moon may appear—or, in other words, how far each side of the Equator can the Moon ever be seen? In what direction does the Moon move around the Earth? the other satellites around their primaries?—11. What is said of Gravitation? What is its definition?

acting on all bodies, even the greatest, and at the remotest distances, binds the universe together. All solid bodies gravitate towards each other,—centre being attracted to centre,—and with a force varying in a ratio compounded of distance and quantity of matter. This ratio is the same as was mentioned concerning the effects of distance in diminishing the apparent size of bodies. If two bodies are equal, and at equal distances from a third body, they will gravitate towards it with equal force; but if one of them has a distance compared with the other of 3 to 1, then the nearer—in a ratio of 9 to 1; that is, the quantity of matter being equal, in the inverse ratio of the square of the distance. But if the size of the farther body were trebled, as well as its distance, the gravitation of the farther body to the nearer would then be as 3 to 9; that is, bodies gravitate towards each other *directly as their quantities of matter, and inversely as the square of their distance.*

12. Hence, although the Sun is so much greater than the Earth, the Moon obeys the more intimate attraction of nearness, and continues to revolve around her primary; and hence the waters of the Earth are more attracted by the Moon than by the Sun. Solids, as we have said, gravitate in masses, centre to centre, but fluids not adhering together, every drop may be considered as a little separate globe gravitating by itself. The waters of the Earth, although held to its surface by a gravitation which impels each drop towards the Earth's centre, yet feel the attraction of the Sun and Moon—chiefly of the nearer influence of the Moon; and as the centres of these bodies pass directly over the waters, the equilibrium of their attraction to the Earth is disturbed, and they rise up unequally. This rising of the waters of the Earth by the influence of the Moon and the Sun is called TIDES.

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11. What is the ratio of the force of Gravitation? Give the example?—12. Give some examples in which the Gravitation of nearness prevails over that of superior quantity of matter. What difference is there in the manner in which solids and fluids gravitate? How is the equilibrium of the Earth's waters disturbed? What are Tides?

13. By the diurnal revolution of the Earth, parts of its ocean-surface are exposed to the direct action of the Sun and Moon. The particles of water are most attracted, and rise towards these points The *crest-wave* of the Tide follows the Moon (her attraction being the greatest) in her apparent daily course around the Earth. The inert matter of the waters does not, however, *immediately* follow the attraction, but about 36° in space, and 2h. 24m. in time, intervenes between the direct action of the Moon and the highest rise of the waters. On the side of the Earth, *opposite* to the crest-wave of the *direct Tide*, is another or *opposite Tide;* while the parts of the Ocean 90° distant from these two highest points, have the waters most drawn from them, and they are consequently the lowest. In the places which the crest-wave is approaching, the waters are rising, and the Tide is said to *flow;* while to those the crest-wave is leaving, the waters are lowering, and the Tide is said to *ebb.*

14. When, by the Earth's diurnal rotation, the Sun and the Moon are either *in conjunction*—that is, in the same part of the Heavens, or *in opposition*—that is, in opposite parts of the Heavens—their united influence upon the waters, *modified by the attraction of the Earth*, causes the *highest Tides.* When they are in *quadrature*, or 90° apart, then the influence of the Sun raises the waters where that of the Moon depresses them, and there is then the *lowest Tides.* In the Moon's revolution about the Earth, she has one *conjunction* (when she is new), and one *opposition* (when she is full), and two *quadratures* (when she is said to quarter). At the Moon's opposition and conjunction, the daily Tides flowing the highest are then called SPRING TIDES. At the two quadratures they are at their lowest ebb, and they are then called *Neap Tides.*

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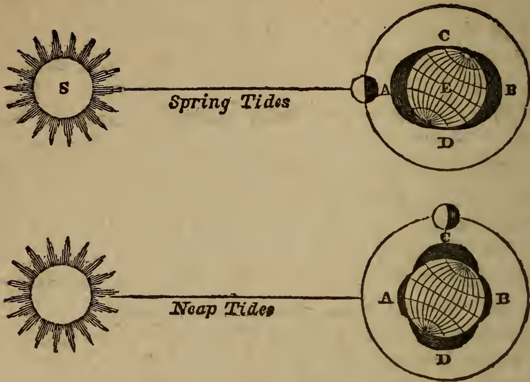
13. Give some account of their formation. What is said of the highest or crest-wave of the Tide? What *space* and what *time* intervenes between the Moon's direct action and the highest Tide? When do Tides flow? When do they ebb?—14. When are Tides the highest? When the lowest? What are the highest Tides called? What the lowest? How many of each in a synodic revolution of the Moon?

Fig. 24.



15. The ordinary explanation of the Opposite Tides is, that as the waters between the Moon and the Earth were drawn away from the Earth, so the Earth is in this case drawn away from the waters, which are farther than her centre from the Sun or Moon.* In whatever way the

* The ordinary solution of the "Opposite Tides" to me appears unsatisfactory. Whatever may be the cause, it is one which operates in regard to the Sun as well as the Moon, and in the same manner. Now, the Sun's distance from the Earth is to the semidiameter of the Earth as 24,000 to 1, and I cannot believe that this minute difference will have any perceptible effect on the gravitation of the different parts of the Earth. Another solution of the problem has occurred to my mind, which I propose to the learned for their consideration. To make the problem more simple, let us leave the Moon out of the question, and regard the figure as if there were upon it only the Sun and the Earth. There will then be two forces operating upon the waters; the gravitation which draws them to the centre of the Earth, and that by which they tend towards the Sun. That which draws them to the Earth's centre is everywhere the greatest, or they would leave the Earth for the Sun. In the figure for the Spring Tides, take the point A. Here the forces of

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15. What three sources of gravitation are here mentioned, of which that of the Earth is the greatest? Explain the causes of the direct Tide by the figure.

Tides are explained, the fact of their existence is undeniable, and also of their beneficial tendency, in thus keeping the whole mass of the waters of the sea in motion; and so preventing their unwholesome stagnation. Navigation is also assisted by the Tides; and the healthy salt water of the seas flows inland through the mouths of rivers.

16. While we thus speak of the universal movement of the waters of the ocean by the Tides, we do not assert that any *particles* are made to travel great distances; but if some move, then those next must move to fill their places, those next to fill theirs, and so on. For the moving of such a myriad of particles, we can plainly see that some *time* is requisite, and that *space* is also needed for so vast an operation. Therefore, it is not strange that the Tides lag behind the Sun and Moon; and that no inland water, not even the Caspian Sea nor Lake Superior, has breadth sufficient for the production of a Tide.

17. Since the Moon's motion, producing a high tide at any place, produces likewise at the same time a high Tide at its antipodes, there will be two Tides for one day

the Sun and Earth are *directly opposing* forces. They are *opposing* forces on the whole side of the Earth turned towards the Sun, but directly, only in that one point, and becoming less and less so as they recede from it. Of course the waters at that point have a greater portion of their gravitation towards the Earth balanced and destroyed by that of the Sun than those in any other place. That is, they are *lighter*, and the surrounding waters must pass under and raise them. But on the side of the Earth opposite the Sun, the two attractions will be, not opposite, but *conspiring* forces; *directly* conspiring at B, and less so farther from that point. Of course at B the waters are *heavier* than at any other point on the Earth's surface; and the surrounding lighter fluid will flow over and raise them, until an equilibrium is established.

If this be the true solution of the Sun's opposite tides, it doubtless is of those of the Moon, whose distance is to the Earth's semidiameter as 60 to 1.

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15. What is the ordinary explanation of the opposite Tide? What substitute has your author proposed? (See note.) What beneficial tendencies have the Tides?—16. Is it supposed that any particles of water travel great distances?

of the Moon; or, rather, for one completion of the Moon's daily circuit, which being in part a real motion in her orbit, added to the Earth's day, is 50 minutes longer. There is, therefore, 12 hours 25 minutes between each successive Tide. The difference in the height of Tides in different places varies from a few inches to 50, 60, or even, as in the Bay of Fundy, to 70 feet. In this Bay, and in some others, the flow of the Tide is so rapid, that the horse and his rider are sometimes overtaken and destroyed. The average Spring Tide is to the Neap Tide as 7 to 3.

18. The Moon's light is borrowed from the Sun. So is that on yonder wall; his rays shine upon it through an open window, and are thence *reflected* to our eyes. We know this brightness on the wall to be nothing but the reflection of the Sun's light, because, if any opaque object is placed so as to intercept the rays, then the wall is so far dark, and the darkness or shadow takes the form of the intercepting object. By this would be known the opaque structure of the body casting the shadow on the wall—that of the wall itself, and also the figure of the intercepting object. When the Moon, being in opposition in her monthly revolution, comes into the Line of the Nodes, the Earth, then, directly between it and the Sun, casts upon it a shadow, which is always bounded by a circular line. No object but a globe will, in every direction in which it can be placed, always cast a circular shadow. The Moon and the Earth are, therefore, opaque bodies, and the Earth is in figure a globe.

19. When at her opposition the Moon is on or near the Node, then the shadow of the Earth, as shown by the figure, falls upon the Moon, and the Moon is eclipsed. When in conjunction the opaque Moon, in her monthly revolution, comes into the Line of the Nodes, then her

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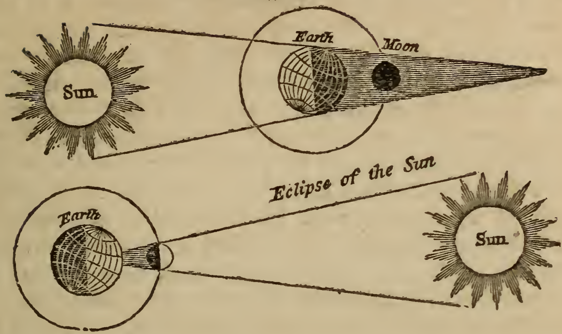
17. In what duration of time will there be two Tides? In what will there be one? What is said of the height of Tides? of the proportion between the Spring and the Neap Tides?—18. From whence is the Moon's light derived? How is it known that both the Earth and the Moon are opaque bodies, and that the Earth is in figure a globe?—19. When is the Moon eclipsed?

Fig. 25.



shadow falls upon the Earth, and to those Observers who are within this shadow (which, of course, is never large enough to cover the whole Earth), the Sun is eclipsed. (See figure.) The Earth being so much larger than the Moon, when her shadow falls direct, the Moon remains eclipsed for about two hours. The circular line is seen upon her disk, as she is going into the shadow and as she is coming out. Eclipses are *partial* when the Observer can see a part of the eclipsed body, *total* when the whole is obscured. An eclipse of the Sun is *annular* to an Observer who sees the Moon's shadow over the centre of the Sun with a luminous ring around it, which is a portion of the Sun's disk not obscured.

20. Eclipses both of the Sun and Moon are calculated with unerring certainty for hundreds of years, either going backwards or forwards in time. This shows the constancy of the Creator's works, proving that the heavenly bodies move on, in exact time and place;—and to be able to make such calculations, is a wonderful exhibition of what man can accomplish, when his investigations are pursued with *educated powers of observation, imagination, and reasoning.* But God is the Author of man.

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19. When is the Sun eclipsed? Can the whole Earth be at once in the shadow of the Moon? What is sometimes the duration of a Lunar Eclipse? When are Eclipses partial? total? annular?—20. What is said of the power of calculating Eclipses for long periods of time? Are man's powers self-created?

21. To illustrate these complicated operations of the Earth's satellite, let us again refer to our allegorical illustration of Mr. Teachwell and his inquiring boy, Charles; now again descending the stairs by the summer-house, to embark on the little lake for a fresh voyage of observation round our lamp-sun.* To show how the Moon eclipsed the Sun, he placed between his own boat and the lamp a little boat with a sail; and he made Charles observe that while they were in the shadow of this sail, their Sun was eclipsed. When they were slowly passing out of the shadow, he made him remark how the line of the shadow passed gradually off, covering less and less of the luminous surface, as does the shadow of the Moon in eclipses of the Sun.

22. Mr. Teachwell had a younger brother, a senior student in college, who was now spending his vacation at his brother's mansion. He entered into the father's views of encouraging the enthusiastic desire of his son to learn astronomy. Coming down the stairs at the moment, he offered his assistance. Mr. Teachwell at once accepted it, and said he wished him, since he was very alert, to get into the sail-boat, and play Moon. As such, it would be his duty to revolve about the Earth-boat (his own, with Charles for first Observer), while this primary planet-boat should sail in her orbit around the Sun. The young gentleman immediately sprang across the Earth-boat into that of the Moon. Both boats headed the same way, and, astronomically speaking, that was of course towards the East. Then, as the Earth moved on from her first position (*a*), where the Observer saw the lamp-sun in the constellation STATUE, to the second position (*b*),† where that luminary appeared in the constellation MANSION. The nimble Moon-boat had *nearly sailed* from its point

* See frontispiece.

† The Moon-boat does not in this position appear on the frontispiece, but must be supplied by the imagination. It would have confused the picture.

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21. Referring to the frontispiece, how is an Eclipse of the Sun illustrated?—22. What may here be illustrated concerning the Moon's motion?

of conjunction once around the Earth, and was again near to her point of conjunction with the island-Sun; but it was clear that he must sail some farther, and occupy more time to come into conjunction than if the Earth-boat had stood still.

23. When the Earth had arrived at the third position where the Sun was seen in the constellation Summer-house, the Moon (*see frontispiece*) had fallen a little back of the point of conjunction. In this station the Moon-boat is represented to be in opposition. Mr. Teachwell here stopped, and showed Charles how the Earth-boat had cast its eclipsing shadow on that of the Moon, and that the form of the shadow corresponded to that of the object intercepting the light.

24. Mr. Teachwell then bade his son remark that the Moon-boat had moved in a series of loops about the Earth, because the Earth meanwhile had been moving too; and thus was explained that the Moon was longer in going from conjunction to conjunction, because the Earth was moving around the Sun in the same way. Had the Earth-boat been moving in an opposite direction, she would have met it, and the time of her change would have been accelerated instead of retarded. Our collegian was so pleased with this mode of illustration, that he declared he would have a little round balloon made to represent the Moon; which he would fill with a light gas, and attach to his boat, and then they would make another joint revolution in such a style as would enable his nephew to understand the *Phases of the Moon*, which are her different appearances from new to full. Mr. Teachwell said the plan was perfectly practicable, and he asked Charles if he did not recollect that, when at the first position the sail was between them and the lamp, the sail looked black, because the side shone on by the lamp was turned away from them; and he bade him observe that now, when the Moon-boat was in its opposition, the sail

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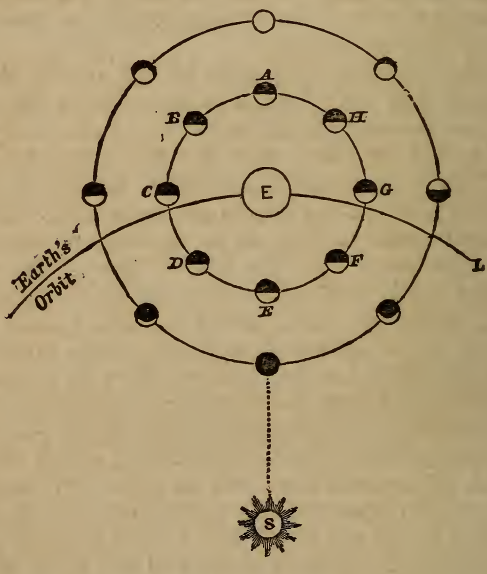
23. What Eclipse is here illustrated?—24. What are Phases of the Moon? What is the distinction between Phases and Eclipses?

was bright, except where the shadow of their Earth-boat fell.

25. There are *Shadows* to be considered in the calculation of Eclipses, but in the Moon's *Phases* there is only a difference of the Moon's *position* with respect to the Earth and Sun. Except when the Earth's shadow intervenes, the Sun always shines full on one half of the Moon; but when the Moon is in conjunction, as at E (*see Fig.* 25), an Observer on the Earth has the dark side wholly turned towards him;—then as the Moon moves

Fig. 26.



on towards her quadrature, at G, half her enlightened side—when through three-eighths of her orbit, at H, she is gibbous, and when in opposition, at A, her whole enlightened side is seen, and she is in the full. Then she

25. Describe the different Phases of the Moon, as represented in the figure?

returns to her conjunction, where she will be again invisible; having waxed and waned by the same degrees, and through the same changes.

EXERCISES.

We wish our learners now to study the Moon's course in the Heavens, and endeavor, as fast as possible, to mingle science with pleasure as they gaze upon her silver radiance. Wherever the Moon appears, recollect that she is near the Ecliptic, never distant more than about 5° on either side, and always at least 3° within the Zodiac; for the Zodiac reaches to 8° on each side of the Ecliptic.

But the Moon, in her course around the Earth, appears to the Observer to pass during one revolution through every constellation of the Zodiac. To comprehend this, look again upon the frontispiece; and suppose that the Earth-boat, with our observer, Charles, is at rest, and that the Moon-boat now carrying a light—for this must be evening—sails around it, slowly, so that Charles can have time to observe the circular line which the Moon's light makes as it passes over the objects—such as the Statue, the Mansion, &c.—which he has made the constellations of his little Zodiac. This lesser light of the Moon-boat will pass, as it revolves once around the Earth-boat, over every one of the twelve. But the *conjunction*, when the Moon-boat comes to be in the same line, and is of course seen in the same constellation as the Sun, represents the *new Moon*. You must always then see the new Moon in that part of the Ecliptic where the Sun is; or, rather, a little to the East, since just at the conjunction the Moon would set precisely with the Sun, and of course would not be visible. When you see the first thread-like crescent in the West, you must measure with your eye its distance from the Sun after its setting. If it is 13° * above the Sun's place, then one day has elapsed since the conjunction. If it is 26°, then the Moon is two days old; and she has already advanced from the place of the Sun in the Ecliptic nearly or within 4° of a whole sign. Thus she goes on to her opposition at the rate of 13° a day; and when she is in it, she rises large and bright and full, while the Sun is setting; and of course if the Sun is then in Aries, the Moon is in Libra; *i. e.*, in whatever constellation the Sun is, the Moon is in the opposite.

From this we may learn whereabouts to look for the Moon's place at different seasons of the year. When the Sun is low in the South at the Winter Solstitial Point, that is where the Moon

* In strictness, 13° 10′ 35″.

will be seen to set at the first appearance of her faint crescent; but just as much to the North of East will she rise at her full; for she is then opposite in the Summer Solstitial Point. The reverse of this occurs when the Sun is in the Summer Solstitial. His amplitude is then towards the North, and the new Moon at her setting is by his side; but in her opposition she is in the Winter Solstitial Point; and she rises as much South of East as the Sun sets North of West. As the Sun nears the Equinoctial Points, this difference between the rising and setting of the Moon, as measured on the Horizon, diminishes, and when the Sun sets in Aries, the full Moon rises in Libra, and the reverse.

This wise arrangement keeps the full Moon in oblique spheres, in that part of the Heavens where the Sun is not, and it also keeps the full Moon longer above the Horizon than the new; and this will be more and more the case as latitude increases: so that in the Frigid Zones the time of the Moon's appearance is vastly greater than that of its occultation.

The *Harvest Moon* is the name given to the Moon which fulls nearest the period of the Autumnal Equinox. It continues to rise nearly at the same time for several successive evenings; and as in certain regions of the Earth some of its fruits are about this time gathered in, it has been supposed an arrangement of Providence to aid in securing the harvest. But it is a necessary consequence of the varying inclination of the Ecliptic to the Horizon, by which, in Oblique Spheres, the smallest possible angle between these two circles is made at this season of the year, as you may see by examining the Globe. So that the Moon makes her thirteen daily degrees more nearly parallel to the Horizon, and not so directly receding from it; and thus she varies less from day to day in the time of her rising.

On the Celestial Globe, complete the study of the Almacantar Zones. What part of the Earth's surface lies within the Fifth Belt or Zone? What is its least distance from your own position at the Upper Vertex? What is its greatest? What part of the Earth's surface lies within the Sixth Zone? Where are your Antipodes? Of what Spherical System is that point the Lower Pole? What is the Upper Pole? The Great Circle. If any Secondary to this Great Circle should pass through these Poles, would its measure be that of the Earth's circumference?

CHAPTER XVII.

The Sun's Effects upon the Earth.—The Oblique Sphere.—Earth's rate of Motion in her Orbit.—Gravitation.—Centrifugal Force.—Sun's Altitude, &c., at New York.—Triangle of Time.

1. It is our object to put our learners in possession of principles, by which they can readily solve that great and multiform problem in Astronomical Geography, what is the Sun's appearance in every place on the Earth's surface, at every day in the year and every hour in the day? One phase of this grand problem of the three Spheres* has been already noticed; and two, viz., the Right and the Parallel Spheres, were partially discussed.

2. The Oblique Sphere, it will be remembered, comprises all the cases where, in the combined Spherical Systems, the Axis of Movable Positions intersects, at an *oblique angle*, the Earth's Axis; neither cutting it at *right angles*, as in the Right Sphere, or being parallel to it, as in the Parallel Sphere; and in every case of Oblique Spheres, the Intersections of the two Systems of the Earth and the Observer produce eight central angles, whereof four are angles of the Observer's Latitude, and the four alternates, angles of his co-latitude.

* That the student need not be confused by similar terms with different meanings, we remind him, that the three Spheres here mentioned are different from the three Spherical Systems heretofore defined and hereafter mentioned.

Chapter XVII.—1. What great problem is here noticed? What is one phase of the grand problem of the Sun's effects upon the Earth?—2. Describe the Oblique Sphere, as to its difference from the other two, and the angles made by the Axis of the System of the Observer, with that of the System of the Earth.

3. The Oblique Sphere being the residence of all the inhabitants of the Earth, except the comparatively small number of those who live on the Equator, should be well considered, and will be best understood by examples. We will presently begin with the commercial capital of our country; and we reproduce in the course of the chapter a former figure, because the Observer upon it is located in New York, and because all our former explanations of this diagram are now in point.

4. But in order to acquire such clear ideas of this complicated subject as to retain them, we recommend to our learners, while on the subject of the Sun's appearance, to keep the Terrestrial Globe in view, with New York, or whatever place is under consideration, in the Upper Vertex; and, besides, to make on the blackboard an enlarged copy of such parts of the illustrating figure as the subject requires. And since there is plenty of room on the blackboard,—where your figure represents merely a Terrestrial Sphere, you can draw around it a concentric Celestial Sphere. In doing this, remember that although you may extend the Poles of your Terrestrial System to the Celestial and the planes of great circles, yet that another method must be pursued to obtain corresponding smaller circles. Straight lines diverging from the centre must here be used. Suppose you wish to obtain on the Celestial Circle, drawn on your blackboard, a line corresponding to the first Almacantar of your Observer, hold with one hand a string at the centre, and with the other carry it through one of the two intersections of the first Almacantar with the Earth's surface, and then extend it in a straight line to the inner surface of the Celestial Sphere, and dot the point of intersection; then carry the string through the other extremity of the Terrestrial Almacantar, and find in like manner its corresponding point on the Celestial Sphere. If you were drawing planes of circles

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3. What is the only exception to the fact that all the Earth's inhabitants live in an Oblique Sphere? Why will the author reproduce in this chapter a former figure?—4. What does your author recommend as helps in getting clear ideas of this complicated subject?

instead of figures representing the half of a convex surface of a Globe, you might revolve your string from one point to the other, and thus produce the true Almacantar Circle:—as it is, you must measure with your eye, and thus draw as best you may the circle between the two exterior points.

5. Never lose sight of the distinction between Movable and Permanent Positions; nor ever allow any mere words, whether new or old, to stand in your mind for self-existent realities; and thus make you forget that all the apparatus of the Observer (which you are in your drawings to represent by dotted lines), is nothing of itself, but only a machinery which science-makers are obliged to invent, on account of man's finite and erring mind; by which he is persuaded that he is at rest on the centre of the Earth, under the very dome-top of the Heavens; when in reality the Earth he stands on is spinning like a top, and at the same time shooting like a meteor through the Heavens, at the rate of 68,000 miles in an hour and 1,100 miles in a minute! It is enough to take one's breath away to think of it. But as our atmosphere moves with us, we are as quiet as is the infant who is carried in his mother's arms.

6. When, however, you enter upon the threshold of the inner temple of the great science of Astronomy, for which it is our ambition to better fit our pupils than any preceding class have been, you will see how, in the arrangements of the Author of Nature, by this rapidity of motion, the safety of the Planets and the stability of their places in the Universe is insured. In the last chapter you were shown that gravitation is that grand influence which binds the satellites to their primaries, and the primaries to the Sun. Perhaps some of you thought to ask, why, according to the laws of gravitation, do not the secondaries rush into the primaries, and the primaries

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5. What are you counselled not to lose sight of, and what must you not allow? What is the Earth's rate of motion in her orbit?—6. What will the science of Astronomy teach you concerning the rapidity of the motions of the Planets? What question might a good scholar ask his teacher concerning Gravitation?

into the Sun? It would have been a sensible inquiry, and manifested you to be an accurate thinker. The full answer to this question we hope you will hereafter learn from the great astronomers, Kepler, Newton, and others. But thus much we now say, that the planets move in circular orbits around the *Sun*, by TWO FORCES, called the *centripetal* and *centrifugal.* The centripetal is that of gravitation, by which, on account of the superior weight of matter in a central body, the revolving one has such a tendency towards it, that it would go to it, but that the other force, the centrifugal, inclines it to fly off; not *directly*, for then the two would be merely opposing forces, and if they were equal, the body would not move at all, or if unequal, the body would move either *directly* towards, or directly *from* the central body—according to the direction given by the prevailing force. But the centrifugal force acts sidewise at right angles to the force of gravitation, and bodies moving between these forces are impelled by the centrifugal to go off from their orbits in tangent lines, but they do not, for they are held by gravitation to their central body. Thus the planets describe, and with such inconceivable velocity, their perpetual circuits around the Sun, each in its appointed orbit.

7. The centrifugal is also called the *projectile force;* that is, the force by which the planets, in the beginning of their career, "when the morning stars sang together, and all the sons of God shouted for joy," were thrown forth by the power of the Almighty, in straight lines, and with a strength which, in the destined place of each, exactly balanced that of the gravitation to which it is subjected; keeping, as it must, its destined rate of velocity, which, in the Earth, is, as we have said, 68,000 miles in an hour.

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6. What general answer may be given to this question? What is said of the direction of the two forces? What is the result? (*If any of the class are able, by previous study of the composition and resolution of forces, let them draw a figure and explain on the blackboard.*)—7. What other term is used to express the centrifugal force, and what does it mean? When and by what was this force impressed?

8. Before resuming the subject of Oblique Spheres, we would remind our learners that the Sun's appearance and effects are changed by a change of place in the Observer, as well as by a change in the relative position of the Sun and Earth. Let us take for example the great traveller, Humboldt, who has seen the Sun rise and set in every possible sphere and position. He went from Alps to Andes, and from Andes to Himalaya, but remember that as he went, he carried with him the whole apparatus of Movable Positions—the Observer's Line, the Zenith, Nadir, the two Horizons, the Vertical Circles, and the Almacantars. Had they been other than imaginary things, he would have needed an archangel's strength to move them; but as it is, they only made him feel at home wherever he went. He would have been strangely miserable had they not all appeared to be in their right places. Had he found some spot when he seemed standing on the verge of the Horizon, with the Zenith on one side, how would the world have appeared to him to be "out of frame!" But this never happens. . . When we have dwelt on these subjects until our imaginations conform to reality, we shall have gained a great point in Astronomical Geography.

9. In *Figure* 27, which is wholly terrestrial, the Upper Vertex is at New York, in N. Lat. 40° 42′. Our Observer on the diagram may, for aught we know, have been Hendrick Hudson himself, looking abroad upon the goodly domain which he had just discovered. Whoever he may be, the dotted lines express positions which will, when he moves, move with him. But the same will also exist for the remaining Observers at New York. Terrestrial vertical circles descend in every direction from the Observer's place, and intersect at right angles a circle which is everywhere 90° from it, and which is of course his Horizon. The Vertical Circle, whose profile is here a straight line, is the Observer's Prime Vertical, since it

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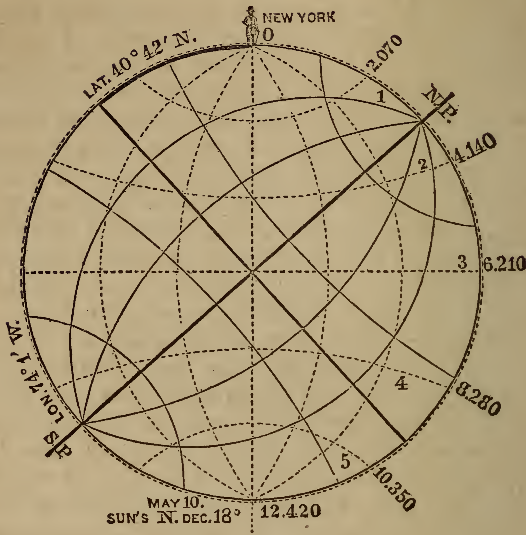
8. By what is the Sun's appearance and effects changed? What example is given of a traveller who has seen the Sun's rising and setting in all possible positions? and what would make him feel at home in all?

Fig. 27.



crosses at right angles the North and South Vertical; which of course that is, in which the North and South Poles of the Earth are found. Observe that the outer circle of the diagram is composed of two, the one in a dotted, and the other in a firm line. It is thus made, because here are two coincident circles, the one an hour circle, belonging to the Permanent, and the other—namely, the Observer's Meridian—identical with his North and South Vertical, belonging to the Movable Positions. Between each of these two principal Verticals are drawn two others. The five Almacantar Circles, of which the Horizon is the third, are here set down, with the easily-remembered numbers; by which our dignified little Observer looks as if "he stood and measured the Earth."

10. All these imaginary circles, it must be remembered, may be transferred from the Earth to the Heavens, or

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9. Draw and describe the figure as respects a New York Observer.

they may have been transferred from the Heavens to the Earth—the Great Circles, by means of imagined planes which cut both spheres alike; and the small circles, by imagined straight lines going to and coming from the centre of the Earth to the Celestial Sphere.

11. Let us now, with our Globe and diagram before us, proceed to consider how we shall find the altitude of the Sun and the length of the day in New York at different times of the year. Such observations are often made at noon. What, then, we will first inquire, is the Sun's appearance at New York at the Summer Solstice? To find his Meridian Altitude on the 21st of June, we may add 23° 28′, his northern declination on that day, to 49° 12′, the complement of the Observer's latitude. The Sun's altitude at New York will then be found on the 21st of June to be 72° 40′, and his Zenith distance 17° 20′. This will be the same in every place on the Earth of the same latitude. The 21st of June is the longest day in the year, not only to the people of New York, but to all persons in North Latitude; and it is the shortest to all persons in South Latitude. Examine the Globe, and learn what will this day at New York be the Sun's Amplitude. The Sun's circle of motion for this day describes, as he passes through the Heavens, the Tropic of Cancer. The number of degrees north of the points east and west in which this circle cuts the Horizon, shows where he rises and sets, and are, by definition, his Amplitude for this day.

12. What is the Sun's appearance at New York at the Winter Solstice? To find his Meridian Altitude for the 21st of December, we must subtract his declination (which is 23° 28′ south) from the Observer's co-latitude. To find the Sun's Zenith Distance, we may subtract his Meridian Altitude from 90°, that of the Observer's Zenith.

13. There are various methods of finding the length of

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10. How may these imaginary lines be transferred?—11. What will be the Sun's altitude, &c., at New York on the day of the Summer Solstice? At what time are the days in the northern hemisphere the longest?—12. Where will the Sun appear to the Observer at New York on the day of the Winter Solstice?

the Observer's day from the Globe, but they are all predicated on the principle that his place being made the Upper Vertex, *the diurnal arc of the Sun's circle of motion for the given day will contain so many times* 15° *as the day sought contains hours; and the odd degrees are to be reckoned four for a minute.* To find these out, use your own method; but in these problems respecting time, we do not recommend much attention to the index hour-circle, as it sets the learner to turning the Globe, which puts the Observer out of his only true place, as having the Horizon 90° from him. Generally speaking, keep your Observer in his Upper Vertex, and consider that it is for him that you are to find the length of the day; but remember, that if you find the length of the day for the Observers of a certain place, you find it for all others in the same latitude. If, therefore, we can discover a general easy method of finding the length of the day for the *latitude* of our Observer, we shall thus find it for him and all others at the same distance from the Equator.

14. To give such a method, and for other reasons—this, however, being the principal—we will introduce our learners to a certain triangle on the Globe, which, for shortness, we will call *the Triangle of Time*, as it might, with propriety, be called the Triangle of Declination, Amplitude, and Time. The Latitude of the Observer and the time, or what is equivalent, the Sun's declination, must be given. We are considering, then, the Sun's appearance to the Observer at New York. We wish to find the length of his longest day, the Sun being then in the Tropic of Cancer. But we shall find it for him if we find it for his Latitude, for which the North Pole is now elevated. We will then revolve the Globe on its axis until we bring one of the Colures (VI o'clock hour-circles) under the Meridian. Let it be the Solstitial Colure.

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13. On what are the various methods of finding the length of the Observer's day predicated? If you find the length of the day for the latitude of your Observer, for whom else will it be found?—14. What Triangle in name and quality does your author here introduce? How is such a Triangle constructed for finding the length of the longest day in New York?

15. Then the Triangle of Time will be formed both in the east and in the west (towards the elevated Pole) by the intersection of three circles—1st, the Equinoctial Colure; 2d, the Horizon; and 3d, the Sun's circle of daily motion for the given day, the 21st of June, the circle being then coincident with the northern Tropic. Examine this Triangle on the Globe. The side which we call the first is the intercepted arc of the Equinoctial Colure, and being a secondary of the Equator, it is the measure of the Sun's declination, which this day is 23° 28′. The side which we call the second is the intercepted arc of the Horizon, which, by definition, is the arc of the Sun's Amplitude for the Time and Latitude. *The third side is the intercepted arc of the Sun's circle of motion for the given place and day.*

16. This third side is a portion of the Observer's Diurnal Arc; and (reckoning from the Meridian downwards on either side) it is what remains after taking out 90°, or its equivalent, six hours. *Reckon the degrees of this third side in time—double the amount, because there are two triangles, and add the double to* 12—the number of hours of the 180° between the east and west sides of the Equinoctial Colure:—and you have the length of the given day. For the latitude of New York, we find the third side of the triangle to be about 37½°, or 2½ hours, the double of which, added to 12, would show the longest day at New York to be about 15 hours. Of course, the shortest night must be on the 21st of June, also; and 9 hours—since that is what remains of 24 hours, 15 being deducted. If we take the same latitude south, the same day will be 9 hours and the night 15.

17. This Triangle of Time belongs to the Oblique Sphere within the Polar Circles. Rectify the Globe for

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15. Describe from the Globe the first side of this Triangle? the second? the third and principal?—16. Explain the manner in which the third side of the Triangle is to be used, to find out the length of the day in any given latitude at a given time or declination? Give the time of the longest day for the latitude of New York? What will, on the 21st of June, be the length of the day and night in the same latitude south?

the Observer on the Equator, and the VI o'clock hour-circle, or Colure, coincides with the Horizon, and every diurnal equals every nocturnal part of each circle of daily motion; and although the Meridian Sun from the 20th of March to the 21st of June is going farther and farther north, and from that time to the 23d of September is coming back, and is on that day Vertical—then going south to the 21st of September, and then returning, still every day is of the same length—twelve hours day and twelve hours night, and the Sun descending direct below the Horizon is soon beyond the reach of affording even a faint Twilight.

18. But as soon as we take an Observer away from the Equator, and put his place in the Upper Vertex, this triangle is formed on the Globe; and since to understand it well, is to be able to answer at once many of the most common problems to be performed on the Globe, we will pursue the subject some farther. Remember that the latitude of the Observer must be given, and the Globe rectified accordingly;—that the declination of the Sun must be given, or the day of the month by which it may be found. Then, of course, we know the circle of the Sun's motion that day. Observe how this triangle will alter as the Observer's latitude is changed. We will still leave the Sun's declination to be 23½°, and now give the problem to find the length of the longest day *in that latitude*. Observe the effect of the convexity of the Earth on the different sides of the triangle. Declination is 23½°, while Amplitude has increased to 30°. And the third side shows 15°, or its equivalent, one hour. This, doubled and added to 12, is 14 hours, the length of the day on the 21st of June, the longest day in that latitude.

19. Next, let our Observer's latitude be 49°. The triangle shall keep its first side, that of the declination, the same, the Sun's extreme northern limit, 23½°—the

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17. To what Sphere does this Triangle belong? What is the position in this respect of the Observer on the Equator?—18. Take some place in Latitude 30°, and by the Triangle find what will be the Sun's Amplitude and the length of the day on the 21st of June, or of the longest day in the year.

second side showing the Sun's amplitude in this declination and in 49° N. Lat. gives us about 40°, and the third side gives us 30°, or 2 hours, which, doubled and added to 12, makes 16 hours, the length of the longest day in Latitude 49°.

20. Keeping still the extreme northern declination of the Sun, that the learner may comprehend how, the Sun remaining stationary, the change of place in the Observer varies the great problem of the Sun's appearance, we will now suppose our Observer in N. Lat. 66½°, the extreme latitude where the Globe, elevated to the Observer's place, will form our useful triangle. And now what surprising effects do we see from the convexity of the Globe! While the first side remains the same, the two other have now increased to 90°. The Sun rises where it sets, and sets where it rises, due north. Here is day without night. If we take a latitude still higher, we shall be within the region where there are days* in midsummer when the Sun never sets, and in midwinter when he never rises; and these days will increase in number as we go towards the Poles.

EXERCISES.

Accustom yourselves, in looking at the Heavens, to reckon by hours as well as degrees. In learning the Stars, be sure to strengthen your impressions concerning the locations of the Colures. If you have not already done so, mark and remember the bright star Alpherat, in Andromeda. It is in the Vernal Colure, about 30° south of Caph. And this Colure forms the initial line from which both Right Ascension and Time begin. When it is the Zero of time (that is, midnight) under the Vernal Colure, it is VI in the morning under the Summer Colure, XII at noon under the Autumnal, and VI in the evening under the Colure of the Winter. Or suppose it III in the morning at the

* That is, using the term day to mean 24 hours, or one diurnal rotation.

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19. What in Latitude 49° do you find by the Triangle is your Observer's longest day, or, which is the same, the length of his day on the 21st of June?—20. Why is the Latitude 66½° given in the next example? What do you find in this latitude concerning Amplitude and Time? Suppose the Observer goes beyond this latitude into the Frigid Zone?

Vernal, then at the Summer it will be IX, A. M., at the Autumnal III, P. M., and at the Winter IX. Consider this in connection with Right Ascension, and you will find 15° are taken for each hour of the 24 when reckoned from the initial or Zero point. At midnight, on the Vernal Colure, are 0 hours and 0°; at the Summer Colure VI hours and 90°; at the Autumnal, XII hours and 180°; and at the Winter, 18 hours and 270°; and the six hours till midnight take it the 24 hours which complete the circle of time, and the 360° which accomplish that of the corresponding space.

It is our object so to explain the Globes that all the problems belonging to Astronomical Geography can be easily solved by them. We do not profess to treat of pure Astronomy; and therefore those problems in the books which have heretofore been written respecting the Globes, and which refer solely to Astronomy, we leave for our pupils to solve, after they shall have become more fully acquainted with that noble science.

When the author of this work was in Europe, an American, who had long resided in Paris, said to her, "Why cannot our young countrymen be persuaded to learn their own country before they come here?" So might the stars if they had voices say to many a young student of Astronomy: Why do you not learn the Earth, before you attempt to understand the Heavens?

But the Earth is herself a star in the Heavens; and to understand terrestrial appearances—to know especially how the Sun affects the Earth, considering her motions annual and diurnal, and the convexity of her form—it is necessary to go a certain distance into Astronomy. But questions which have no relation to the Earth, we do not undertake to explain.

We have said little in our Exercises concerning the use of the index of the hour-circle, because we have, in the course of our experience in teaching, found pupils who had become expert in its use, and in solving problems connected with it, who did not understand the principles on which they proceeded. But we trust that those who have faithfully followed our instructions can now answer all the questions which can be made out of these problems, so far as Astronomical Geography is concerned, either with the use of the index or without it. The upper brazen Meridian in many cases answers the same purpose as the index. For an example, take New Orleans. Bring it under the brazen Meridian. The hour VI is under the Meridian, also. If you turn the Globe either way, 4 hours to X east, or to II west, you will have turned it 60°. The hours east will be earlier, and those west later, and all places under the same Meridian have the same hours.

Suppose it now to be six o'clock in the morning at New Orleans. You wish to know what will be the hour at any other place or places. First let it be Halifax. Turn the Globe the way that will soonest bring Halifax to the Meridian, and then observe the hour on the circle. You find it about VII and 45 minutes, which is of course later in the day, it being east. Next we ask concerning the time at San Francisco, it being VI in the morning at New Orleans. We find it about 8 minutes after IV. It must of course be earlier than the time at New Orleans, since the place is west. How many degrees of longitude are these two places from New Orleans? Halifax is $1\frac{3}{4}$ h. × 15°, which is equal to $26\frac{1}{4}$°. San Francisco, multiplying in the same manner the hours by the degrees, is 32° from New Orleans. In the same way bring the place to the Meridian, and set the index to the hour, and turn the Globe, and the index, when the place sought comes under the Meridian, will point out the hour. But knowing the longitude, you can always readily change it into time. And it amounts to precisely the same thing if you count the hour-circles as so many hours. For example, place your finger on Philadelphia, which is on an hour-circle.* What places will have all their hours the same? Those on the same hour-circle. What will have all their hours one hour later than Philadelphia? All those which are under the hour-circle next east. Those under the hour-circle next west will have all their hours one hour later, and so on till you come to the inferior Meridian, where it is noon when at Philadelphia it is midnight; there being 180° and 12 hours difference.

CHAPTER XVIII.

CAUSES OF THE DIFFERENCE IN THE LENGTH OF THE DAYS AND NIGHTS.—EFFECTS AND APPEARANCE OF THE SUN.—THE OBSERVER AT NEW YORK ON THE 10TH OF MAY.—WHAT THE LENGTH OF HIS DAY, &C.—OBSERVER AT BUENOS AYRES; AT STOCKHOLM; AT CAPE HORN; AT QUITO; AT THE NORTH POLE.

1. WE should become so thoroughly familiar with the grand problem of the Sun's terrestrial appearance, that when we read in any book of travels or geography that such or such is the latitude north or south of any place, we shall at once raise our thoughts to the Heavens

* Strictly speaking, 75° 11″ from Greenwich.

CHAPTER XVIII.—1. What information is it desirable that latitude should afford?

from thence, and in fancy behold the Sun;—if in or near the Equinoctial, rising in the east, mounting upwards towards the Zenith, and setting in the west;—or elsewhere, at noon bending either to the north or south according to the latitude, and setting with a larger or smaller amplitude. Patient investigation is the mother of accurate knowledge; and we must not too soon tire of important subjects.

2. Let us remember that there are two causes of difference in the length of the days and nights. The first is the difference of the place of the Observer on the Earth's surface. We now understand that if the Sun held exactly the same position,—and that position not in the Equinoctial, the length of the Observer's longest day would wholly depend on, and vary, with his own place, as it approached or receded from the Equator, since in receding he carries his Horizon along with him, which, according to his latitude, intersects differently both the Equator and the Ecliptic.

3. But, secondly, the days, except at the Equator, vary in length also, as we have seen in the chapter on the seasons, by the Earth's annual motion around the Sun with an axis oblique to the plane of the Ecliptic. Thus the stationary Observer, not on the Equator, experiences a constant transition in regard to the length of his days;—slow when he is near the Equator, and becoming more and more rapid as he approaches the Polar Circles; the length of the days *diminishing* from the summer to the winter solstice, and *increasing* in the reverse order from the winter solstice to the summer. So that every such Observer has two days in the year of the same length, with the exception of the longest and shortest days, which come but once a year: and as a general rule, with exceptions hereafter noticed, the two equal days will be those equally remote from the longest and shortest. Should

2. What are the causes of the difference in the length of the days and nights? What is it presumed that the learner now understands?—3. What does the stationary Observer without the Tropics experience? What is said of certain equal days? of nights in one latitude equal to days in the other?

you desire to find the length of the day in any south latitude, it would answer the same purpose to find the length of the night, in the corresponding latitude north.

4. For the purpose of showing how (the Observer remaining stationary) the Sun's appearance changes with the time of the year, we will next inquire where, at the 10th of May, and in the latitude of New York, is the Sun's circle of daily motion. On the Analemma we shall find that the Sun's Declination on the 10th of May is 19° north; and the parallel of latitude passing through this point, will therefore be the terrestrial line where the Sun's vertical rays pass over the Earth on this day. What, then, will be the Sun's Zenith distance to the Observer at New York on the 10th of May? Since his Declination is north, his Zenith Distance will be the latitude of New York, minus his Declination; that is, 40° 42′—19°= 21° 42′. . . What at this time and place will be the Sun's Altitude? From the Zenith to the Southern Horizon being 90°, subtract from this, 21° 42′, the Zenith Distance, and 68° 18′ is found to be his Altitude.

5. For the length of the day in New York, May 10th, observe our Triangle of Time, of which the third side will, on this day, be the parallel of North Latitude 19°, instead of the Tropic of Cancer. Of this parallel we find, by examining the Globe, there is intercepted between the Horizon and the VI o'clock hour-circle about 21°, which is nearly equivalent to 1 hour and $\frac{1}{4}$ in time. Twice $1\frac{1}{4}$ added to 12 makes 14 hours and a half, which is therefore the length of the day at New York, and all other places of the same latitude, on the 10th of May. How many degrees from the point east and west will the Sun at New York, on the 10th of May, rise and set? This is inquiring what is the Sun's Amplitude; and our convenient triangle will show, by the intercepted arc of the Horizon, that it is about 28°. Nature, with us in

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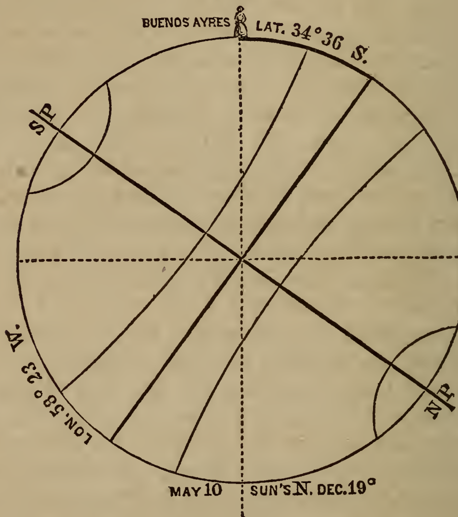
4. How may the Sun's Altitude and Z. D. at New York on the 10th of May be determined?—5. How on the Triangle of Time can you find the length of the day at New York on the 10th of May? And what is the Sun's Amplitude?

New York, is now smiling in the loveliness of spring, and rejoicing in the prospect of approaching summer.

6. Now, let us vary our grand problem by removing our Observer to the South of the Equator. Let his place be Buenos Ayres, 34° 36′ S. Lat., and the time the 10th of May. To this Observer, as to us, the topmost point

Fig. 28.



of the Heavens appears to be precisely over his own head. On the 20th of March, when we had our Vernal Equinox, he had his Autumnal, and when we saw the Equatorial line which the Sun described on that day bending to the South, he saw the same line in the Heavens bending to the North. Still farther is it now receding towards the North, for to our present Observer the Winter Solstice, the 22d of June, is approaching, and vegetation has already felt the withering power of frost.

7. The Sun's Zenith Distance must here be found by

6. Where are you next to locate the Observer? Taking the same time as at New York, what contrasts are observable?

adding his declination (19° north) to the latitude, and his altitude, by subtracting the Zenith Distance from 90°. For the length of the day when the Sun's declination is towards the depressed Pole, we cannot conveniently examine our triangle, because it is below the Horizon; but we can, for the occasion, change the declination to 19° south, and then for the length of the days as shown by the intercepted arc of daily motion—that is, of the Diurnal, which we thus make the Nocturnal Arc—we shall get the length of the nights, and subtracting that from 24, we shall have the length of the day, which, when the declination is towards the Pole, is of course always less than 12 hours.

8. Thus, people of opposite latitudes have opposite seasons. Those whose latitudes are *equal* as well as opposite, and whose meridian is the same, are called *Antœci*. Thus, the people of Valdivia, in Chili, are the antœci of those of New York. Their hours of the day are the same. They have noon and midnight at the same moment; but while in November we are suffering all the discomforts of approaching winter, the Valdivians are enjoying the soft green of the fields and the bloom of the opening flowers.

9. We will now give our learners two other diagrams —one of an Observer at Stockholm, in a high Northern Latitude, and the other at Cape Horn, in a high Southern Latitude. We leave them to draw these figures at large on their blackboards, to rectify the globe at the same time for the Observer at each place, as the two are successively taken under consideration;—then to learn from the Triangle the Sun's amplitude and the length of the days

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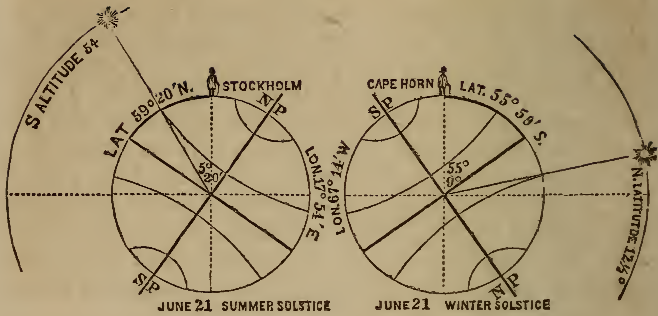
7. How is the Sun's Zenith Distance to be here found? Why can we not in this case, as in that of New York on the 10th of May, examine our Triangle of Time? But, for the occasion, what will answer the same purpose?—8. What persons have opposite seasons? When on the same Meridian, what are they called? What is said of the people of Valdivia, in Chili?—9. Draw a figure representing an Observer in Stockholm; and in contrast draw another, representing one at Cape Horn. The latitude is given, and the time being the 21st of June, what is the length of the day in each?

Fig. 29.



and nights; and, in short, to answer, concerning these places, the same questions respecting the Sun's position and effects, in regard to climate and seasons, as have been considered and replied to, in the cases of the Observers located at New York and Buenos Ayres.—Thus far we have treated of Oblique Spheres.

10. In order briefly to review the subject of the Right Sphere, suppose we fancy ourselves to be Observers at Quito, on the Equator, at the 20th of March. We are on the declivity of the sublime Andes; but even although the Sun is vertical to our position, still our climate is as a perpetual spring. Being 9,500 feet above the level of the sea, we experience the coolness of the upper regions; and, besides, the sloping mountain receives not directly but obliquely the rays of the Sun. We see him rise in the east, mount directly upwards to our Zenith, and descend directly to the west. But he is passing onwards to the north. Every day he will describe a circle a little north of that of the preceding day, until, on the 21st of June, he will rise with an amplitude equal to his declination $23\frac{1}{2}°$, and describing his whole daily course thus far to the north, set with the same.

11. The globe will not now show for our position any

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9. What is to each the Sun's Altitude and Zenith Distance? What his Amplitude?—10. Reviewing the Right Sphere, what, if we fancy ourselves Observers at Quito, shall we observe?

Triangle of Time. The third side has disappeared, for the two first now coincide. Nowhere else, except at the Equator, is this the case. But although the Sun goes thus far north, returns, and in six months is just as far south,—still every circle of his daily motion has to us its nocturnal, equal to its diurnal arc, and our days and nights are invariably 12 hours each in length. But our seasons seem strangely confused. Our nearest approach to winter occurs twice a year at both the Solstices, and our two summers are when the Sun is vertical; our two autumns are when he is going from us, and our two springs when he is approaching; and we have the glorious privilege of seeing, in the course of the year, every star that decks the firmament, as each, save Cynosura, in the northern Horizon, performs in its season, its quarter of a circle or 6 hours direct from the Horizon up to the Meridian, and directly down again in the same 6 hours' time. The Moon, as usual when she is new and young, is in the west, close by the side of her lord, the Sun; but when she comes to maturity, she shows him her full face in direct opposition, both as respects the Horizon and the Ecliptic. Her amplitude to an Observer on the Equator will, in her opposition, be therefore south, when the Sun's is north, and the reverse.

12. Concerning Parallel Spheres, although we are not aware that any human being has yet seen the Sun from either of the Poles, yet travellers have approached them within eight degrees; and the principles on which we reason are so thoroughly established, that we know for certainty how the Sun would appear; and to dwell there for a time, though but in fancy, gives to the mind a feeling of strange sublimity. We will suppose ourselves at the North Pole, and that it is the beginning of the Astronomical year—the noon of the Vernal Equinox. We

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11. In a Right Sphere, how is it respecting the Triangle of Time? Have the inhabitants at the Equator four seasons only like those of Oblique Spheres? What is said of the Moon?—12. Concerning the Parallel Sphere, have we knowledge that the Sun has been seen from either of the Poles? Do we know what would be its appearance?

shall then, as dwellers of a Parallel Sphere, have lived six months without seeing the Sun. The northern Polar Star has shone brightly from our Zenith, and all the stars of the northern constellations have moved around it, each describing its perpetual Almacantar Circle once in 24 hours. The Moon meantime has been our friend, having been below the Horizon with the Sun only when she was new; but as she approached maturity, she began to wind her spiral up our sky—reached her maximum altitude of $28\frac{1}{2}°$ at the full, and then descending as she rose, she was absent a few days from our view, shortly to appear again, and with her brightness renewed, to trace her monthly windings up and down our sky. The Twilight, too, shone as long as the Sun was within 18° of our Horizon, and thus cheered all, except five weeks, of our dreary night of six months. Then the *Aurora Borealis* gladdened us by its most beautiful coruscations, sometimes gorgeous with all the colors of the rainbow, and sometimes dazzling us with flashing streamers of uncolored light. As the glorious Sun approached, the Twilight increased in brightness, until it became the full radiance of morning. How did we rejoice when his first rays broke forth! Now at the noon of the Vernal Equinox, half his disk—intersected by the Southern Meridian—is above our Horizon.

13. The Earth turning on her axis in the order of the signs, is revolving towards the East; and the Sun—his circle of motion to-day being the coincident Equator-Horizon—is apparently moving in the contrary direction from South towards the West, and is found in that point of the compass at the evening VI o'clock. He still moves in the Horizon, and is at the North at the midnight XII, in the East at the morning VI, and at the noon XII, again in the South. We find as he comes to the Meridian on the succeeding days that he has risen about a quarter of a degree. And so for three months, or about 91 days, he

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12. If we were actually there at the beginning of the Astronomical year, what would have been the state of things for the months previous?—13. Describe the Sun's appearance for the six months during which he is in a Parallel Sphere above the Horizon.

keeps circling round and round in his spiral motion, rising a little higher and a little higher every day; until at length, on the 21st of June, he comes to his upper declination of 23½°. There he seems to be stationary for a few days as he performs his diurnal circuits, and then he winds and wheels down and down by little and little, until at length, at the end of another three months, he is on our Autumnal Horizon—soon to descend and visit with his cheering rays the Southern Pole; while again he leaves the Northern to six long months of cold and darkness.

EXERCISES.

Suppose that at midnight the moment of commencing the Astronomical Year the Earth should stop rotating on her axis for just one year, what appearances would the Sun and heavenly bodies present? This is an important problem, for when complicated things are to be understood in connection, it is of great use to understand each single thing by itself. The appearances of the heavenly bodies are complicated, and result from the combination of three distinct things. First and much the most striking is that of the Earth's diurnal motion, by means of which all appear each day to revolve round the Earth; second, the Earth's annual revolution, by which the Sun appears to move round the Earth once a year; and, third, the proper motion of the heavenly bodies belonging to the Solar System, especially that of the Earth's own satellite, the Moon.

The apparent daily motion of the heavenly bodies does not confuse and trouble the young learner so much as the apparent annual motion of the Sun. Moving, then, in a plane so near that of his diurnal motion, and in the same direction, they are all apt to be confused together. Such a problem as we have stated will, we believe, make the annual motion of the Sun appear, as it is, distinct from the diurnal.

And first we must have a located Observer. Let him be at Quito, under the Equator. It is midnight with him at the 22d of March. Where is the Sun, and when by the annual motion of the Earth will he see it? The Sun is in the first degree of the sign Aries; and of course in the inferior Meridian, while over his own head in the superior Meridian, is the place of the Ecliptic which the Earth is in, viz., First of Libra. The Earth must move through Libra, Scorpio, and Sagittarius, to the First of Capricornus, before the Sun, moving through Aries, Taurus, and Gemini, to Cancer, is seen peering above our eastern Horizon. In the mean time, all the stars which were on our Meridian at the beginning of the year have gone directly but gradually down, and as the Sun is rising in the east, they are setting in the west, while those which were rising as our dreary midnight struck, have now (rising at the rate of a month for two hours) come to the Meridian. But we see them not, for the Sun is rising. But where? In the Equator, at the point east? No. For in the last three months he has gone in his apparent course from Aries to Cancer, and he is rising at his extreme northern declination with an amplitude which, at the Equator, equals the declination. So the Sun is rising 23½° north of us.

He is in Cancer. Where will he be (moving now above the Horizon) at three months from this time? Directly in our Zenith, crossing the Equinoctial, having travelled in the Ecliptic from the Summer Solstice to the Autumnal Point. In three months more he will have descended to the west in the same direction as he rose, and he will be setting at the Winter Solstice with an amplitude of 23½° south of the Equator. At the end of another three months, he will be in our inferior Meridian, where it intersects both the Ecliptic and the Equinoctial. This problem will be varied by the different location of the Observer and by the different time of the year, or the day, when you suppose the diurnal motion to cease. Let every one work it out as regards his own position, and as many other places as he chooses.

Suppose, in reference to the subjects of the last chapter, we take our stand at Washington, the seat of government for the Republic of America, what is the length of its longest day? what of its shortest? When do each occur? From the longest to the shortest day, how many months in time? How many degrees of space has the Earth actually, and the Sun apparently passed over in going from one Solstice to the other? At Washington will there be another day of the same length as the 1st of May? In what latitude and at what time will the nights be equal to the days in Washington at the 10th of May?

CHAPTER XIX.

CLIMATES.—ISOTHERMS.—CAUSES OF EXCEPTION TO THE LAW THAT CLIMATE IS AS LATITUDE.

1. THE climate of any place is the effect of the Sun's heat, modified by the various circumstances connected with the peculiar position of that place upon the Earth.

And the great general rule is, that Climate is as Latitude: that the greatest degree of heat is at the Equator, and the most intense coldness at the Poles, and hence that any place is warmer in proportion as it is nearer the Equator, and the reverse.

2. Although this grand rule has its exceptions, yet it is good to dwell exclusively upon it for a time. In education, the attention of the pupils should not be taken too soon or too much from great general truths expressed with brevity, to consider long and intricate exceptions. The reason why the Equatorial regions are the warmest is, that they are so presented to the Sun, that they receive his direct rays; while, from the globular figure of the Earth, the parts towards the Poles receive his rays obliquely; so that less and less heat, as we go towards the Poles, is communicated to the same quantity of surface.

3. To illustrate this fundamental principle, we refer you to a diagram (see *Fig.* 30) where, in N. Lat. 42° 23′, stands an Observer of Boston. In order to show the effect of latitude and the contrast of the opposite seasons, we have brought two things together, which cannot exist together in nature; for we have but one Sun, and he cannot be at the same time in two places. But to show this contrast, we submit to imperfections in our figure, which we trust will not at this stage of progress give false ideas to any of our learners. They know, notwithstanding the figure does not indicate it, that the Sun, shining from the Tropic of Capricorn on the 21st of June, would shine beyond the North Pole to the Arctic Circle, and in the same manner to the Antarctic, if he were shining from the Southern Tropic on the 23d of December. But with all its imperfections, our figure shows strikingly the contrast between the Summer position of our Observer, when, on the 21st of June, he has the Sun's rays nearly

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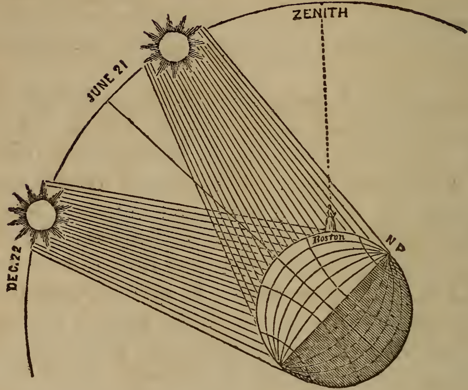
Chapter XIX.—1. What is the Climate of any place? What is the great general rule concerning Climate?—2. What says your author concerning the sudden withdrawal of the mind of the learner from rules to their exceptions? Why are the Equatorial regions the warmest?

Fig. 30.



vertical, and his Winter position on the 22d of December, when only a few slant rays touch the surface of the Earth.

4. The Earth has heretofore been divided by circles of latitude into 30 Climates; 24 from the Equator to each Polar Circle, and 6 from each Polar Circle to the Pole. In this enumeration, the first 24 are predicated on the increase of half an hour to the longest day; and the remaining 6 on the Sun's appearance as being for one whole month, present or absent, and so on to 6. This division becomes, towards the Polar Circles, on account of the Earth's convexity, too minute to be useful. But we approve of some division of climates founded on the same principle, since, although circumstances, as we shall show, modify the great general rule respecting the heat of places, yet the length of the days and nights, and the appearance of the heavenly bodies, are always in accordance with the latitude of the place.

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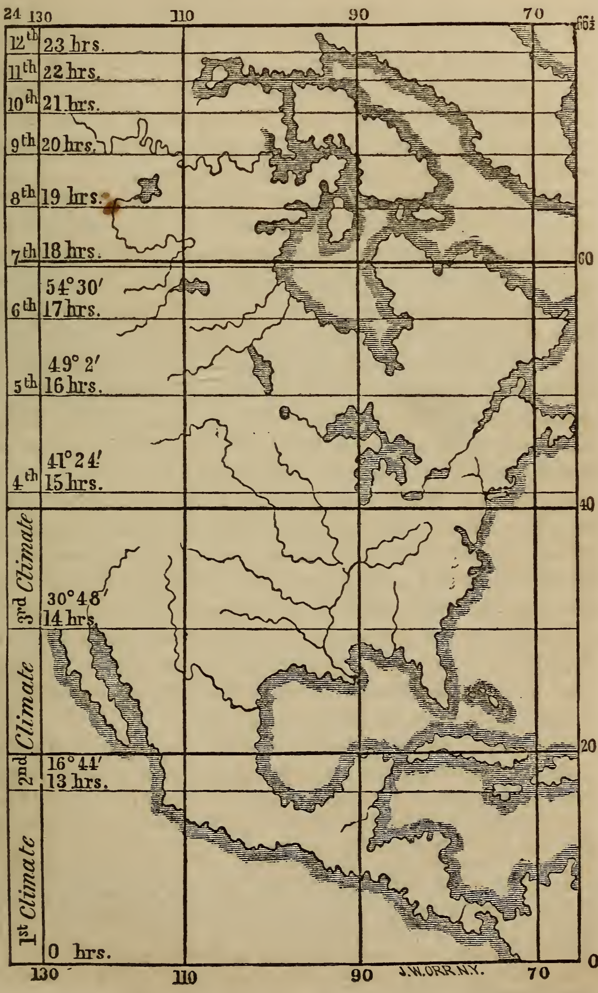
3. Why has your author here introduced a figure? Name its imperfections and its use.—4. How has the Earth been divided into Climates? What is said of this classification?

Fig. 31.—Climates.

Twelve from the Equator to each Polar Circle—differing by length of day—one hour to each Climate.



5. The Southern Frigid Zone is wholly uninhabited, and the Northern nearly. Leaving their six Climates of months unaltered,* we will divide the parts of the Earth extending from the Equator to the Polar Circles into 12 Climates of hours, predicated on the increase of one hour in the longest day in going from the Equator each way to both Polar Circles. Observe the effect of the Earth's convexity on these 12 belts or zones, as shown in the diagram. The first Climate, or that next the Equator, is nearly 17° broad; the second is about 14°; the third, 10° 36′; the fourth, 9° 36′—extending to Latitude 49°, the northern extent of our Republic. After this the belts grow narrow very fast, and that next the Polar Circle is but two-thirds of a degree in breadth. Probably two-thirds of the Earth's inhabitants are contained in the five first northern Climates.

6. Having now noticed Climates as to the general rule that they diminish in heat as latitude increases, we shall next treat of the exceptions to that rule, with their causes. That cause of variation from the rule which it seems to us is worthy of the first mention, is *the internal heat of the Earth.* While the surface is cool, fires are raging within. If we dig into the Earth to the small distance of 80 or 100 feet, the orifice thus far grows colder; but if we continue to dig downwards, the internal heat begins to manifest itself, and it increases a degree for every 60 feet which we descend. At this rate every substance known to man, even granite itself, would be in a state of fusion at a distance of 21 miles below the surface. No

* See Appendix.

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5. Are the Frigid Zones inhabited? What division into Climates is here made? Make a sketch of the figure on the blackboard, and give a general account of the countries through which the four first Climate lines pass. What do you observe by the figure concerning the effects of the convexity of the Earth on these 12 Belts or Zones?—6. What is next to be your subject—a rule or exceptions to a rule? What rule is spoken of? What is the first of the causes named of exceptions to this rule? What concerning heat is learned by digging into the ground? To what startling conclusion might these facts lead? How far does actual knowledge extend?

depth beyond about 1700 feet has, however, been actually tested.

7. But that there are internal fires and masses of heavy matter in a melted state, is abundantly proved by the VOLCANOES through which they find a constant outlet—such as Etna and Vesuvius. Both of these are near the sea; and others, such as Mauna Roa, in the Sandwich Islands, rise up from the midst of the ocean. The coldest as well as the warmest regions have their Volcanoes—as Hecla, in Iceland. The Boiling Springs, which, from the bowels of the Earth, send up many feet, and with great force, hot water and mud, are phenomena which also prove that the Earth has an internal heat, not derived directly from the Sun. Such are the Icelandic Geysers.

8. But the most sublime and terrific of the effects of internal fires are felt in EARTHQUAKES. Sometimes the solid land shakes like the sea in a tempest, and sometimes the Earth yawns, and cities sink into the fearful chasm. There is good reason for believing that these are the upheavings of the crust of the Earth, pressed from beneath by some substance suddenly expanded—perhaps some collection of water suddenly thrown into a great internal fire, and converted into steam. What makes this probable is, that Earthquakes generally have their origin in the bed of the Ocean. After the great Earthquakes at Lisbon and Cadiz, the sea rose 50 and 60 feet. Earthquakes accompany eruptions of Volcanoes; and but for these outlets, or safety-valves, the internal fires of the Earth would doubtless be still more destructive. We do not, however, believe, as some seem to suppose, that the nucleus of the Earth is a boiling mass of liquid fire, because it would be very dangerous, if it were so, to man, for whose use the Earth was made; and it would therefore militate against the wisdom of the God who made

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7. What other proof is there that internal fires exist? Is there reason to believe that these fires are as much under the water as under the land?—8. What is the most terrific effect of internal fires? Where do Earthquakes generally have their origin? and what is probably their cause? Why does the author not believe that the nucleus of the Earth is liquid fire?

it. As far as we can trace the effect of internal fires, they have advantages which far overbalance the dangers and inconveniences which attend them.

9. The fact thus established, that the Earth has a source of heat in its internal fires, the warmth of climates may well be affected by it. There may be inequalities in its distance from the surface, in its intensity, or in the effect which it may have according as the Earth's surface is covered with land or water. Its effects on land will be more enduring than on water, for it will not be so easily transmitted. The northern Hemisphere has far more land than the southern, and, generally speaking, it has more heat. The *Thermal Equator*, or Equator of Heat, passes a degree north of the Earth's Equator. The Baron Humboldt has found that the *snow-line*, or line above which, on account of the height of the atmosphere, there is perpetual snow,* varies in the same latitudes; and also the *thermic scale* of the cultivation of plants—(*i. e.*, the degree of heat necessary for their production)—where their height is the same, varies in different parts of the Earth, under the same latitude. These facts show clearly the presence of other causes of difference of climate than the heat of the Sun, though in comparison they are inconsiderable.

10. *The Sea is a great equalizer of the Heat of the Land*, making it cooler in the Torrid regions adjoining, and warmer in the Temperate. That the sea, receiving the same heat from without, should yet be cooler than the

* According to Humboldt, the snow-line in the southern declivity of the Himalayas is 12,962 feet, while in the warmer region of Thibet it is 16,630. As a general rule 267 feet elevation makes the difference of one degree of latitude.

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9. Is it probable that internal fires affect Climates? Suppose that internal heat exists, is it probable that its action would be equal? How would the land be affected in comparison with the water? Which side of the Equator has the most land? And where is it found that the central line or Equator of heat is? What is a *snow-line?* What a thermic scale of the growth of plants? What has the Baron Humboldt observed concerning these? What is proved by these facts?—10. What effect has the sea on climate?

land in the Torrid Zone, is easily accounted for, by the ease with which the particles of water move among themselves, and by the effects of heat and of the gravitation of the Sun and Moon, to move and mingle their particles, and thus to diffuse to colder regions the heat which it receives in the hotter, from the direct rays of the Sun. But it is not easy to heat water by communicating caloric merely to its upper surface; and why shall we not believe that the Earth's internal fires have an effect to warm those waters of the ocean which lie deep in submarine valleys? How else should the climates of those islands and countries of high latitudes surrounded by it, be much warmer than others in the same latitude? We know that if any region is intersected and divided by seas, gulfs, and bays, it will in its climate experience the effects of the mild and equable temperature of the waters. Thus Europe, cut into peninsulas by intervening waters, is much warmer than the parts of North America in the same latitude. But western coasts are warmer than eastern for another reason.

11. To understand this, we must consider *that* ATMOSPHERE *as well as water has influence on climate.* Both air and water, when heated, expand, and their particles rise: when cooled, the reverse. The central waters about the Equator, from this cause, would become lighter, and the waters next would press beneath, raising them up and forcing them to flow out in currents. So the air, too, warmed at the Equator, would rise, and the denser particles from the north and the south blowing over the surface of the Earth as the lighter rise to the upper regions of the air, there would thus be, in both the atmosphere and waters, upper currents towards the Poles, and lower currents from the Poles to the Equator. But it is the

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10. Why should it be cooler than the land in the Torrid regions? But what reason have we to suppose that far from the Torrid Zone the sea is warmer than the land? How does your author account for its heat? What examples of countries affected by the proximity of the sea are given? What is said of coasts? —11. What besides the sea affects climate? How are both the air and the water affected by the Sun's tropical heat? And what currents may be expected to be formed?

lower currents of the air which are at the surface of the Earth, and the upper currents of the water. So the lower air blows inwards towards the Equator, while the upper waters flow out from it.

12. These currents in the water, and winds over the sea and land (for currents of air are winds), have their annual course modified and changed by the rapid motion of the Earth at the Equator, as she moves from west to east in her diurnal rotation. This produces a tendency in the air to a motion in a contrary direction—viz., from east to west. Its actual motion is therefore between these two directions, the wind blowing on the north side of the Equator towards it, in a southeast direction (which is a northwest wind), and on the south side of the Equator, in a northeast direction (which is a southwest wind). These great constant currents of air, from the northeast and southeast towards the Equator, are called *Trade Winds.* But the direction of the Trade Winds is rather in curved than in straight lines, being, as they approach the Equator, deflected towards the East. The diurnal motion of the Earth affects the winds of the Equatorial regions, as there much friction is produced; but less and less as we go towards the vanishing points, the Poles.

13. Constant winds and currents are diverted from their course by various causes. In the Tropical regions the land is more heated during the day than the surrounding waters. The heated air over the land, therefore, rises, and the cooler over the surrounding water flows in to supply its place. But during the night the land is coolest, and the wind then blows from the land to the sea. These are the *Land and Sea Breezes,* so comfortable in the warm regions. The great extent of land which in Asia extends into the northern part of the Torrid Zone, becomes heated in Summer; and the whole mass

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12. By what are these currents, which the heat of the Sun would cause to blow from the north and the south towards the Equator, modified? Describe the Trade Winds and their causes. —13. Are these constant winds and currents ever diverted from their course? Describe the Land and Sea Breezes and their causes.

of air over the Indian Ocean then blows towards it; while in Winter it blows in the opposite direction, the Sun being then in his Southern declination. These winds are called *Monsoons*. The Trade Winds from the north meeting, near the Equator, with those of the south, they completely neutralize each other, and produce at sea such dead *Calms*, that a candle will burn without flickering. . . It is a well-known fact that in the Atlantic Ocean, between Europe and America, a southwest wind prevails to such an extent, that the passage from New York to Liverpool is ordinarily made, in a sailing vessel, in about half the time required for a voyage from Liverpool to New York. Mrs. Somerville says: "The southwesterly winds so prevalent in the Atlantic Ocean between the 30° and 60° of North Latitude, are caused by the upper current being drawn down to supply the superficial current, and as it has a greater rotatory motion than the Earth in these latitudes, it produces a southwesterly wind."

14. We have here causes developed why the western coast of Europe is warmer than the eastern coast of America in the same latitude. This southwest wind which visits it comes from warmer regions; and the ocean's warmer currents tend to western shores in middle latitudes, and not to eastern. Again, the seas of Europe opening from the south, rather than from the north, cannot introduce the floating ice from the Arctic regions. But Baffin's and Hudson's Bay receive down the icebergs, and thus become causes of unnatural cold upon the shores of North America and Greenland.

15. The waters of the ocean and the atmosphere are doubtless alike in having their entire masses continually moved by the disturbing effects not only of heat but of gravitation. The atmosphere has probably its *Tides* as

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13. Describe the Monsoons. What is the cause of Calms near the Equator? To what does Mrs. Somerville attribute the southeast winds which blow in the Atlantic Ocean between Europe and America?—14. What reasons are here given why western Europe is warmer than northeastern America in the same latitudes?—15. What resemblance is here noticed between the water and the air?

well as the water. The air is more rarified at the Equator by heat, yet the barometer shows that its whole weight is greater there than at the Poles. This manifests greater height, and may be produced in part by the centrifugal force, since by it even the solid Earth bulges at the Equator; but it may be in part the effect of Aerial Tides.

16. On account of the internal heat of the Earth, and the greater density of that portion of the atmosphere which rests upon its surface, and which therefore receives and retains not only the Earth's heat but a greater portion of the Sun's, the heat is greater, and the thermometer stands higher at the surface of the Earth than at any elevation. In ascending high mountains, even under the Equator, the air at a certain elevation becomes cool, and the grains and grasses of the Temperate Zone are found. Another elevation carries us beyond all vegetation, and under the Equator, at about 17,000 feet, we come to the region of eternal snows.

17. Snow-clad ranges of mountains depress the temperature of surrounding countries. Ranges of mountains so placed as to impede the currents of warm air brought from the sea, depress the temperature of places beyond, but a contrary effect is produced when ranges of mountains impede the access of sharp winds from icy regions. Countries with natural marshes and heavy forests are cooler, than when by drainage, and clearing away the trees, the Sun is admitted to the soil. Many springs are then dried up, and water-courses diminished.

18. The Baron Humboldt has done more than any other man in improving what he calls *Climatology*. Finding such important exceptions to the division of the Earth into Climates of Latitude and Time, he substituted the division by ISOTHERMAL* LINES,† by which are to be un-

* *Iso-thermal*, from two Greek words, signifying equal heat.

† The Isothermal Lines of Humboldt were, by his personal

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16. Why is the heat greatest at the Earth's surface? What occurs at about 17,000 feet elevation under the Equator?—17. Mention some other causes of variations of temperature.—18. What is here said of the Baron Humboldt?

derstood *lines drawn on the map of the world, through places whose medium heat, as measured by the thermometer, is equal.* On examining a system of these lines, we shall be struck by observing that the Thermal Equator, or Equator of heat, which has a mean temperature of 84° Fahrenheit, is about a degree north of the Earth's Equator, and that of the two Isotherms on each side of it, which mark a medium heat of 80°, and include the hottest part of the Earth, sometimes the northern, is found as far from the Equator as 15°, while the southern never ranges farther than the 6th degree of S. Latitude. Tropical Africa is the hottest region on Earth.

19. The most interesting to us of all Isothermal lines is that of 50° mean temperature, which is that of New York. This line bends north from New York both as it goes east and west. Crossing the Atlantic, it traverses England to the north of London, whence it bends to the southeast as it crosses Europe; and as it passes on it touches the northern confines of the Black Sea.

20. The *Rainy Seasons*, where they occur, follow the apparent course of the Sun. On the Equator and a few degrees each side, there are two rainy and two dry seasons each year. The rain does not continue through the day. About two hours before noon, the sky becomes cloudy; at noon, the rain sets in; and at sunset the clouds disappear. This is not experienced in India, on account of the Monsoons. There is more rain in a year falling on a Zone a few degrees north of the Equator, than on any other equal portion of the Earth's surface. A few coun-

friend, William C. Woodbridge, copied into his Geography;—a work of authority in Europe, as well as in America. It has been recently revised, the late census introduced, and the maps altered according to recent discoveries and extensions.

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18. What are Isothermal Lines? Where is the Thermal Equator, and what is its mean temperature? What account is given of the two Isotherms on each side of it?—19. What is to us the most interesting of the Isothermal Lines? What is said of the interior of Africa?—20. What is said of the Rainy Seasons? Where are they found? Does the rain fall all day? Where are found countries which haye rainless seasons?

tries have *rainless seasons:* such are the northern interior of Africa, Thibet, and Mongolia in Asia, and California in America.

EXERCISES.

The order of the signs of the Ecliptic, as has been often mentioned, is, by definition, from west to east; and the motion of any heavenly body in that course is *direct;* but if opposite (*i. e.*, astronomically speaking, from east to west)—then it is *retrograde.* But we have counselled our learners to use their eyes to look at the Heavens, and their imaginations to complete circles, and thus to conceive of the parts which they cannot see. We must not here confuse our minds by confounding the *permanent* astronomical east and west with the *movable* east and west, which depends on the position of the Observer, and which is expressed by his Prime Vertical, only just so far as the plane of his sensible Horizon is concerned. By the latter on the Equator, at one of the Equinoxes, the Sun's motion is one way during the day, and the opposite way during the night; that is, above the Horizon it is from east to west, and below the Horizon, in the contrary direction, from west to east. And as this makes the Sun's apparent daily motion, and that of the other heavenly bodies, range from west to east during the night, and from east to west during the day, so also, as taught in the last Exercises, as regards the Observer, would be the Sun's apparent annual motion, should the diurnal cease. For the six months which the Sun is below the Observer's Horizon, the apparent motion caused by the Earth's real motion through the opposite signs would be from west to east, while in that half of the Ecliptic above the Horizon, the Sun's apparent motion through the six upper signs would be from east to west.

These circles of motion thus made according to the System of the Observer, half east and half west, while according to the System of the Heavens they are all east, are from the nature of the case apt to create confusion in the mind, and it is well worth one's while to give sufficient attention to the subject fully to understand it. Look out upon the circumpolar stars as they revolve around the North Pole. Take note of the position of some of the most remarkable of the constellations, as our old acquaintances, Cassiopeia and the Great Bear, which are in opposite positions. Suppose the first to be directly above Cynosura, and the last below it. Wait two hours, and then go view them again. You will find that the constellation above the Pole has moved 30° towards the west, while the one below has moved just as far towards the east. Hence you perceive that these Heavenly bodies, according to the Observer's system, have apparently moved through the upper hemisphere from east to west, and through the lower from west to east, while all real planetary motions have, as astronomically defined, been made in circles constantly going from west to east.

If, while you are making this observation, you hold your watch so that its face shall coincide with the plane of your circle of latitude, or, which is the same thing, the plane of the Equator, then its centre will represent the North Pole, and the point of the minute-hand may be taken for a circumpolar star. Suppose the action of the pointers reversed, and the minute-hand to point east; then from east through south to west; and from west through north to east again: this pointer will represent the seen motion of the circumpolar star; and in the same manner that of the Sun. This, in contradistinction from the *astronomical* round through which the planetary bodies *really* move, might probably be called the *geographical* east and west; which, as we have seen, goes on *with* the reversed motion of the hands of the watch, and refers to the *apparent* motion of the heavenly bodies; whereas the astronomical round, from west to east, is made in the same direction as the ordinary movement of the hands of a watch.

On the Terrestrial Globe, trace the dividing lines of the third and fourth northern climates, and tell what countries and great cities they contain. What is the length of the longest day and shortest night in each?

CHAPTER XX.

EXPLANATION OF THE NIGHT FIGURE.—THE EDUCATED EYE—MUCH LEARNED BY SEEING LITTLE.

1. If aught human is endued with a spark of divinity, it is an educated eye, with vast and comprehensive powers like that of Humboldt, Cuvier, Newton, and the two Herschels. An educated eye, leads both the reason and the imagination; and its possessor, in seeing little, knows much. Cuvier, from seeing one bone of an animal of a kind not before recognized, was able to describe the species of animal to which it belonged. And the astronomers, Leverrier and Adams, looking upon the Heavens

CHAPTER XX.—1. What may be said of an educated eye?

with an eye astronomically educated, and seeing certain disturbances in the motions of the outer planets, pronounced that a large unknown planetary body existed, whose orbit was without all those which were then discovered. Telescopes were accordingly pointed in the direction indicated, and Sept. 25, 1846, the great planet Neptune or Leverrier was discovered by Galle, and their prediction completely verified.

2. The education of the eye imparts the power of OBSERVATION, which should commence early. The little child should be taught TO OBSERVE—to refer his time and his place to the Sun, and to the direction of the shadows.* He should afterwards be taught to observe the rising and setting of the Sun at the Equinoxes, as this marks the exact points east and west; and also to examine (through smoked glass) the course of the Sun at the days of the Equinoxes, in order to locate the Equinoctial in the Heavens; and as soon as he understands angles, he should be taught that the angle which the Sun's path makes with the Horizon on these days is the angle of his co-latitude, and that the distance of the Sun's Meridian Altitude from his Zenith is the arc of his latitude. Then by night he should be called to observe that the height of the Polar Star above his Horizon is equal to his latitude. A child thus taught to connect what he sees with the great truths which he learns, will be gently inducted to the vantage ground of science; and may be expected

* Many persons having, when children, learned to refer the points of compass only to the terrestrial objects around them, as the fronting of their father's house, of the village church, &c., as soon as they lose sight of these objects, are entirely at a loss, and form a wrong notion of the points of the compass of the place they are in, and they complain that their heads are turned, If they had learned to calculate from the Sun, they would not have been subject to this great annoyance.

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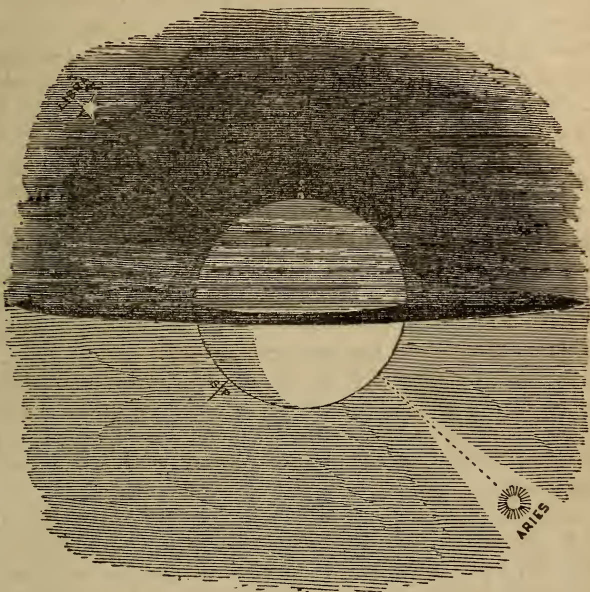
1. What examples are given of persons possessing an educated eye? What has been discovered in astronomy by this means? —2. What power is imparted by educating the eye? What should children be early taught? What may be expected of a child thus taught?

in after life, with native talent and habits of industry, to occupy some of its most honorable heights.

Fig. 32.



3. We here present a simple picture of a night scene. It is to aid our learners in this cultivation of the mind through the eye;—to induce them, when they look out upon the Heavens, and see the Polar Star, the place of the Colures, the Pole of the Ecliptic, and the place of the Equinoctial, to exercise their imagination and their reason to fill out the picture; that thus, while they see with the bodily eye what is above their Horizon, they may look with no less assurance through "the mind's eye" upon what is below, and thus complete the picture.

4. We will now fancy a dialogue between a Teacher

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3. What is the character of the figure here presented, and what is the author's object in presenting it?

who has thus far instructed a docile and intelligent pupil in the principles of Astronomical Geography as thus far exhibited.

Teacher. I here show you a small and simple night figure, where there is little to be seen, but much (from what you have already learned) to be inferred and imagined. Tell me first what, in the picture, do you SEE?

Pupil. I see the Earth, with a little Observer upon the Upper Vertex looking forth upon the night. The plane of his Horizon is fancied to be of sufficient solidity to intercept the rays of the Sun, which is seen below shining from Aries, his direct ray falling upon the Lower Hemisphere. In the opposite and Upper Heavens is a great star sending a ray upon the Earth from Libra directly opposite to that of the Sun. The places of the North and South Poles are faintly indicated by their initial letters. Is there in reality a great star in Libra?

5. *Teacher.* There is not; but as Sir John Herschel recommends putting an imaginary star into the Vernal Point, I have, on this occasion, taken the liberty to put one into the Autumnal Point. Where is this Observer's Equator?

Pupil. Of course equally distant from both Poles. It is, I see, where the direct rays of both the Sun and the star fall upon the Earth. I wish to know, whether, by the words Aries and Libra on the picture, I am to understand the signs or the constellations, since both are called by these names, and they do not come together?

Teacher. First tell me why they are not now together, since they once were?

Pupil. By the Precession of the Time of the Equinoxes, the place where the Sun came to the Equator at that time changed, and went back a little each year, so that there was a Retrocession of the Equinoctial Points, and this has amounted since it began to be observed to 30°, or one-twelfth part of the Ecliptic.

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4. Draw the figure, and describe what you see upon it?—5. By what reasoning do you decide where is this Observer's Equator? How can it be shown that the Sun and the star are in the signs Aries and Libra, and not in the constellations?

Teacher. This is correct; and the little picture affords you the means of deciding whether the words Aries and Libra refer to the signs or the constellations.

Pupil. I see it now. Both the Sun and the star are in the Equinoctial, since their direct rays strike the Equator. But Aries and Libra, whether signs or constellations, are in the Ecliptic. But there are only two points of contact between the Ecliptic and the Equinoctial, and these are not where the constellations are, but where are the first degrees of the signs. The Sun and the star must then be in the first degrees of the *signs* Aries and Libra.

Teacher. What are these points called?

Pupil. The Equinoctial Points. The Sun is in the Vernal and the star in the Autumnal Point.

6. *Teacher.* Where do you understand this Observer's Meridian to be?

Pupil. From the way in which I have seen other figures of this kind drawn, I should judge it to be concentric with the outer circle of the Globe, that being his Terrestrial Meridian.

Teacher. You are right. That is the intention of the figure, and if you had not made a right guess from the probability of the case, I should have told you; for the exterior of the circle is not *necessarily* the Observer's Meridian. But since the maker of the figure intended it as such, you are now certain that you are right in considering it so. What do you judge to be this Observer's latitude?

7. *Pupil.* The star is in his Meridian, and it marks the place of the Equinoctial. From the star to the Zenith, or, which is the same, from the *point* of its direct ray's intersection with the Earth's surface to the *Observer*, is the arc of his latitude. Measuring with my eye, I see that this arc of the latitude is not so great by a few degrees as the arc of the co-latitude, from the star to the Horizon. I therefore judge this Observer to be in north latitude (*north*, because he is nearest the North Pole),

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6. What in this figure is the Observer's Meridian?—7. How do you find the probable latitude of this Observer?

somewhere about 42°. Perhaps our grave little Observer is one of the Professors of Yale or Harvard College.

8. *Teacher.* Since you are called on to exercise your imagination, it is but fair to allow it all innocent play. But whoever this Observer may be, I am now about to make some minute inquiries concerning his position. What is his day of the month? What is his hour of the day, or rather of the night, and what is his minute of the hour?

Pupil. This is very minute indeed. First, what is his time of the year? That is decided by the place where the Sun is, and the Sun is in the first degree of Aries at the Vernal Equinoctial Point. The time is then the Vernal Equinox, which now occurs at the 22d of March.

9. *Teacher.* Right; and now you are to tell me what is our Observer's hour of the night. Before you answer this question, however, I wish you to consider if there be not now some important circle of the Heavens coincident with this Observer's Meridian.

Pupil. There is. It is the Equinoctial Colure; for that is a secondary to the Equator passing through the Equinoctial Points, and the Sun and the star are at this moment in it, and they are by the figure at the same time both in the Observer's Meridian. Therefore, the Meridian and the Equinoctial Colure are in the same place. I observe you call them *coincident;* would it not be as well to say they are *identical?*

Teacher. For our present purpose of finding the time, it would make no difference, but when we have disposed of the present question, I will show you why they should be considered as not blended into one, but as each existing and running along together. With them there is in fact still another and third circle, whose separate identity must also be retained. That is the Observer's North and

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8. How and wherefore do you decide concerning this Observer's time of the year?—9. How does it appear that there is a second circle of the Heavens coincident with this Observer's Meridian? What difference is noticed between the terms coincident and identical? What third circle is coincident with the Observer's Meridian and the Autumnal Colure?

South Vertical Circle. But we now return to the question, what is our Observer's hour of the night?

10. *Pupil.* Clearly it is midnight; for the star on the opposite Meridian to that the Sun is in, passes through the Zenith of the Observer.

Teacher. Is the hour just twelve? Suppose it wanted four minutes to twelve, or was four minutes after?

Pupil. In either case the Meridian, in which are the Sun and the opposite star, *would not be in the Observer's Meridian by one degree.* Four minutes before twelve it would be one degree east of it, and four minutes after twelve one degree west. So that our Observer's time, on the supposition that these Meridians are exactly coincident, is in reality made out to the minute.

11. *Teacher.* And do you not already perceive how much you may *know* by a little that you *see*, when you have a truly *educated eye;* for if, from the little which you and I know, we can thus multiply the gift of sight, how must it be with an astronomer like Sir John Herschel?

Pupil. There is, indeed, something very animating in the thought that we may learn to know much in seeing little. I am thinking as I look at this figure—for this exercise, I believe, makes my imagination active—that if you will give me the exact place of this Observer in latitude and longitude, that I will go on with this subject still further, and perhaps accomplish something beyond what you yourself at first expected.

Teacher. This will give me the pleasure of enjoying the fruits of my labors. I will give you, then, Troy, in New York, as the place of the Observer. Its latitude is 42° 44′ north, and its longitude is from Greenwich, 73° 40′ west. What do you propose to do?

Pupil. You know my fondness for drawing. I now give to it two hours a day. I propose to enlarge this little night figure, and make it a beautiful and useful pic-

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10. How do you decide this Observer's hour of the night? What is it? Suppose it either lacked four minutes of twelve or exceeded it by four minutes?

ture; for since I have now the latitude and longitude of the Observer, I shall find no difficulty of filling this eastern hemisphere of the convex figure of the Earth, and this western concavity of the Heavens above it, with the things which really belong to each. I will sketch the continents and seas of the Earth, putting them in light or shade as they are situated with regard to the Sun. In the upper Heavens I will place the most remarkable stars in their own appropriate dark ground. I think I will introduce the pale Moon a little past quadrature into the west. I will take away this fancied Horizon, and keep the light of Sun, Moon, and Stars each to its own proper place.

Teacher. It is a good plan, and if executed well, will make an admirable picture. If it were but carried out with chalk sketches on a blackboard, it would be a very useful exercise, and illustrate still farther our subject of the wonders which can be wrought out by an EDUCATED EYE.

12. *Pupil.* Will you now inform me concerning those circles, of which three may be considered as passing over the head of the Observer; his own Meridian, the Equinoctial Colure, and his North and South Vertical. Why are they all to be considered, notwithstanding they exist together, not as identical, but as coincident, and as having each a separate existence?

Teacher. Suppose, looking to the Heavens, you point your finger to the North Polar Star, then bring it down in the line of the Meridian to the point north on the Horizon. In what direction will you have moved your finger, north or south?

Pupil. North, I suppose. I shall have moved it towards the point north on the Horizon.

Teacher. Yes, but you will have carried it in a direction from the North Pole towards the South.

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11. How may the plan of this Night Figure (the latitude and longitude of the Observer being given) be still carried forward and made more minute?—12. If you move your finger from the North Pole along the Meridian to the point north on the Horizon, in what direction do you carry it?

Pupil. I now recollect your former instructions; and I see that I was wrong, and that it is South.

Teacher. There is an inherent difficulty in this subject, which I know no other way to dispose of but to consider these lines as being distinct, though co-existent; and to decide *in reference to the Observer's System* that the arc in question goes *North*, since it goes towards the point North on his Horizon; but *as to the System of the Earth*, the same direction being on a Meridian going direct from the North Pole to the South, *it is South.* We see from this the necessity of not mingling together and confusing different circles, as they may for a time coincide. On the contrary, we must maintain for each its separate existence and peculiar properties. We shall find occasion to remember these instructions in studying the Northern Heavens, where the different systems come in perplexing contact.

EXERCISES.

"It is often of use," says Sir John Herschel, "to know the situation of the Ecliptic in the visible Heavens at any instant; that is to say, the points where it cuts the Horizon and the altitude of its *highest point*," or, as it is sometimes called, "the *nonegesimal* point of the Ecliptic." Sir John Herschel lays down a method of finding this point by joining the elevated poles of the three axes of the systems of the Heavens, the Earth, and the Observer; but his method requires more mathematical knowledge than our students are supposed to possess;* and, besides, we believe we can give a more simple and an easier method of finding the position of the Ecliptic, especially at night, when the stars are visible.

By the *Highest Point* of the Ecliptic is meant the Summer Point, or that nearest the elevated Pole, and whose meridian altitude is greatest, and of course having the greatest declination (23½°). We know it is on the Summer Solstitial Colure, and

* A gentleman not behind any other in our country for the union of science with the power of imparting it, on examining this work, said to the author, "You have done for the young what Sir John Herschel has for the more advanced, in bringing down scientific subjects to the comprehension of the unlearned." That is all the praise I covet. It is the very problem I undertook to solve. Few can appreciate its difficulties.

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12. What reason do you find in this to be careful in the use of the words *identical* and *coincident?*

90° *distant* from the Ecliptic Pole, that being on the Winter Colure, distant 23½° from the North Pole, and having at 90° distance the lowest point of the Ecliptic, or that point (the Solstitial) which has 23½° Southern declination.

We trust our students now know where to look for the Ecliptic Pole and the two parts of the Solstitial Colure divided by the Polar Star into the Summer and Winter Colure. By these Colures, then, the position of the Highest and Lowest Points of the Ecliptic may always be known when we look out upon the stars; and these being known, it is easy to decide whereabouts the Ecliptic crosses our Horizon. Yet that depends in no inconsiderable degree on our latitude; for suppose, in looking at the Heavens, we see Caph in our *Meridian*, we know that the Vernal Colure now coincides with *it* and passes through our Zenith. Where is *then* the Highest Point of the Ecliptic? It is in the Summer Colure, 90° or six hours from the Vernal; and Summer is next after Spring, and the direction of the signs of the Ecliptic are from west to east. The Highest Point of the Ecliptic is then six hours or 90° east of us, and the Lowest Point six hours west of us. If we live on the Equator, these Colures being great circles, and the Equinoctial at right angles with our Meridian, the Vernal will coincide with our Horizon, and the Highest Point will be in the Eastern Horizon, with 23½° of Northern Amplitude, and the Lowest Point will be in the Western Horizon, with the same degree of Amplitude South; and the Ecliptic will cross the Equinoctial precisely in our Zenith, which now coincides with the Equinoctial Point. This is the same case of position of the Ecliptic as that supposed in delineating the yearly course of the Sun, from Summer to Winter, the Earth's rotation being stopped. But to a person not living on the Equator, but in north latitude, the points of the Horizon cut by the Ecliptic are different; as a greater portion of the Ecliptic will be in the northern hemisphere, and a lesser portion in the southern. This you will at once see by taking some latitude, as that of Paris, and elevating the North Pole 49°.* Now, observe the Triangle of Time, and you will find the Highest Point of the Ecliptic is where the VI o'clock Colure meets the Equator, and between this and the eastern Horizon there are two lines of hour-circles, showing 30° of space; and the Ecliptic, after standing a while at that height above the Horizon, goes not directly but diagonally from that Highest or Solstitial Point towards the Eastern Horizon, and then meets it with an amplitude of about 33° north. As much of the Ecliptic as appears within this Triangle on the east beyond the VI o'clock hour-circle, so much will fall short of the VI o'clock hour-circle on the west, and the Ecliptic will have the same amplitude of 33°, but south. But it will fall short of what is above the VI o'clock hour-circle

* The latitude of Paris is 49° 50′.

in the east, a quantity equal to the excess there, viz., two hours or 30°. If in the problem of the Sun's appearance, the Earth's rotation being stopped, we had taken the latitude of Paris instead of the Equator, this description of the Ecliptic as above the Horizon would show the Sun's path through the six months' day, and it would show that of the six months which the Sun would be above the Horizon, when rising with the Ecliptic as here described, four of the months would be between the eastern Horizon and the Meridian, and only two between the Meridian and the western Horizon. But place the Autumnal Colure in the Meridian, which will make the case that of our Observer in the Night Figure, after a time will come Winter, and we must look east, but at the same time south of the Equator, for the Ecliptic, and here we shall find the two hours cut off which were in the last case in excess, and the Sun, if rising in the Ecliptic now, with a six months' day before him, would be coming from his winter station in the south to his summer station in the north, and would have his turning point before his setting, as in the other case after his rising.

Observe the diagram of the climates, and then look on the Terrestrial Globe, in north latitude, for the principal countries and cities where the longest day is 16 hours, and from that to 18 hours. What two climates are these, and between what latitudes? Look on the Globe for the principal countries and cities where the days are 18 hours, and from that to 21. What climates are these, and in what latitudes? What are the lengths of the longest days in the three last climates, and what the latitudes?

CHAPTER XXI.

Time.—The Common Year.—The Civil Year.—The Sidereal Day.—The Sidereal Year.—Astronomical Instruments and Observatories.—The Solar Year and Day.—The Astronomical Year.—The Cause of the difference in Time of the Solar and the Sidereal Years.—The Retrocession of the Equinoctial Points the Cause of the Precession of the Equinoxes.

1. The Common Year, comprising the 12 calendar months, is a portion of Time consisting of 365 days, 5 hours, 48 minutes, and 47 seconds. The *Civil Year* is so called. because upon it are predicated all arrangements

connected with the civil law referring to Time. It commences at the midnight XII o'clock, of January 1st; so, that in it, no odd hours and minutes are recognized. It has 365 days only, except that every fourth or leap year it has 366 days. There is a farther arrangement respecting the odd minutes and seconds, which will be explained in the next chapter.

2. But what are the Days of which the Common Year is composed? Is each of them, that wonderfully exact Unit of Time, marked out by one rotation of the Earth on her Axis? That Unit of time is so exact, that if a million Observers, each having a perfect time-keeper, should each take any fixed star as it comes to his meridian, and observe it as it returns, each would find the same time to have elapsed, to the ten-thousandth part of a second. This invariable Day, ascertained to be such by the stars, is called the *Sidereal Day.* But it is not so long by 3 minutes 56 seconds* as the day which goes to make up the 365 days of the Common Year.

3. As the Sidereal Day differs a little in time from the Common Day, so also there is a SIDEREAL YEAR, differing a little in time from the Common Year. The *Sidereal* Year is determined by the length of time which elapses from a certain Star on the Meridian to the annual return of the Observer's Meridian to the same Star. If the learner has now conceived of the appearance of the Sun during the year, in case the diurnal rotation of the Earth was stopped, he can easily conceive of the Sun in the Ecliptic as apparently moving from any Star in the Ecliptic round to the same Star again; and that this annual movement would form the Unit of a year's time.

4. But so overpowering to the senses and the imagina-

* In strictness, 3° 55′.9

1. What is the Common Year? Why is the Civil Year so named? When does it begin? Does it recognize any odd hours and minutes?—2. How is the Time of the Earth's rotation mentioned? How may it be known to be an invariable Unit of Time? What is this invariable Day called? What is its length?—3. What is the *Sidereal* Year? How might the learner conceive of the Sun's annual motion as apparently moving from any Star in the Ecliptic to the same Star again?

tion is the sublime and rapid spectacle presented by the daily apparent motion of the heavenly bodies, that it is somewhat difficult for the young learner clearly to conceive how yearly Sidereal Time is determined by the Stars. To do this, you must suppose an Observer in some definite place, taking his observations at precisely the same time. Take our Observer in the night figure, having on his Meridian his star in the first of Libra, on the 22d of September at midnight. The same time in the succeeding month he goes forth at midnight to look for his Star. He finds it 30° west of his Meridian; for he having moved on the Earth 30° towards the East, there has been an apparent motion of his Star as many degrees to the West. He goes at the end of the second month at midnight, and finds his Star 60° to the West; at the end of the third, 90°; and then for six months he loses sight of it, while it performs the inferior half of its circle of daily time. After that he sees it emerging in the East, and advancing towards the West. It is now near his Meridian, and he goes every midnight to watch for it; for he wishes to know the very second in which it is precisely cut by his Meridian. At last, by his instruments, he knows it is there, and he notes by his chronometers and by his calculations the exact time since he saw the Star on the Meridian before, and he has now the precise measure of the Sidereal Year.

5. It must strike the mind at once that such minute observations on the heavenly bodies cannot be made without special preparation. But they are of vast importance; and to provide for them, even governments of countries make expensive preparations. Observatories—high buildings where can be had the whole unobstructed view of the Heavens—are made; and they are furnished with telescopes, chronometers, and various other astronomical instruments, which men of great science have invented for

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4. What is the grandest, although the most familiar spectacle of the Heavens? What effect has it upon our clearly conceiving the apparent annual motions? But how must an Observer (suppose the one on the night figure) do to find the Time of the Sidereal Year?—5. What must here be apparent concerning instruments?

the benefit of mankind. The Observatory of Greenwich, near London, from which Longitude is ordinarily reckoned, is perhaps the most noted in the world. To the great philosopher Galileo, of Italy, is referred the first use in Astronomy of the telescope. This was about the close of the 16th century. In 1667, Sir Isaac Newton greatly improved this instrument, to which that science is so vastly indebted. In the last century, Sir William Herschel produced his wonderful telescope, 40 feet in length, with which he made many discoveries. In our days, Lord Rosse, of Scotland, has a still larger instrument, with which he discovers objects too minute to be seen with any former one. In particular it is to be noticed, that more and more stars are discovered, as the telescope has increased in its magnifying power.

6. From this digression we return to the consideration of Days and Years. We now fully understand what is meant by the Sidereal Day, and the Sidereal Year. The Solar Day is the Time which elapses between two successive noons or appearances of the Sun on the Observer's Meridian. And the Solar Year is the Time which elapses between the Sun's centre being on the Meridian of the Observer to the return of the same after the Earth's annual circuit. *The common Year and Day is mean* (or medium) *Solar Time*, as measured by a perfect Timekeeper, having 24 hours to the day, 60 minutes to the hour, &c. The Sidereal Year is not a year of Sidereal Days, but of Solar Days. The length of the Sidereal Year is 365d. 6h. 9m. 10s.: this exceeds the Common or Solar Year by 20 minutes 19 seconds.*

* Professor Maury, at the Observatory of Washington, has recently invented an instrument by which the minutest portions of time are distinguished, and they are, by the magnetic telegraph, instantaneously transmitted.

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5. What is the *great* instrument of Astronomy? By whom and when first used? By whom and when greatly improved? What great telescope was the means of important discoveries? What is the largest at present?—6. What is the Solar Day? The Solar Year? What is said of the days which compose the Sidereal Year? What is the length of the Sidereal Year? How much does it exceed the Sidereal Year of mean common Time?

7. The ASTRONOMICAL YEAR is a year of Sidereal days. It commences at the noon XII o'clock of the Vernal Equinox. The Observer, in this case, is supposed to stand not on the surface but at the centre of the Earth, and to an observer there it would be indifferent whether he reckoned his year from a Star or from the Sun: the result would be the same; and in either case his year would have one more day, than either the Sidereal or the Solar. The Astronomical Year, then, according to which Eclipses are reckoned and Longitude calculated, has, of Sidereal days, 366d. 6h. 9m. 9s. All Observatories are furnished with *Sidereal Clocks*, which divide the Sidereal Day into 24 hours, and hence the Sidereal Hour is less by about 10 seconds than the Common Hour, the day being shorter by nearly 4 minutes.

8. The Solar Year has then one day less than the Sidereal, while the Solar Day is about 4 minutes longer. Why is this? It is because *the Earth revolves annually, and rotates daily in the same direction.* A day is thus lost to the Solar Year; but absolute Time is the same, and this lost day may be considered as divided into equal portions, which will give an average of nearly 4 minutes more to each of the remaining 365 days: that is, just as much, as the mean Solar Day exceeds the Sidereal.

9. Suppose, for illustration, that the hours on the face of the clock were not to be reckoned by the revolving of the minute-hand from XII to XII again; but from the time in which the two hands being together at XII o'clock shall come together again. Now, on account of both the hands going the same way, the minute-hand, after getting to the starting point, will have to go several minutes farther before it overtakes the hour-hand, and they

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7. What is the Astronomical Year? When does it commence? Where is the Observer supposed to stand; and what difference, reckoning from this position, will there be between the Astronomical, and the Solar and Sidereal Years? What is the length of the Astronomical Year? With what are all Observatories furnished?—8. What point to be settled is here put in an interrogative form? How is the question answered?—9. Explain why a day is lost in number, but in minutes the remaining day is longer —by the illustration of the two hands of the clock?

are again together. So the Earth, in her daily revolution, when she comes to the initial point of any one day, finds not the Sun just where she left him, but advanced one day's course in the Ecliptic, and she must go on until she overtakes him, before the day is accomplished. Since the degrees of the Circle of the Ecliptic are 360, and the days of the year 365, this is nearly a degree to a day, and a degree in space corresponds to four minutes in Time; so that if on any day the Earth should begin her axial rotation with the Sun and a Star under any Observer's Meridian, when this Meridian, having swept the Heavens, comes again under the Star, completing the Sidereal Day, the Earth must turn four minutes longer and nearly a degree further before the Meridian would come under the centre of the Sun, and thus complete the Solar Day.

10. For the Meridian of any Observer to be under the centre of the Sun, is but another expression for *noon*. At this time any object placed perpendicularly to the surface of the Earth, will cast a shadow (except at the Equator) which will be a North and South line. But this is *Solar Noon*. *Mean Noon* is the Day–XII of a perfect clock. The difference between Solar and Mean Noon will be explained in the next Chapter.

11. Any Observer keeping the same place on the Earth, and reckoning his day from one Solar Noon to another, will have in his year one day less in number than there are of actual rotations of the Earth or Sidereal Days; but he will have four minutes more time in each day. This effect will be doubled if the Observer, instead of remaining stationary, goes round the Earth in the year, travelling from West to East. In this case he will neither have the 366 Sidereal, nor the 365 Solar Days in his Year; but he will have 364 days, and these days, instead of being 4 minutes longer than the Sidereal, will be twice that number. If another traveller should start from the same place, at the same time, and go round the Earth during the same period, he,

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10. What is noon? What is said of shadows at noon? What kind of noon is it where shadows fall thus? What is *Mean Noon?* —11. With what assertion does the 11th paragraph commence? How is this illustrated by two hands of the clock.

instead of having to overtake the Sun, would meet him a little before his full Circuit was completed. He would gain a day. If the two travellers should meet on their return, they would, by their journals, find themselves two days apart. While the one who went East would call the day Monday, the one who went West would call the same day Wednesday, he having had two days more in his year. Yet each has had the same number of minutes; so that if he who went East had two days less in his year, he had eight minutes more in each day.

12. We refer again for illustration to the hands of a clock. Suppose two clocks stand side by side, one with the hands moving in the ordinary manner, and the other with the minute-hand so arranged as to move in a direction contrary to the hour-hand. Then let both clocks have their two hands together at the upper XII. As they move around to the same XII again, the one where the minute-hand goes the same way as the hour-hand will not have overtaken it by several minutes, whereas the one which went the contrary way will have overtaken and passed it, by the same number of minutes which the other falls short. We take a year as the time of the traveller's going round the Earth, because we wish to compare the effect with the Solar Day, as losing in the same way a day in the year, and gaining about four minutes in a day. But there is no necessity of stating the traveller's time as a year. If he goes round the Earth eastward, in whatever time, whether half a year or two years, he loses a day; but he gains minutes in his day, according to the time—if half a year, then 8 minutes a day; if two years, then 2 minutes a day; and the reverse, if he travels round the Earth westward.

13. Having disposed of the question concerning the

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12. What will occur to the traveller who goes round the Earth the same way in which she revolves on her axis? What to him who goes the opposite way? Suppose both set out on the same day and return the same day, one having gone round the Earth East, the other West? How is this concerning the two travellers illustrated by the hands of 2 clocks? Why is a year mentioned as the time of the two travellers?

difference between the Solar and Sidereal Day, we come now to inquire why the Sidereal Year is longer by 20 minutes 19 seconds than the Solar. This is owing to the slight movement formerly mentioned of the System of the Earth upon the System of the Heavens. By means of this, the Equinoctial Points very slowly retrocede in the Ecliptic. That is, the Sun every year comes to the Ecliptic a little east of his former place. But by definition, the Sun's place is the Ecliptic; and the Equinoctial Points must be where the two Great Circles come together; and therefore this retrocession of the Equinoctial Points can only happen by the one System moving back upon the other.

14. The effect of this retrocession of the Equinoctial Points is to make the Solar Day shorter than the Sidereal. For the Solar Year is completed at the noon of each succeeding Vernal Equinox, the time when the day is exactly equal to the night all over the Earth. And this time must occur when the Sun's circle of daily motion coincides with the Equator. So that if the Sun's place, when the Equinoxes occur, is pushed back in the Ecliptic, the time will, on this account, be pushed forward. That is, so much angular space as the Equinoctial Points *retrocede*, so much yearly time the Equinoxes will *precede*.

15. The space on the Ecliptic thus annually retroceded is a little less than one second of a degree,* while the time preceded, or the Precession of the Equinoxes, is 20 minutes 19† seconds. Small as are these portions of space and time when taken for one year, yet as years accumulate, their effects become very apparent, and cause great annoyance to astronomers, as it obliges them from time to time to reconstruct their tables of the Latitude and

* 50″.10. † 20m. 19.6s.

13. With what inquiry does the 13th paragraph commence? How answered? What is said of the Retrocession of the Equinoctial Points?—14. Explain the effect of the Retrocession of the Equinoctial Points.—15. What is the yearly angular amount of the Retrocession of the Equinoctial Points? What is the amount of time of the annual corresponding Precession of the Equinoxes?

Right Ascension of the Stars. The Vernal Equinox is made the initial or Zero Point both of Celestial Longitude and of Right Ascension; and both are reckoned in the order of the Signs quite round the whole 360° of the circle. The Vernal Colure is that Secondary of the Equator, from which Right Ascension is reckoned, and the First of Aries, that Secondary of the Ecliptic, from which is calculated Celestial Longitude. As all these are moved eastward—since the stars move west—then their Longitude and Right Ascension increase with and as the removal; and astronomers are, after a course of years, obliged to reconstruct their tables. Every thing, however, is now understood and calculated upon.

16. The Retrocession of the Equinoctial Points has carried back the Signs since the time of the early astronomers 30°, so that the first degree of the sign Aries is now in the first of the constellation Pisces. In 25,868 years, the Equinoctial Points, retroceding at the rate mentioned, will accomplish a complete circuit of the Ecliptic. The two Colures will in that time successively sweep over every star in the Heavens.

The Solar Year, thus reckoned from one Equinox to the same Equinox again, and from one Tropic to the same Tropic again, is sometimes called *the Equinoctial Year*, and more frequently *the Tropical Year*. From the year thus obtained is reckoned the Common or Civil Year, and also the Astronomical. They are all therefore 20 minutes 19 seconds shorter than the Sidereal Year.

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15. Why does the Retrocession of the Equinoctial Points change the Celestial Longitudes and Right Ascension of the Stars? What inconvenience is thus given to astronomers?—16. How many degrees have the Equinoctial Points receded since the days of the early astronomers? What time, at the rate of angular motion at which they now move, will be required to complete the circle of the Ecliptic? What is said of the Colures may be predicated of every Secondary, both of the Ecliptic and the Equator—What is it?

EXERCISES.

Astronomers refer the Precession of the Equinoxes to the revolving of the Pole of the Equator about the Pole of the Ecliptic; but having, by our definitions, connected in one Spherical System the Axis and Equator of the Earth and their appendages; in another, the System of the Heavens—the Ecliptic and its Axis, and their appendages—we conceive it more correct as well as far more expressive, to say that the System of the Earth moves upon the System of the Heavens; because by the motion, all belonging to the one System changes its place as regards all belonging to the other.

Suppose, for illustration, an ingenious lad, who understands the distinction between the Systems of the Earth and the Heavens, shall have got up, with wire and strips of tin, a rude piece of apparatus,* to illustrate this knotty point. He holds it in his hands. It represents two Spherical Systems combined. The outer, that of the Heavens, and the inner, that of the Earth. Each has its Great Circle, Poles, and two Secondaries, crossing at right angles at the Poles. Those Secondaries on the Earth's, or inner System, are the two Colures dividing the Equator, as they cross it at right angles, into four equal parts. Those Secondaries on the System of the Heavens, or outer System, are circles of Celestial Longitude, cutting the Ecliptic at right angles. First let the two Systems coincide, axis with axis, and secondary with secondary. Then keeping one of the secondaries together for a bond of union between the two Systems, slide them upon each other, until the axes make opposite vertical angles with each other of 23½° ; that being the actual angle, and the measure of the arc between the Poles of the two Systems.

The two coincident secondaries, in which are the Poles of both Systems, are the Solstitial Colure and the First of Cancer. The other two secondaries, representing the Equinoctial Colure, from which is reckoned right ascension, and that secondary of the Ecliptic, from which is reckoned Celestial Longitude (the First of Aries), make with each other an angle equal to that made by the axes, and also that made by the two great circles, the Ecliptic and the Equator. For, as on the Solstitial Colure, the two axes were drawn apart 23½ degrees, the same angle must be made by their Great Circles, so that wherever the Solstitial Colure is, trace from

* If these new arrangements of the combined Spheres should be regarded as furnishing a permanent improvement to this department of educational science, some maker of apparatus will doubtless furnish us with the three spheres combined. The old Armillary Sphere will show that it may be done. The piece of apparatus which we contemplate would, however, be less complicated, though far more useful: perhaps not less difficult to make, but easier to understand when made.

the Pole of the Heavens through the Pole of the Earth, and there you must find the highest point of the Ecliptic advanced 23½° towards that Pole; or if you trace from the Pole of the Ecliptic opposite to the Pole of the Earth, there you must find the extreme opposite or lowest part of the Ecliptic, pushed 23½° beyond the Equator.

Now, with your ideas perfectly clear concerning these two Systems and their connections, you will find it easy to understand the Retrocession of the Equinoctial Points. Keeping the axes of the two Systems at the same central angle, slowly revolve the axis of the Earth's System around that of the Heavens, and in a direction contrary to the rude signs which we suppose placed on your Ecliptic. At once that Secondary of the Ecliptic which has, by coinciding with that of the Equator, formed the Coincident Circle, must be left behind, and the Ecliptic must, for the connection with the Solstitial Colure, furnish another Secondary farther to the west; and still another to coincide with the Equinoctial Colure, and their intersection crossing the Ecliptic and the Equator, forms the Equinoctial Points, which thus retrocede, causing the Equinoxes to precede, and the Vernal to meet the advancing Sun 20m. 19s. before the yearly Sidereal Circuit is accomplished.

On the Terrestrial Globe give a general account of the parts of the Earth which lie in the first northern climate, ending where the longest days are 13 hours. Give a general account of the parts of the Earth comprised in the first southern climate. Which climate contains the most land in the Eastern Continent? Which in the Western?

CHAPTER XXII.

IRREGULARITY IN THE TIME OF SOLAR DAYS.—THE MEAN DAY FOUND BY THE EQUATION OF TIME, AND MEASURED BY THE CLOCK.—TWO CAUSES OF THE INEQUALITY OF SOLAR DAYS.—OBLIQUITY OF THE ECLIPTIC—THE EARTH'S UNEQUAL MOTION IN HER ORBIT PERFORMING EQUAL AREAS IN EQUAL TIMES.—DISPOSAL OF THE ODD HOURS AND MINUTES OF THE SOLAR YEAR.—REFORMATIONS OF THE CALENDAR.

1. AT first thought nothing seems easier to understand, than the import of the word Year and the word Day. But we have already seen that the subjects are complicated; nor are we yet through with their intricacies. We mentioned in the last chapter the *Mean Solar Day.* That

there should be a Solar Day of mean or medium length, implies that Solar Days are not all equal. From one solar noon to another the time varies constantly, and the longest Solar Day has just half an hour more time than the shortest. But it is necessary for the daily avocations and labors of mankind that there should be a common standard of daily time. Learned Astronomers, then, finding by observation the exact length of every Solar Day in the year, have, by working out an important problem called THE EQUATION OF TIME,* found the *Mean Solar Day;* which is of just such a length that 365 such days, with an allowance for Leap-Year, and the other odd minutes and seconds, exhausts all the minutes of the tropical common year.

2. The clock, one of the most useful of human inventions, is made (unless when used for astronomical purposes) to keep mean solar time of 24 equal hours to the day. A clock perfectly regulated is therefore the true standard and exponent of MEAN SOLAR TIME. The mean or medium day of 24 hours having been thus established, tables are made out, which are found in every common almanac, and by which is shown, the agreement or disagreement of each Solar Day in the year, with the clock, that is, with mean time. If it is said that on such a day the Sun is so many minutes "*slow* of the clock," then we know that solar noon comes on that day so much *later* than mean noon. If it said, on the contrary, that the Sun is "*fast* of the clock," then on that day Solar or *apparent* noon comes so many minutes *sooner* than mean

* Equation from *æquo*, to make equal. Has not the expression Equation of Time been perverted from its original and proper use?

CHAPTER XXII.—1. What is implied by the expression, Mean Solar Day? What is said of the inequalities of solar days? What is that problem called by which the mean solar day is found? By what is mean solar time kept?—2. If you had a clock which kept perfect time, and a noon-mark showing apparent time, could you decide for yourself whether the sun was fast or slow of the clock? If your clock stopped, how could you set it by the noon-mark?

noon. Suppose the family clock to be stopped, and you wish to set it at noon by the noon-mark; you must first consult the almanac. If that tells you that the Sun on that day is 10 minutes fast of the clock, you must set your time-piece, when it is noon by the mark, at 10 minutes after XII; but if slow of the clock, then so much earlier. The clock, it must be recollected, is not to keep solar or apparent, but mean time.

3. There are four days of the year when the Sun is on the meridian precisely at the time when a perfect clock strikes XII. These are the 15th of April, the 15th of June, the 1st of September, and the 24th of December. The difference of the sun and clock is the greatest on the 11th of February, when the Sun is 14½ minutes slow of the clock, and the 1st of November, when the Sun is 16¼ minutes fast. The difference between the longest and the shortest Solar Day is thus found to be 30*m.* 45*s.*, a little more than half an hour. *But why should the Solar Days be unequal, since the times of the Earth's diurnal rotation are equal even to the minutest fraction?* To understand fully why this is so, requires a profound knowledge of Astronomy; but a partial understanding of an important subject, if correct as far as it goes, is profitable, as leading the way to its future comprehension. In nature we have the dawn of the morning before the radiance of the day.

4. The cause of the inequality of the Solar Days, since it is not in the time of the Earth's diurnal revolution, must be looked for, and will be found in the only additional increment of daily time, viz., that which comes from the minutes of the lost Sidereal Day, and is connected with the Earth's yearly progress, as day by day she proceeds from west to east in her orbit, in the same direction as that

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3. How is the point, to be next discussed, here expressed question-wise? Does your author suppose that nothing should be learned of a subject unless it can be fully understood?—4. What increment, or item of increase, is the only one added to the sidereal day to make up the solar? In what is the inequality in the length of the solar day? Explain (referring to the last chapter) what is said of that sidereal day, lost to the solar year, and its minutes added to the remaining days?

in which she turns on her axis. This is made manifest by the corresponding apparent motion of the Sun in the plane of the Ecliptic, with which the plane of the Earth's orbit is coincident.

5. The Sun's Circles of Daily Motion, as divided by the 24 Hour Circles* of the Globes, are the same, as regards the division of time, as if they were all performed in the Equator. Suppose you had a globe six feet in diameter, which, instead of 24 equal divisions, by longitudinal lines should present 365. Now if the Earth's orbit coincided with that of the Equator, and the motion of the Earth in her orbit was uniform, then just one of these equal spaces (there being 365) would be passed over in each day; that is, all in exactly the same time, each with each; and in that case the Solar Day would be as uniform in length as the Sidereal. *But the common plane of the Earth's orbit, and that of the Ecliptic, is oblique to that of the Equator; and the Earth's motion in her orbit is not uniform;* and these are the TWO CAUSES of the inequality in the lengths of the Solar Days.

6. To be convinced that the obliquity of the Earth's orbit, and consequently that of the Ecliptic to the Equator, is a cause of the inequality of the Solar Days, we have but to examine the divisions on the Globe by the 24-hour circles. Look at the Equinoctial Colure and the two-hour circles next, each side, and your eye will at once inform you that they cut off longer parts of the Ecliptic than of the Equator; but the Ecliptic and the Equator being both great circles of the same sphere, are equal; and since these Hour Circles divide both into 24 parts, the whole 24 parts of the one must be equal to the whole 24 parts of the

* Rather, 24 Hour Semicircles.

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5. How many longitudinal divisions of time are on the globe? How do they cut the sun's circles of daily motion? What supposition is made as to a larger globe, and an added number of circles? Under what two conditions would the solar days be equal? What then are the two causes why the solar days are not equal? —6. How may we satisfy ourselves that the obliquity of the Ecliptic to the Equator is one cause of the inequality in the length of the solar days?

other. Hence, when adjacent to the Equinoctial Points, the parts of the Ecliptic are seen to be the longer of the two,* we know that on the other portions of the Globe they must be as much shorter.† This reasoning would be the same, if instead of 24, there were the supposed large Globe with 365 longitudinal divisions, cutting the Equator and all circles of daily time into so many equal parts. If any two of these longitudinal lines intercepted a portion of the Ecliptic exactly equal to the corresponding intercepted portion of the Equator, then solar time would be on that day (WHAT day would be decided by the Sun's place in the Ecliptic) equal to mean time, but if the intercepted part of the Ecliptic was shorter than that of the Equator, then that day would be shorter than mean time. Thus is proved that the obliquity of the Earth's orbit to the plane of the Equator is one cause of the inequality of the length of Solar Days; and the preceding calculation proceeds on the supposition that it is the *sole* cause, which is not the case.

7. For of this irregularity there is a second reason, viz., the want of uniformity in the velocity of the Earth's annual motion. We are here to consider that the orbit of the Earth is not a circle, and although the Ecliptic is ap-

* The Equator with its secondary makes a right angle, of which the Ecliptic being the hypotenuse, must be longer than either side. By the convexity of the globe, the parts of the Ecliptic near the solstitial points would be shorter than the corresponding portions of the Equator:—parallel lines of latitude at that distance are perceptibly so.

† And when we look at the parts cut off by the hour-circles adjacent to the Solstitial Colure, we perceive that here the Ecliptic is almost like a straight line parallel to the Equator, and of course, being at the distance of 23½°, the two lines (surface spaces between secondaries) are less in breadth there, than at the Equator.

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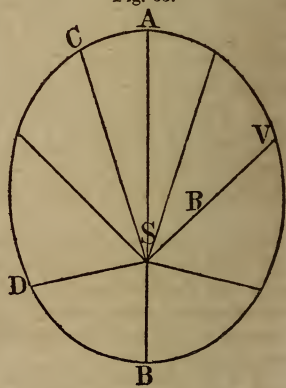
6. How would the reasoning apply if longitudinal lines divided the Ecliptic and Equator each into 365 equal parts? When would solar and mean time be equal? When would solar time be less than mean time? when greater? What case is here supposed?—7. What is the second cause of the irregularity of the solar days?

parently such, yet the Sun's motion there is only apparent, and caused by the real motion of the Earth in her elliptical orbit; where she moves with what may be called a regular irregularity, for it is an inequality of motion; faster in some parts of the orbit, and slower in others; but yet according to a certain determinate law, which is found to prevail with all the heavenly bodies. Universally they are found *to describe equal areas in the plane of their orbits in equal times.* This law was discovered by the great astronomer Kepler, by whom it was first taught that the Earth's orbit was an ellipse.

8. Without attempting to explain the beautiful mathematical demonstration by which the law of "equal areas in equal times" is perfectly proved, we will merely show what the words which announce it mean, and how this law affects our present subject. You see in this diagram an oval figure, representing the Earth's elliptical orbit, with S the Sun in one of the foci; and you perceive that the figure is divided into eight triangles, meeting in the centre. These 8 triangles are equal in area each to each. Those adjacent to S B the shorter axis, are shorter triangles than those adjacent to SA the longer axis; but these are as much broader as to make up the deficiency. And to obtain this requisite breadth, you perceive that the arcs subtending these equal triangles, are *very* unequal; B D being *much* longer than A C.

Fig. 33.



9. Now these equal triangles are the *equal areas* men-

7. What are we here to consider? What is said of the motion of the Earth in her orbit? What is universally true of the moving heavenly bodies? By whom was this law discovered?—8. How far does your author attempt an exposition of "Kepler's law?" Draw the figure, and explain it as far as it may be understood by our description.

tioned; and however unequal are the arcs, the Earth, in her annual revolution, passes over these arcs in *equal times*. An imaginary straight line from the Sun to the Earth, called the RADIUS VECTOR, is supposed to sweep the *plane* of the Earth's Orbit as she moves in its *ellipse*, cutting off these *equal areas of space* in equal *times of motion*. To do this, we see that the Earth must move the faster the nearer she approaches the Sun, and the reverse. That is, velocity is inversely as distance, not merely in a simple, but in a compound ratio. Hence comes the great law to which all bodies moving around a central body in space are subject; viz., that *the velocity of any heavenly body in its orbit is inversely as the square of its distance from the central body.*

10. When the Earth is at B, its *Perihelion* or least distance from the Sun, its motion is so rapid as to make the Sun, in the opposite part of the Ecliptic, appear to move in 24 hours over an arc of one degree and one minute; whereas when it is at A, its *Aphelion*, or greatest distance, his motion in the same time falls short of a degree by three minutes. The Earth is known to be at its Perihelion by the measure of the Sun's apparent diameter, which is then the greatest; and it is found, by observation, to have its greatest angular diameter the 3d of December. The Earth is then 3,000,000 of miles nearer the Sun than in the opposite part of the year; but its more rapid motion hinders, in some measure, the Sun's effects. Thus a hand may be passed rapidly by a hot fire, when, with a slow motion, its heat could not be borne.

11. Thus have been shown two causes; first, the obliquity of the Earth's orbit; and second, her unequal motion in

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9. What is the Radius Vector? What do we learn—from the fact that the Earth passes over these unequal arcs of the equal triangles—of equal areas in equal times? What is the great law by which the motions of the heavenly bodies are regulated?—10. What is the rate of the Earth's angular motion per day when in her Perihelion? When in her Aphelion? At what time in the year is the Earth in her Perihelion? What effect has the greater rapidity of motion on the degree of heat derived from the Sun? How much nearer is the Earth to the Sun in Winter than in Summer? How is it known when the Earth is nearest the Sun?

it,—why that increment of daily time, whose average is about four minutes, affects the Solar Days so very unequally. Since the longest Solar Day is half an hour longer than the shortest, to perform the Problem of the Equation of their Time, it becomes necessary, in order to find the true medium, to borrow for the shorter days the excess of the longer. A traveller, in going round the Earth, in just a year would have the increment of four minutes added to each day, on account of the one day which he would lose by going east. But this time which, by the Equation, has a medium of four minutes a day, would, if the circumnavigation of the globe were made in a year, actually be, as respected the days, very unequal. Whenever he stopped, or went very slowly, the time would unduly accumulate; whereas, whenever he travelled very fast, it would fall short of the due proportion.

12. *A natural month*, called also the Lunar Month, is the time of the Moon's revolution around the Earth. There is in this case also an addition to the time of completing the full revolution, on account of the Moon's moving round the Earth from west to east, in the same way that the Earth is moving round the Sun; and the time added is much greater in proportion. The *Sidereal Month*—that is, the time of the Moon's passing from any star till it returns to the same star—is 27¼ days. But she must *go on* to overtake the Earth. If the time of the Moon's being seen with the star was a conjunction, and she a new moon, she will not *be* a new moon again until she has travelled more than two days, and nearly 30 degrees after returning to the star. From new moon to new moon again, is called the lunar *Synodical Month*, and its time is 29d. 12h. 44m. The Lunar Month, as a division of the civil year, would be inconvenient; as the number 13, into which it divides the year, is an odd number, and besides, this division of the year is not exact.

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11. Repeat the two causes of the inequality of Solar Days. By what is the medium day found? What comparison is here made for illustration?—12. What is a natural month? What is a Sidereal month, and what its length? What is the Synodical month, and what its length—and its difference from the Sidereal?

13. Therefore, by common consent, the year is divided into 12 months, the full time of which exactly corresponds with the year, which always begins on the first day of January.

This division is doubtless the best possible. The number 12 agrees with the signs of the Ecliptic, and being an even number, aliquot parts of the year are easily expressed. Thus we speak of the summer half and winter half of the year, or more definitely of its quarters, the four seasons. Annual time is also readily referred to the correspondent angular motion of the Sun in the Ecliptic; 30° being a month, 90° three months, and 180° six.

14. The standard, or tropical Solar Year, has, as we have seen, 365 days, 5 hours, 48m. 47s. But the year recognized by the civil law has no odd hours or minutes. How are these disposed of? They are, in the first place, cleared off, or *leaped over*, by Leap-year, which, once in 4 years, adds a day to February, the shortest month in the year, thus making that a year of 366 days. But this is getting along in time a little too fast; for the odd time is not quite 6 hours, or a quarter of a day, but it lacks 11 minutes and three seconds. This, in a hundred years, would amount to three-quarters of a day. Hence, in the rule adopted by Pope Gregory, Leap-year is to be omitted at the end of the century. But this would advance the beginning of the year too far by a quarter of a day; which, in four centuries, would become a whole day. There is not, therefore, by the Gregorian rule, to be any leap-year at the close of the fourth century.

15. If these odd hours and minutes were not provided for, but the Civil Year reckoned merely by 365 entire days, one year would begin before its predecessor had

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13. What then is the month of the common year? What reasons are given for supposing this division the best possible?—14. What difficulty arose in former days with respect to chronology, and how was it disposed of? After Leap-year was added, what difficulty still remained? How was this difficulty met by the rule of Pope Gregory?—15. Explain how, without the odd hours being provided for, the calculations of time run into confusion.

closed by the return of the Sun, and too soon by nearly a quarter of a day each year; the Equinox would thus come later and later in the Civil Year, at the rate of about one day in four years. Thus all calculations of Time would run into confusion. This was once the case, as we are informed in ancient history. Julius Cæsar has the honor of partially reforming the Calendar. He restored the Equinox to its original place, and added the Leap-year. But the odd eleven minutes and three seconds, by which the true reckoning was exceeded, ran on; and, in a hundred years, amounted to 18 hours, or $\frac{3}{4}$ of a day; and, at this rate, advancing the Equinox. In a thousand years, this advancement amounted to $7\frac{1}{2}$ days. It is known that in A. D. 325, the Vernal Equinox occurred on the 21st of March. In 1582, it had gone back to the 11th of March—10 days. Pope Gregory XIII., again in 1582, reformed the calendar, setting back the time—reckoning the Equinox to be on the 21st of March, and establishing the rule mentioned—by which the years will no more run into confusion.

16. This reformation was not at once adopted throughout Europe. The reception of the Gregorian Calendar by England did not occur until 1652, when eleven days were added to bring the Equinox to the 21st of March. The 3d of September, 1752, was by Statute reckoned the 14th. This was accompanied by another alteration in the Calendar. The 25th of March had been till then regarded as the beginning of the year,—which, from this time, was to be reckoned as beginning on the 1st of January. The new method of reckoning was called New Style (N. S.); and the former, Old Style (O. S.). Hence arose in the dates of that period many cases of utter confusion. Some persons attached to old ways would not use the

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15. What was first done to relieve this confusion of the Calendar, and by whom? Explain what occurred after the amendment of the Calendar by Julius Cæsar? What was done by Pope Gregory, and when?—16. When was the Gregorian Reformation adopted in the land of our forefathers, and what change was made in current time? What other change, which had no connection with this, was made at the same time?

New Style; while others, unduly zealous in its favor, carried it into the past. Thus the legal English date of those times is said to have been the New Style, while the historical date was the Old. It is not unusual to see both dates, so far as the year is concerned, used together. Thus, Charles I. is said to have been beheaded in 1648–9. His execution had occurred between the 1st of January and the 25th of March. Hence, according to Old Style, it was in 1648; and, according to New Style, in 1649.

EXERCISES.

Our subject refers to the Heavens only as they are connected with the Earth. We have therefore said little of the Planets. But we send our students forth to study the Stars. They must understand which are the principal constellations and the brightest stars, in order to be able to locate those circles of the Earth and Heavens, without which the Earth's position in regard to the Sun cannot be known. In thus watching the Heavens, we cannot but desire to understand the motions of the Planets, the brightest and most peculiar of the Stars.

In what part of the Heavens are we to look for the Planets? A young lady once inquired of a gentleman whether Vega, in Lyra,* the most magnificent star of the northern hemisphere, was a Planet. Some would say she should have known the difference, because the Fixed Stars twinkle, and the Planets do not. But to some eyes, the Planets rather than the Fixed Stars appear to twinkle. But from the place of Lyra we think no student of ours would have asked so mistaken a question. The Planets—we speak not now of the Asteroids, the largest of which is not larger than a fixed star of the 5th magnitude, and the smaller are merely telescopic stars; *their* orbits extend several degrees beyond the Zodiac;—but the Planets, so interesting to our view, are never seen but in the Zodiac, which extends about 8° on each side of the Ecliptic. To Lyra we have given particular attention, as the directing star to point out the Winter Colure, 5° to the west; and the Pole of the Ecliptic, which is on that Colure, close to the star *α Draconis*, and 25° north of Lyra. The Winter Colure is on one account the most remarkable of great circles. The permanent connection of the two Systems of the Earth and Heavens exists in the coincidence of this Secondary of the Equator with

* Commonly called Lyra. Sir W. Herschel discovered this to be a double-double star—four stars seen as one.

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16. What causes of confusion arose? Why was Charles I. said to have been beheaded in 1648–9?

a Secondary of the Ecliptic; and while these parts of the two Systems coincide, no other Secondaries in the two Systems can coincide. So in the connection of the Observer's System with the other two, if the axes of the three Systems shall ever be in the same plane, it must be the plane of the Solstitial Colure, and the three Poles above the Horizon must be in the Winter Colure. Let us suppose, then, that the Winter Colure is in our Meridian at the Summer Midnight. Then in the Meridian in its northern half, including the Zenith, are the upper Poles of the three Systems, and in no other circle but the Winter Colure, could this be the case.* Then the lowest point of the Ecliptic is due south, since its Pole is on the Meridian, and as far south of the Equator as its Pole is of the Earth's, that is, 23½ degrees. But Lyra is 25° south of the Ecliptic Pole, that is, 65° north of the Ecliptic itself. But the 8° of the northern half of the Zodiac must be subtracted from this to find how near to Lyra a bright Planet might possibly come, and we find it to be 59 degrees. But the greatest northern declination of a Planet which might be observed, when, on a winter midnight, the Summer Colure was in the Meridian, is $23\frac{1}{2}°+8°=31\frac{1}{2}°$. But Lyra's declination is about 48½°, which is 17° north of the possible place of any brilliant planet. But the young lady who asked the question, with so plain a star as Lyra to guide her to the place of the Ecliptic Pole and the lowest point of the Ecliptic, was out the way sixty degrees save one.

If the Planets are watched on consecutive evenings, in connection with the Fixed Stars, their annual movements will appear singular and confused, and their apparent sizes sometimes greater and sometimes less; and any Shepherd of the Stars, as the earliest astronomers were called, who, like us, gazed at them without the aid of instruments, will soon conclude that these are peculiar bodies, having motions different from other stars. Sometimes they appear to advance from west to east in the order of the signs, their motions being then *direct.* Sometimes, for a succession of nights, they appear to stand still, not moving at all with respect to the Fixed Stars; they are then *stationary.* And sometimes they move westward, contrary to the order of the signs, when they are said to *retrograde.*

To show the causes of this seeming confusion, we produce a simple diagram. The orbit of one of the inferior Planets, of which there are only Mercury and Venus, is here represented by the circle A B C D. They are never seen far from the Sun, since their orbits are within that of the Earth. They have two conjunctions with the Sun, but no opposition, and no quadrature. In the figure, if we suppose the Planet at A, it would be in its *superior* or upper conjunction; when at C, in its *inferior* or lower conjunction.

From the eye of an Observer on the Earth, tangents to the orbit are drawn to the celestial Sphere, of which a section of 60° is

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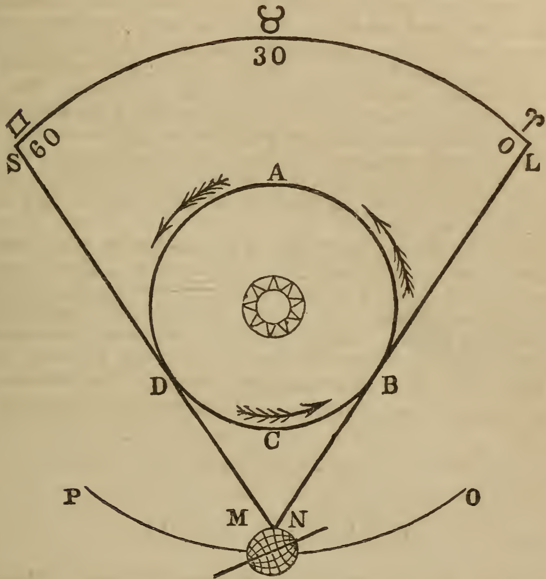
* See Figure 26.

taken, passing from the Sign Aries through Taurus to Gemini. Suppose the Observer to see the Planet, it being at B in the Heavens, in the first of Aries. While it is passing in its orbit from B, one of the stationary points, through A, its superior conjunction, to D, the other stationary point, it is seen by the Observer to

Fig. 34.



move in the Heavens *direct* from Aries, through Taurus to Gemini. Then apparently being stationary for a time, the Observer will see it—while in its orbit it moves from D through C, its inferior conjunction, to B—apparently to have turned its course in the Heavens, and gone backward in the Ecliptic from Gemini through Taurus to Aries. It appears stationary at the Observer's two side-views of its orbit at B and D, where the circle of the orbit nearly coincides with the two tangents N L and S M. Suppose the Planet were moving on the tangent S M from D towards the eye, it is evident that it would not change its place in the Heavens, but as it approached it would become apparently larger. So when it was receding along the tangent N L at B, it would not change its place in the Heavens, but its apparent size would diminish. If, when it is passing through A, its superior conjunction, it falls into the line of the Nodes, there will be an *occultation* of the Planet, or a hiding behind the body of the Sun; but if it is in conjunction at c, the inferior conjunction, then it will *transit* from east to west, like a black round spot across the Sun's disk. The inferior Planets, when viewed through the telescope, exhibit all the phases of the Moon, being *crescent* near the inferior, and *full* at the superior conjunction. Their apparent motions are most rapid when nearest the eye, that is, at the inferior conjunction.

The Superior Planets would, if the Earth were at rest, constantly move round the Ecliptic in the order of the Signs; slower and apparently of less magnitude when in conjunction with the Sun, because then farthest from the Earth; but faster and apparently larger, because nearer when in opposition. But the Earth mean time is moving, and sometimes faster than the superior planet; and sometimes, as the inferior planets to her, in a direction opposite to theirs. Owing to these causes, the Superior Planets have their stationary and retrograde appearances. They may be *occulted*, or hid by the body of the Sun, but they never transit across his disk.

Next to Venus, the most brilliant of the Planets, when seen by the naked eye, are Jupiter, Mars, and Mercury. Mars is distinguished by his color, as of fiery red; whereas the light of Jupiter, like that of Venus, is uncolored and brilliant. Seen through the telescope, Jupiter exhibits dark belts, supposed to be clouds. But when viewed through the telescope, Saturn, with his moons and rings, is the most interesting and curious of the Planets.

NOTE.—Fig. 24 should be drawn on the blackboard, and explained.

CHAPTER XXIII.

ASTRONOMY DOUBLY HONORS GOD, IN REFERENCE BOTH TO MATERIAL OBJECTS AND TO MIND.—DERIVATION OF THE TERM.—NATURE OF MIND, THE INSTRUMENT AND THE RECIPIENT.—HISTORY OF ASTRONOMY.—NATIONS WHO FIRST CULTIVATED THE SCIENCE.—CHINESE, INDIANS, CHALDEANS, PHENICIANS, EGYPTIAN PRIESTS, GREEKS.—IONIAN SCHOOL.—THALES, ANAXAMANDER, ANAXAGORAS.—SCHOOL OF CROTONA, PYTHAGORAS, DAMO, PHILOLAUS.—SCHOOL OF ALEXANDRIA.—ARYSTILLUS, TIMOCHARIS, ARISTARCHUS, EUCLID, ARCHIMEDES, ERATOSTHENES, HIPPARCHUS.

1. ASTRONOMY is the most magnificent of sciences. It doubly honors God, by showing man the distant wonders of the visible Creation, and by affording him the occasion

CHAPTER XXIII.—1. Why does Astronomy doubly honor God?

of the highest development of that inner region of Mind, equally the work of God, and not less sublime than the starry Heavens. Astronomy is the result of Mind operating on Stars and Worlds, and learning the laws which guide them. The term Astronomy is from two Greek words signifying a Star and a Law.* But the human Science of the Stars can advance only by the efforts of the Human Mind. Let us, then, for a moment turn our attention to the Mind—that wonderful Instrument which makes the Science it cultivates, and that great Recipient which is cultivated by the Science it makes.

2. On the 11th of December, 1830, the author heard, at the College of France, a Lecture from CUIVIER, and at the time thus wrote her impressions on the sublimity of a great Mind, as compared to the grandest of material objects: "His large and strongly marked head is to me sublime. I regarded it with attentive observation, and considered how the works of God exceed those of man. Within the little circle of that wall of bone, what stores of knowledge reside! The Mind which there inhabits, has been nourished to its prodigious growth by the products of the whole earth; and it has sent forth an impulse which every part of the civilized world has felt. Suppose for a moment the whole knowledge of events and facts, and all the reasonings and deductions, past and present, of that mind, were developed in words, the world could scarce contain the books that would be written. Suppose every conception of things external, whether of the concave Heavens or of the broad Earth, with her mountains and vales, which those eyes have conveyed to that mind, could be brought forth and stamped on some material medium, in the size which it has conceived or now conceives them,—with all the mingled forms into which fancy has arranged them, and all the images which other minds

* Our title—Astronography—if supposed to have a Greek derivation, would be from Αστρον and γραφο, signifying to describe the Stars. We prefer regarding it as but a shorter sound for Astronomy and Geography, thus united, as in this work.

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1. How is Astronomy connected with the Human Mind?—2. Give an example of thoughts suggested on beholding the head of a great man?

have furnished to that skull of a span's diameter; if the channels of the deep were dry, the mighty cavities could not contain the pictures."*

3. Thus Planets and Suns are not more grand or wonderful than the Mind which has measured their sizes and their distances, and comprehended the Laws of their motion. Man, by Astronomy, cultivates both his noble Faculty of SIGHT, and his nobler IMAGINATION, that inner sight of the mind; and as REASON accompanies his researches, what he sees in the Sun, the Planets, and the more distant Stars, comes to his mind with the equal impression of reality, whether beheld by the outer or the inner eye; and this grand imagery, thus received, remains aglorious region of the Astronomer's Mind. . . . What is the history of this sublime Science? . . . What are the nations, and who are the men, to whom we are most indebted for its cultivation?

4. When we look back into remote antiquity, we are met by facts which would seem to show that there was once an anterior civilization in the nations of the East, of which fragments alone have been preserved in the authorities on whom we depend for historical information. Chinese historians assert that with Fohi, contemporary with Noah (and some suppose identical†), began, in CHINA, the studies both of Astronomy and Mathematics, and that

* See Willard's Journal and Letters from France and Great Britain, page 120—published in 1833, in aid of female education in Greece.

† Fohi was said to have been the son of a rainbow, which is regarded as one proof that he was either Noah or one of his sons. China is now attracting more attention than heretofore, and is becoming better known; and this added knowledge gives confidence to the statements of their National Historians. It does not appear that the Chinese make any pretensions to an absolutely veracious History which goes higher than Hoan-ti. They regard that more ancient as mixed with fable, like the early records of all ancient nations. But subsequently an excellent method prevailed of keeping the annals of the Kingdom, which is thus

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3. What special faculties of the mind are cultivated by Astronomy, and what does the Astronomer's mind retain?—4. What is asserted by Chinese Historians concerning the beginning of the great sciences of Astronomy and Mathematics?

both had so far advanced, that in the reign of Hoan-ti, who lived in the time of Abraham or earlier, his minister, Fanar, made a System of Mathematical Chronology, founded on Astronomical Observations. He adopted, instead of our Century of 100 years, the Period, or *Cycle* of 60 years. An Eclipse is described, and is claimed to have been calculated, 2155 years B. C. The books of Confucius, published about 500 years B. C., contain predictions of 36 Eclipses of the Sun. The Jesuit Gaubil relates that he examined them, and found among them only two false and two doubtful.

5. By the Emperor Yu or Ju, who was contemporary with Confucius, the great Philosopher and Lawgiver of China, was founded an *Observatory*, which he caused to be attached to the wall of his capital, rising above and resting upon it in the form of a square tower. Here it is said he placed an *Armillary Sphere** of six feet diameter, and a *Celestial Globe* equally large, having the Stars

described by Clerc, a reliable French writer of the last century: "De tout temps il y a eu à la Chine, le Tribunal de Mathématique et le Tribunal d'Histoire réunis: ces deux Tribunaux ont continué d'années en années, l'un ses mémoires, l'autre ses observations pour la suite et la vérification des faits contenus dans les cent-vingt volumes des grandes Annales. Ces Annales ont toujours été rédigées avec le plus grand soin, et l'exactitude la plus scrupuleuse."

* "The *Armillary Sphere* is an artificial sphere composed of a number of circles of the Mundane Sphere (Sphere of the Earth), put together in their natural order, to assist in giving a just conception of the constitution of the Heavens, and the motions of the celestial bodies." This artificial sphere revolves upon its axis within a horizon divided into degrees, and movable every way upon a brass supporter. By the axis and circles constituting an Armillary Sphere, as they appear in the drawings formerly placed in books of Astronomy, we are reminded of our figure,

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4. What Cycle, or period of time, was introduced by Fanar? In whose reign, and at about what time did this reckoning commence? How does it appear that the Chinese calculated Eclipses at an early period?—5. Who was Confucius? In whose reign did he flourish? What was done concerning Astronomy by this Emperor in regard to a building? What two pieces of apparatus are said to have been placed within it? What is an Armillary Sphere?—(*See Note.*)

marked upon it in their natural positions. But if this was so, then the Chinese knowledge of Astronomy must have been greatly in advance of that of Geography; for they held that China was the middle of the Earth—their name, Chang-qua, signifying the Kingdom of the Centre—and they supposed it to be not only the middle of the solid land of the Earth, but nearly the whole of it, the remainder being only small scraps, of which they reckoned 72, ranged around like small islands, or as satellites which accompanied and decorated their own "Celestial Empire."*

6. INDIA, as well as China, claims great antiquity in regard to Astronomy. . . In EGYPT, the priests, those dark and fearful men, knew perhaps more than any other Astronomers of ancient times concerning the heavenly bodies; but the exact extent of their knowledge can never be known, since they cultivated Science not to enlighten, but to subjugate mankind; and hence they made it occult and mysterious, to be taught only to the initiated, and under the seal of secrecy. . . . The Shepherds of CHALDEA and the Mariners of PHENICIA early watched the Stars, and formed their Observations into Systems. When Alexander the Great invaded those regions, he brought from BABYLON to GREECE the recorded Observations which their Astronomers had been making for 1900 years. They predicted (720 years B. C.) Eclipses of the Moon. Their predictions were not made, however, on the unerring prin-

showing the combination of our three Spherical Systems; but we think the former are less perspicuous and suggestive. We hope our three Systems will soon be exhibited by apparatus, where their connections and possible motions may be seen, and the whole be adjusted to show desired particular cases.

* See Clerc's Histoire Chinoise, p. 12.

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5. What comparison may be made between Chinese Astronomy and Geography? What were their impressions concerning the habitable Earth?—6. What other nation claims great antiquity in regard to Astronomy? What is said of the Egyptian Priests, in regard to Astronomy? In what countries did the Shepherds and the Mariners, in very early times, begin their scientific observations of the Stars? When and by whom was the Astronomical learning of eastern nations brought to Greece?

ciples since discovered and now in use; but on long-continued and recorded observations of the time intervening between Eclipses of a similar kind. By these they learned the actual period, which occurred between the Moon being in a similar position with regard to the Sun. The years which intervene between two of these periods are a *Lunar Cycle.* The Cycle in use with the Chaldeans they called the *Saros.* It consisted of 223 lunations, or 18 years and 10 days. Subsequently the *Metonic Cycle* of 19 years, so called from its author, Meton, was used by the Greeks.

7. The beginnings of Astronomy come to us through the Greeks. The first great men of Greece who cultivated the Science, went to Egypt and studied with the priests. The earliest of these, whose name has come down to us, was THALES of Miletus, who, after spending his youth in Egypt, returned to Greece and founded the IONIAN SCHOOL. "He maintained that the Stars were of the same substance as the Earth; that the Moon borrowed her light from the Sun; that the Eclipses of the Moon were occasioned by her immersion into the Earth's Shadow; that the Earth was round; that it was divided into five Zones by the Polar Circles, the Tropics, and the Equator; and that the Equinoctial Line was cut obliquely by the Ecliptic, and perpendicularly by the Meridian. By means of the instruction which he received in Egypt, Thales predicted an Eclipse of the Sun, and the fulfilment of this prediction raised him to a high place among his countrymen."* Although this philosopher taught so many truths, yet they were mingled with many errors. It

* Edinburgh Encyclopedia. If Thales taught all these things, he must have made some fortunate guesses; for surely Science was not in a state of sufficient advancement that they could all be known. There is discrepancy among authors as to what these very ancient philosophers did teach.

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7. From whom do we obtain the beginnings of Astronomical knowledge? Where did the first great men of Greece, who cultivated Astronomy go? Who was the first emiment Astronomer of Greece? What celebrated School did he establish? What doctrines is Thales said to have maintained? What gave him a high place among his countrymen?

shows how little was then known of Mathematics, that it was considered a wonderful achievement which the priests had taught him to perform, that he could decide the height of the pyramids by the length of their shadows.

8. ANAXIMANDER, also of Miletus, the pupil of Thales, succeeded him as chief of the Ionian School. He regarded water as that element, from which every thing else was made. Filled with all the enthusiasm for Astronomy which the noble Science is calculated to inspire, he boldly taught that the Planets were analogous to the Earth, and were peopled with beings of a similar nature; and he sublimely conjectured that the "*fixed stars were centres of other systems more glorious than our own.*"

9. ANAXAGORAS, of Clazomene, a later chief of the Ionian schools, was so devoted to Astronomy, that he gave up the affairs of life, maintaining that the contemplation of the stars was the natural destiny of man. A *meteoric stone* having fallen into the river Egos, in Thrace, his mind was greatly excited, and he produced the idea, then original, that the large mass composing this stone was a body which was revolving around the Earth lower than the Moon; and since the matter which composed it was similar to that of the Earth, he hence concluded that the heavenly bodies generally were formed of the same materials as the Earth. Some of the solid stony bodies revolving around the Earth he believed were made to glow by the fiery ether around them; while some, nearer the Earth, remained dark. These, he supposed, sometimes eclipsed the Moon, and sometimes, like the one at Egos Potamus, they fell to the Earth. The phenomena of the Heavens he attributed to the agency of fire. The Sun he regarded

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7. What was done by Thales in a Mathematical way? What inference may we make from this being considered a great achievement?—8. Who was the successor of Thales in the Ionian School? How did he regard water? What did he teach concerning the Planets? To what conjecture is it said his thoughts reached concerning the Fixed Stars?—9. Who was it that maintained that the study of the stars was the natural destiny of man? What event excited his mind? What idea concerning this remarkable aerolite, originated with Anaxagoras?

as a *great inflamed stone;* but the Moon he supposed to contain hills and valleys, and to be inhabited. He was the first Greek to write respecting the Moon's phases and eclipses. The Athenians, for this, accused Anaxagoras of rashly intermeddling with the affairs of the gods; and it was with difficulty that his friend PERICLES saved him from perishing by their fanatical fury, and prevailed with them, to change his sentence from death to banishment.

10. We come now to speak of another Greek, whose name looms up amid the darkness of antiquity like some tall mountain on the waste. This was PYTHAGORAS, of Samos, often mentioned as "the Samian philosopher." Pythagoras, after having studied with Thales, travelled in search of knowledge through Phenicia, Chaldea, and India; and then went to Egypt, and there became acquainted with all the learning of the priests. Warned by the fate of Anaximander, he turned from his native land and opened his celebrated SCHOOL OF CROTONA, in Calabria, Italy. But after the manner of the priests, he taught only those whom he had bound to secrecy by solemn promise, and tested by a probationary discipline of silence. In his school he taught, as was after his death revealed by one of his pupils, that the Earth is a globe, that she moves in her annual course around the Sun, while she revolves daily on her own axis. Above all, Pythagoras *taught, for the first time, the true system of the world, that the Sun is in the centre, and that the planets, with the Earth, perform annual revolutions around him.* This is the true system, and the same

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9. What visionary and fanciful ideas had he, respecting the Sun and Stars? What did he teach concerning the Moon? What was the effect of his teaching upon the Athenians, in regard to their treatment of him?—10. What are the introductory remarks of the author concerning Pythagoras? Where did he go in search of knowledge? Why, when educated and ready to begin teaching, did he turn from his native land? Where did he establish his school? In what respect did he follow the example of the Egyptian priests? How were his teachings finally made public? What did he teach respecting the Earth? What, however, was the most remarkable of his doctrines?

which, after 2000 years, was revived by Copernicus. But what with Pythagoras, was only sublime and reasonable conjecture, modern philosophy, working by Mathematics, has made a glorious certainty. The degree of advancement in Mathematics necessary for this had not then been attained; although Pythagoras was the greatest mathematician of his time. The demonstration of the beautiful theorem in Geometry* which bears his name, was then regarded a proud advancement in that science, although now standing but as its initial point.

11. Pythagoras was so wrought into the study of the Heavens, that his imagination became over-excited. Having a great love of music, and not knowing the causes of the planetary motions, he fancied that there were different concentric solid spheres, in each of which, one of the planets was fixed; and as they moved one upon another, they emitted harmonious sounds, although the human ear was, in general, too gross to enjoy the ravishing delight of "the music of the Spheres." Pythagoras left his secret doctrines to the keeping of his learned daughter Damo; but his pupil, Philolaus, after his decease, 450 B. C., made them public. Neither Plato nor Aristotle,† though so great in philosophy, did much, either for Mathematics or Astronomy,—and our attention will next be called to the great school of Alexandria.

12. The conquests of Alexander the Great so dazzle

* Pythagorean theorem is the 47th of the First Book of Euclid.

† Often called "the Stagyrite," because he was born in Stagyra, in Macedonia.

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10. What is said of the system taught by Pythagoras? Why was it impossible that Pythagoras should then have made his system as certain as it has since been made by modern philosophy? What is said of Pythagoras in regard to mathematics?—11. How was it with this great philosopher in regard to imagination and a love of music? What are some of the fanciful theories framed to account for the motions of the planets? Who was the chosen depositary of the secret doctrines of Pythagoras? When and by whom were they revealed? What great philosophers of Greece followed, to whom Astronomy, however, is not much indebted?

us as military achievements, that we are apt to forget their more important scientific advantages. Alexander was the pupil of Aristotle, and his soul was imbued both with the love of knowledge, and with friendship for his great master; and he took those to accompany him in his expeditions, whose special duty it was, to make observations on various subjects, and report them to the public—and especially to Aristotle, who taught them orally, and embodied them in his works. Vast unknown countries, with their productions, were now brought to the knowledge of the Greeks. Thus, a new fountain of information, exciting to thought and effort, was opened to the world; and it was continued by the connections of trade and social intercourse with the newly discovered nations.

13. After Alexander's death, one of his generals, Ptolemy, who shared his leader's zeal for knowledge, succeeded to the sovereignty of Egypt. He began—and his sons continued—to collect the most learned men and the best writings of the world; and thus to lay the foundation of the great LIBRARY and SCHOOL OF ALEXANDRIA, which, for several centuries, remained as the greatest scientific light of the world. When we compare this school with the Ionian, we find a great advance in exactness of knowledge, and less of the false and fanciful. EUCLID belonged to the Alexandrian school, and ARCHIMEDES was connected with it. These two men laid the foundation of those principles of geometric mensuration by which Astronomy at length ceased to be a conjectural, and became a certain science. Humboldt, in his Cosmos,* says, "during the epoch of the Ptolemies, splendid progress

* *Cosmos*, a Greek word, signifying world or universe. Sometimes used as synonymous with universal nature.

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12. What is here said of the conquests of Alexander the Great? Of what importance to science was, in this case, the teaching of a great master to his pupil?—13. What occurred after Alexander's death in Egypt, especially at Alexandria? How does the Alexandrian school compare with the Ionian? What two men are first mentioned, and what is said of them and the effects of their labors in Astronomy? What says Humboldt of the epoch of the Ptolemies?

was made in the scientific knowledge of the Heavens." ARYSTILLUS and TIMOCHARIS determined and described the places of the Fixed Stars. ARISTARCHUS, of Samos, who was conversant with the Pythagorean views, was the first to recognize the immeasurable distance of the Fixed Stars from our own Planetary System. He conjectured the twofold motion of the Earth upon its axis and around the Sun. ERYTHEA, a century afterwards, endeavored fully to establish the hypothesis of Pythagoras, but in that age it met with little attention.

14. But HIPPARCHUS was the great luminary of the Alexandrian school. He was both *the founder of scientific Astronomy and the greatest astronomical observer of antiquity.* He collected in tables all the descriptions that could be found from the previous records of Astronomy; and from observation of the Stars at the time of the Equinoxes; and from learning what their position at the time of equal days and nights had formerly been, he discovered the Precession of the Equinoxes, and the correspondent retrocession of the Equinoctial Points. A peculiar feature in the labors of Hipparchus was the use he made of his observations of celestial phenomena for the determination of geographical positions.

ERATOSTHENES, of this school, who preceded Hipparchus, was the most celebrated of the Alexandrian librarians. He availed himself of the materials at his command to compose *a System of Universal Geography.* He taught the great problem of *the equal level of the whole external sea, surrounding all continents.* Eratosthenes caused a degree of the Earth's surface between Syene and Alexandria to be measured, thus seeking to find an element by which he might approximate to the real size of the Earth. He made a map, which, after his decease, Hipparchus

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13. Who first determined and described the places of the Fixed Stars? Who first recognized their immeasurable distance?—14. But who was the great astronomical luminary of the Alexandrian School? What is said of him and his labors and discoveries? What was peculiar respecting his teaching? What great geographer preceded Hipparchus at Alexandria? What was done and taught by him?

crossed with lines of latitude and longitude. These were the beginnings of the science of Geography, which, in the next century, was cultivated by STRABO, a native of Pontus. But at this period, and for centuries afterwards, the boundaries of the eastern continent had not been ascertained; and what dangers might be hidden in unknown regions, none could tell. As for Astronomy, although it was in advance of Geography, still no progress had been made in knowledge of the absolute size, form, mass, and physical character of the heavenly bodies.

EXERCISES.

We expect your interest in the examination of the starry Heavens will be increased, as you read of the great men of antiquity who have gazed with so much pleasure and profit upon the same stars, which are standing now essentially in the same position with regard to each other as then. The Moon was walking through the same bright path, then, as now. There were then NINE STARS which were noted as marking her monthly course, and the mariner now watches for the same stars, as did the mariners of old. These nine stars, which thus mark the track of the Moon, are Arietus, Aldebaran, Pollux, Regulus, Spica Virginis, Antares, Altair, Fomalhaut, and Markab. Learn them, as you are able, with their Declinations and Right Ascensions. But take one star at a time, and let that be well considered, as to its appearance and position, before you attempt to learn others.

Let your star for study this evening be Spica Virginis. Burritt, in his excellent work, "The Geography of the Heavens," thus describes its position. "Spica Virginis, in the ear of corn which the Virgin holds in her left hand, is the most brilliant star in the constellation Virgo, and is situated nearly 15° E. N. E. of Algorab in Corvus, about 35° S. E. of Denebola, and nearly as far S. S. W. of Arcturus—three very brilliant stars of similar magnitude that form a large equilateral triangle pointing to the South. Arcturus and Denebola are also the base of a similar triangle on the North, terminating in Cor Caroli, which, joined to the former, constitutes the *Diamond of Virgo.* The length of

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14. How were his labors extended by Hipparchus? What geographer afterwards appeared? What, however, was the state both of geographical and astronomical knowledge?

this figure, from Cor Caroli on the North to Spica Virginis on the South, is 50°. Its breadth, or shorter diameter, extending from Arcturus on the East to Denebola on the West, is 35½°. Spica may otherwise be known by its solitary splendor, there being no visible star near it except one of the 4th magnitude, situated about 1° below it on the left." When you have identified the star, then proceed to judge concerning its Right Ascension and Declination, and finally consult the Globe or a Table of Right Ascension, in order to correct your judgment.

When you look at Spica Virginis, think of Hipparchus, who discovered (B. C. 130) the Retrocession of the Equinoctial Points, in part by comparing the position of this star as he saw it, with what had been, as he learned, its former situation; and also consider that the accurate description made by him, and afterwards renewed by Ptolemy and others, has put it in the power of later astronomers to decide exactly the time (50″) of the Precession of the Equinoxes, and the space (about one-third of a degree) of the Retrocession of the Equinoctial Points.

Find on the Terrestrial Globe, China, India, Chaldea (its capital ancient Babylon), and Egypt. Describe the position of Greece and of Athens, the seat of the Ionian School; of Samos, the birthplace of Pythagoras; of Crotona (in Italy), where Pythagoras kept his famous school; of Alexandria, in Egypt, where was the greatest Library and the greatest School of ancient time, where Eratosthenes taught Geography, Euclid Geometry, and where Hipparchus laid the foundation of scientific Astronomy.

CHAPTER XXIV.

HISTORY OF ASTRONOMY AFTER CHRIST.—PTOLEMY—HIS SYSTEM.—THE ALMAGEST.—HISTORICAL GREAT EVENTS QUICKEN INVENTIVE GENIUS.—DISCOVERY OF AMERICA.—COPERNICUS—HIS SYSTEM:—COMPARED WITH PTOLEMY'S.--TYCHO BRAHE.--KEPLER—HIS THREE LAWS.—THE DISCOVERY OF THE TELESCOPE.—GALILEO—HIS PERSECUTION.—HUYGENS AND OTHERS.—SIR ISAAC NEWTON—HIS EXCELLENT CHARACTER.—GREAT LAW OF UNIVERSAL GRAVITATION.

1. PTOLEMY, of the Alexandrian school, who was born A. D. 70, at Pelusium, in Egypt, and flourished in the beginning of the second century, was the most eminent astronomer who lived after Hipparchus, until the time of Copernicus. But although for so many centuries he led the opinions of mankind, we may now perceive that his mind and genius were not of the first order; for that seemed to him to be truth which was not truth; but which, lacking simplicity and clearness, bore rather the mark of specious error.

2. The system taught by Ptolemy, supposed the Earth to be at rest in the centre, and the Sun, Moon, Planets, and Fixed Stars to move around it once in twenty-four hours. To account for the irregular motions of the Planets, Ptolemy, with great ingenuity, invented a machinery of retrograde spheres, called epicycles,* into one of which

* Humboldt, in the *Cosmos*, says: "The idea of a crystalline vault of heaven was handed down to the Middle Ages by the Fathers of the Church, who believed the firmament to consist of from 7 to 10 glassy strata, incasing one another like the different coatings of an onion. This supposition still keeps its ground in some of the monasteries of southern Europe, where I was greatly surprised to hear a venerable prelate express an opinion in refer-

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CHAPTER XXIV.—1. Who was the great astronomer of the Middle Ages? Since Hipparchus flourished about 130 years before Christ, and Copernicus about 15½ centuries after, how many centuries elapsed without an astronomer of equal eminence? What opinion may now be formed concerning the mind and genius of Ptolemy?—2. Give some account of the system of Ptolemy.

each planet was supposed to be fixed, each having its proper motion sometimes backwards, and sometimes forwards. These epicycles he supposed to be mingled with solid spheres, one of which having power to move the others, he called it the *primum mobile.** Ptolemy collected the fragments of ancient Astronomy. He made an *Artificial Celestial Globe,* on which he placed the Constellations, rectifying the situation of the stars for his own time, and giving their differences from that of Hipparchus. His catalogue of the Stars—by far the most valuable of his works—still remains, and is the oldest extant.

3. He was an accurate observer, an industrious collector of facts, and a diligent and voluminous writer. Ptolemy and Strabo were the greatest geographers of the period, and both wrote extensively on geography. Ptolemy's work on Astronomy was, however, his capital performance; and it was long regarded as the most learned work existing. It was divided into 13 books, and was trans-

ence to the fall of aerolites at Aigle, which at that time formed a subject of considerable interest, that the bodies we called meteoric stones, with vitrified crusts, were not portions of the fallen stone itself, but simply fragments of the crystal vault shattered by it in its fall. Kepler, from his considerations of comets, which intersect the orbits of all the planets, boasted, nearly two hundred and fifty years ago, that he had destroyed the 77 concentric spheres of the celebrated Girolamo Fracastaro, as well as all the more ancient retrograde epicycles."

* When Alphonso X., king of Castile, collected at his capital the great astronomers of the world—who believed with reverence what Ptolemy had taught, his mind revolted at such a cumbrous and complicated scheme of the Universe. He did not believe that God had made what man could see to be unwise, and he rebuked their blind belief somewhat too boldly by declaring that "if the Almighty had called him into counsel when he was about to create the world, he could have given him good advice." It was by the direction of this monarch that the Alphonsine Tables were undertaken, in 1252. They were corrections of the Ptolemaic Tables.

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2. How, in endeavoring to prop up absurdities, did he manifest ingenuity, if not genius?—3. In what respect did he manifest great industry, and do good service to the cause of Astronomy? What other science besides Astronomy did Ptolemy cultivate?

lated, A. D. 700, into Arabic. The Arabians gave it the title of *Almagest*, or "The Great Composition," by which it has ever since been known. It was translated from Arabic into Latin; but at the revival of letters in the fifteenth century, the Greek text was found and printed. The work is still valuable for its minute description of the stars, by which the difference of their places at that time, at the era of Hipparchus, and at the present or any future period, can now be known.

4. The Arabs, under the Caliphs, cultivated Astronomy, and the Caliph AL-MAMUN was himself an eminent Astronomer. The Arabians at this period excelled other nations in Mathematical Science, particularly in Algebra; and although they received the false system of Ptolemy, yet they contributed to the establishment of the true, by observing and recording all appearances and variations in the places of the heavenly bodies, by which later astronomers had a greater range of data collected for their use. The Tartars acquired from them a taste for Astronomy, and ULIEGH BEIGH, one of the descendants of Tamerlane, at his capital, Samarcand, built and furnished an observatory, collected learned men, and caused an independent catalogue of the stars to be drawn up, which has also proved serviceable to later Astronomers.

5. The progress of the human mind in scientific discovery is sometimes led on by great historical and geographical events. Thus, the opening of a new world to the ancient Greeks by the expedition of Alexander the Great, led the way to the Alexandrian Library and School, and to that scientific awakening of mankind, which took place in the days of Archimedes and Hipparchus. And thus, the opening of another and more astonishing new world by Columbus, was followed by a similar and still

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3. Give some account of Ptolemy's greatest work.—4. Who next to Ptolemy are mentioned as having cultivated Astronomy? In what did the Arabians particularly excel? In what respects were their labors serviceable to Astronomy? What people derived a knowledge of Astronomy from the Arabs, and what individual among them?—5. How is the human mind sometimes led in scientific discovery? What two examples are here given?

more remarkable awakening of the scientific energies of the human mind in the 15th and 16th centuries.

6. The first of the intellectual giants who at this period put forth his strength upon Astronomy, was Copernicus, a native of Thorn, in Prussia, who was born 1473, and who published the result of his labors in 1530. He taught the true system of the universe; that system which places the Sun in the centre, with the Planets, including the Earth, revolving around him—the Earth and the other Planets performing diurnal rotations on their axes. This scheme was now no mere fortunate guess. Copernicus had before him a large amount of Astronomical knowledge in the recorded observations of his predecessors, with a good degree of advancement in mathematical science; and his theory of the Solar System was founded on proven facts, and sufficient reasons.

7. Copernicus not only manifested an intellect of the highest order, but he showed also a corresponding moral elevation. He boldly stood up against the "hoary error" of the Almagest, and braved the displeasure of the priests; for the Church was zealously attached to Ptolemy's system, regarding it as proved by the evidence of the senses, and according with the Scriptures. In opposition to its intricate absurdities, Copernicus thus describes the simplicity of his own grand scheme of the Heavens. "By no arrangement," he exclaims with enthusiasm, "have I been able to find so admirable a symmetry of the universe, and so harmonious a connection of orbits, as by placing the lamp of the world, the Sun, in the midst of the beautiful temple of nature, as on a kingly throne, ruling the whole family of circling stars that revolve around him."

8. Although Pythagóras had sketched the same majes-

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6. Who was the first of the men of great genius to come forward after the discovery of America? That event happened 1498. How old was Copernicus at that time? How long after that did he publish his system? What does the Copernican system teach? How was it founded?—7. What was the intellectual and moral character of Copernicus? By whom was he specially opposed? How does he describe his own system?

tic and simple view of the Heavens, yet Copernicus did not borrow from him. He produced his own more perfect system by the original working of his own genius, upon far more ample materials; and his system, unlike that of Pythagoras, could never have been lost; not only because he taught it publicly, and committed it to writing, and by the then recent discovery of the art of printing copies were multiplied, but because it was thus produced *with proofs*, which satisfied the greatest and most logical minds. But Copernicus left his system encumbered with the imaginary and inadequate idea of those interminable solid spheres, in which it was supposed that the heavenly bodies must, since they moved, be placed.

9. JOHN KEPLER was born in 1571, in Wiel, in the duchy of Wurtemburg. During the lifetime of his father, who was an innkeeper, his advantages for learning were small; but on his death, his mother found means to forward the cultivation of his great natural abilities, by placing him in the university of Tubingen, where he made such rapid advances in philosophy and mathematics, that TYCHO BRAHE, the great Danish astronomer, then much distinguished by Rodolphus, emperor of Austria, invited the young scholar to reside with him at Prague, the capital of Bohemia, and study Astronomy, with the advantages afforded by his instruction and observatory. Tycho Brahe denied the great truths taught by Copernicus, and he read with reverence the Almagest of Ptolemy; denying, however, some parts of his system, and substituting a scheme of his own scarcely less absurd. Kepler was too independent in his thoughts, to make the connection pleasant between him and the opinionated Tycho Brahe.

10. But notwithstanding this, Kepler was, in his future

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8. What parallel is here drawn between the Copernican and Pythagorean systems? What drawback still existed to the scientific light spread by the system of Copernicus?—9. Give an account of the birth and early years of JOHN KEPLER. By whom and to what place was he invited from the university? For what object was he invited? Give some account of the opinions of Tycho Brahe. What is said of the connection of Kepler with Tycho Brahe?

astronomical course, greatly benefited by the unwearied celestial observations which Tycho Brahe himself made, and which he imposed on Kepler, who was thus laying up a store of new facts and data for reasoning. When Tycho Brahe died, he left it to his pupil to complete the tables which he had begun. This Kepler did, and dedicating them to the Emperor, called them the Rodolphine Tables. He was made by the Emperor royal astronomer, but he was afterwards ill-treated by him, and left to suffer from poverty; so that he removed from Prague to Lintz.

11. But whatever was his outward fortune, Kepler experienced within himself the stirrings of a mighty mind fixed on the most sublime of subjects, and by degrees bringing forth results which to this day astonish the scientific world; and which, as he truly said, made "a total reformation in Astronomy." He had before him the new stock of facts derived from the mingled observations of Tycho and himself, and especially those resulting from the fixed scrutiny of years upon a single astronomical object, the orbit of Mars. Kepler saw that the system of Copernicus, as to the arrangement of the heavenly bodies, was true, but that the whole theory of solid spheres and epicycles was fabulous. But how did the planets move?—in what orbits?—and how were their seeming irregularities to be traced to regular laws?

12. Long and patiently did he investigate, and at length, after nineteen years of study, he brought to light and fully proved the three laws, designated as "the laws of Kepler;"—rather they are laws of the Almighty, discovered by him. As they are now a part of the study of every liberally educated person, they stand arranged as they should be learned, but not in the order of discovery, for Kepler produced the second before the first.

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10. How was Kepler benefited in his astronomical course? Whose work did he complete? What had Kepler from the Emperor Rodolphus?—11. But what may be said of the inner scientific life of Kepler? And what of the results produced by the working of his mind? What materials had he to work upon? How did he regard astronomy as left by Copernicus?—12. What is said of the time and manner in which Kepler produced his three laws? In strictness, are they laws of Kepler?

13. Kepler's three laws, as found in books of science, are, first, *The orbits of the Planets are not circular, but elliptical, having the Sun in one of the foci.* The second in place, but the first discovered, Kepler wrought out after observing that Mars moved with a rapidity proportionate to his distance from the Sun; and after inventing the fancied medium of measurement, which is called the RADIUS VECTOR, he enunciated the law that the *radius vector*, as the body revolves, *describes on the plane of its orbit equal areas in equal times.* Last, he discovered his third law, that in the revolutions of the planets and their satellites *the squares of the times of their periodic revolutions are as the cubes of their distances.* These laws prove that the Maker of all worlds is the Infinite Geometer—the Perfect Mathematician.

14. This third discovery was Kepler's crowning achievement. The thought occurred to him on the 8th of March, 1618. The elements by which he was to decide were before him. He proceeded to calculate, but at first made a mistake;—the result disappointed him, and he abandoned his principle. But on the 15th of May he rallied to a fresh attempt, again made the calculation, succeeded in bringing out the result required, and the great principle was forever established.*

15. Hitherto the study of the Heavens had been pursued by astronomers solely by the unassisted sense of sight; but a great change was now in progress. Contemporary with Kepler was GALILEO, the great astronomer of Italy (born in Florence, 1564); who, although not abso-

* See Note in "Cosmos," p. 695.

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13. What is set down in ordinary books as the first of the three laws? What is reckoned as the second? And what is the third and greatest of these laws? When we find the great works of God made according to the most abstruse rules of mathematics, what must we conclude?—14. Give the time and circumstances of Kepler's final solution of the great problem of the relations between the times and distances of the planets.—15. Up to this period how had astronomers pursued their studies and observations? By what instrument was a great change effected? What is the country of Galileo, and the date of his birth?

lutely the inventor of the TELESCOPE, has the honor of being the first who adapted and applied it to astronomical purposes. There were, at the beginning of the 16th century, simultaneous improvements made in eye-glasses; and two Germans, working separately, came to the knowledge that they might be so arranged as to magnify distant objects, and bring them to an apparent near view. This was the principle of the telescope. This discovery was made in 1607, by HANS LEPPERSHEY, a native of Wesel, in Germany, and about the same time by JACOB ADRIANSZ. The double microscope was invented a little earlier, by ZACHARIAS JANSEN. Both Leppershey and Jansen were spectacle-makers of Middleburg.

16. Galileo heard of their discoveries in 1609, and conjecturing what must be the essential points of a telescope, he being at Padua, constructed one for his own use, and there, for the first time, the magnified Heavens were viewed by man. By the extension of the powers of his vision, Galileo at once made important discoveries. The Moon's surface, as showing its variant shadows of mountains thrown opposite to the light, and its darker valleys receding from it, was thus seen by him to be opake, like the Earth. Numbers of fixed stars, which had never before been seen, now met the gaze of the delighted astronomer, in whatever direction he turned his telescope. When it was directed to the Milky Way, he saw so many stars that he conjectured its whiteness to be—what Sir William Herschel afterwards demonstrated—but the blended light of myriads of distant stars. When he examined the Planets, new wonders appeared. Venus, as Copernicus had asserted, waxed and waned, like the Moon. Jupiter, Galileo discovered, was not solitary, but attended by four satellites. He looked upon Saturn, and pronounced it unlike the other Planets, believing there were three bodies

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15. How far is Galileo entitled to the honor of introducing the telescope? Who were its absolute discoverers? Who discovered the microscope?—16. Where and by whom were the magnified Heavens first seen? What discoveries did Galileo immediately make by the use of his telescope?

united. But his telescope was yet too small and imperfect to show with exactness its peculiar figure.

17. By the phases of Venus, and other discoveries which Galileo had made by means of the telescope, he had proved that the system of Copernicus was inevitably true; and he openly taught it as comprising the annual and diurnal motions of the Earth. The Inquisition, then in full power in Italy, regarding the new doctrine as anti-Christian and irreligious, forbade Galileo to teach it. To evade the prohibition—for he strongly felt the natural dread of imprisonment and torture, as well as the discoverer's impulse to impart his discoveries—he wrote on the system of the world, in the form of a dialogue, where one speaker takes ground in favor of the Ptolemaic, and another in favor of the Copernican system. And although the author carefully abstained from expressing any preference of his own in favor of either, yet his book being observed by the inquisitors to make converts to the Copernican system, they issued a decree, in which they declared that the motion of the Earth was a doctrine "absurd, false, heretical, and contrary to Scripture," and they condemned the book, and imprisoned the author. Galileo was now old. An assembly of cardinals, before whom he was called June 22d, 1633, required him to recant his errors, and he knelt down before them, and, at their dictation, declared that he "abjured, execrated, and detested the absurdity, error, and heresy of the Earth's motion." And even this did not so satisfy his fanatical persecutors that he obtained his full liberty. Some have said that he whispered, as he rose from his knees, "It moves, notwithstanding." Whether he uttered these words or not, he no doubt so believed; for all mankind united cannot hinder the truth of God, nor make the mind which has learned and known—ever unlearn, or unknow it.

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17. What had Galileo proved by the use of the telescope? What did he teach? What is said of the Inquisition? What was now the course of Galileo? What was its effect, and what was done and declared by the inquisitors? Give an account of the requirements of the inquisitors, and the recantation of Galileo as an example of the folly and weakness of mankind.

18. A host of Astronomers followed in the train of Kepler and Galileo. HUYGENS improved the telescope, and by adding pendulums to clocks, he aided in the exact measurement of time, and led to a knowledge of the spheroidal form of the earth; and he discovered that the singular appearance of Saturn was caused by a large ring inclined 30° to the Ecliptic. He also made profound researches respecting central forces, which prepared the way for the discoveries of Newton. DOMINIC CASSINI, professor of Astronomy at Bologna, Italy, discovered the diurnal revolutions of Jupiter, Mars, and Venus. He prepared tables, from his own observations, of the eclipses of Jupiter's satellites, which were of great use in finding longitudes; he discovered five of the satellites of Saturn, and the rotation round its axis of one of the number; he observed the belts upon Jupiter and Saturn; and finally, he discovered that Jupiter was an oblate spheroid, flattened at the poles, and having its equatorial diameter to its polar as 15 to 14.

19. In England, under Charles II., the Royal Observatory was erected at Greenwich, and a succession of eminent astronomers was placed at its head, the first of whom was FLAMSTEAD, who explained the Equation of Time; and the second was HALLEY, distinguished for his unwearied observations upon the Moon.

20. There was still in the Science of Astronomy a void; for although Kepler had embodied in his Laws the great facts concerning the motions of the heavenly bodies, yet none knew the reason why such facts existed. The man who supplied this void was ISAAC NEWTON. He was born in Woolstrope, Lancashire, England, on the 25th of December, 1642. The common idea that genius creates opposition and leads to worldly misfortunes, seems not to have been a reality in the case of Newton. So sunny was

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18. Who of the Astronomers following Galileo and Kepler, is first named? What services to Astronomy and discoveries are attributed to Huygens? What to Dominic Cassini?—19. What was done to encourage the Science of Astronomy in England? Who were the first Directors of the Royal Observatory at Greenwich?—20. Why was there still a void in Astronomical Science? Who supplied this void? Where and when was he born? What is a common idea respecting genius?

his disposition, so meek and conciliating his demeanor, that all who knew, loved him; and although he could not escape some disputes with the opposers of his new doctrines, yet, on the whole, life was to him as a pleasant voyage.

21. Newton manifested such early spontaneous talents, that his mother* gave him advantages of education which his moderate fortune had not entitled him to expect; and he was early sent to Trinity College, Cambridge. Here favors and honors awaited him. After his education was concluded he received government patronage without his own solicitation—being made Master of the Mint on a liberal salary. In 1703 he was elected President for life of the Royal Society; and two years afterwards, he was knighted by Queen Anne at Trinity College. He was liberal, saying that those "who gave nothing till they died, never gave;" but he was at the same time so economical, that he remained not only free from pecuniary embarrassment, but at his death, 1727, he left to his relatives (never having married) a fortune of thirty-two thousand pounds. Such was Sir Isaac Newton—meek as the most lowly, yet possessing that grandeur of intellect and purity of morals, which connect man with angelic natures.

* It is worthy of remark, that both Kepler and Newton were, during childhood, under the sole charge of their mothers; Newton's father dying before his birth, and Kepler's, who had been an inn-keeper, dying while he was yet a child. In both cases, the mothers gave their highly gifted sons unexpected advantages of education, without which the world would never have been thus benefited by their labors. They were both great Mathematical scholars at the University; and without Mathematics, though they might have had brilliant hypotheses, they could never have confirmed them by proof; and Mathematics can only be attained by long study. Kepler had the grief, as is related in a note in "*Cosmos*," to be obliged to defend his mother in her old age, in those days of superstition, from a prosecution for witchcraft.

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20. What qualities did Newton possess which seemed, in his case, to command universal good-will?—21. Relate some of the events of Newton's childhood and youth? What is worthy of remark concerning the mothers of Kepler and Newton? (*See Note.*) What is related of Newton after his education was concluded? What is said of his liberality? His economy? The time of his death? His character?

22. Astronomy, as left by Kepler, was as a statue; Newton's discovery, as the breath which gave it life. It is said the fall of an apple first excited his thoughts. He probably associated this falling fruit with that of other trees in every latitude—the nuts of the frigid, and the oranges of the torrid Zone. All fruits fall from their parent trees in straight lines converging from all parts towards the centre of the Earth. There was then in Nature a law impelling the centres of bodies towards each other, the smaller to the greater. To this force he gave the name of GRAVITATION. He next considered how far Gravitation extended upwards. It existed on the tops of the highest mountains. Why not still higher, even to the Moon? Why not to all the heavenly Bodies? But the philosopher soon saw, that not merely quantity of Matter, but *distance*, must affect the law of Gravitation, or else terrestrial objects,—even the Moon, would fly to the Sun, rather than remain attached to the Earth. At length, after years of observation, thought, and study, he completed his grand discovery, and announced to the world the great Law of Universal Gravitation—that *the centres of all bodies are attracted towards each other, directly as the quantity of matter, and inversely as the square of their distance.*

23. The fertile mind of Newton was not confined to Astronomy. He made important discoveries in Optics, and profound advances in Mathematics. He bent the energies of his mind to Theology,—believed that the God of Nature had made a Revelation to man—and arranged a system of Scripture Chronology. He embodied his discourses on the various branches of Natural Philosophy

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22. Describe the beginning of the mental process of Newton, in discovering the universal law of gravitation? How might the fall of an apple lead his thoughts? How the consideration that bodies on the highest mountains gravitate towards the earth? Why might it not be supposed that all bodies gravitate merely according to quantity of matter? What is the Universal Law of Gravitation?—23. What studies besides Astronomy did Newton pursue, and with what success? What is the title of his great work?

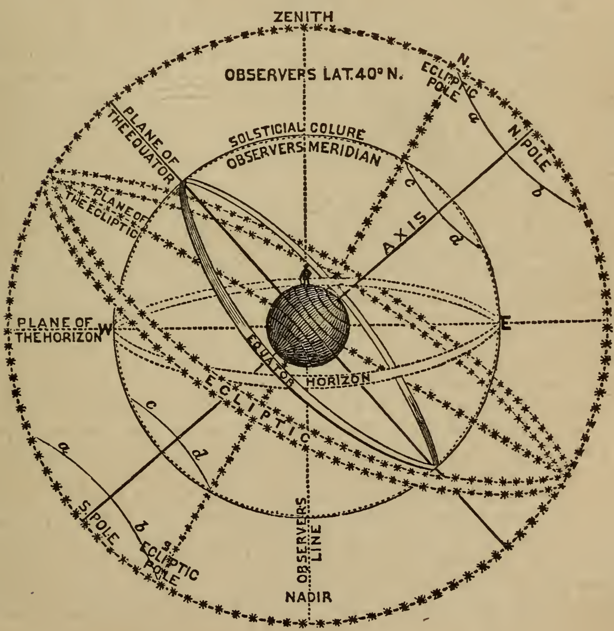
in a great work, written in Latin, and entitled, "Philosophiæ Naturali Principia Mathematica," familiarly quoted as "Newton's Principia."

EXERCISES.

We will now review our three Spherical Systems; and then in idea we will add a Fourth System, as introductory to the following chapter.

We will first suppose the three Systems to be connected as in Fig. 35. Each is here designated by a distinctive character. If, as

Fig. 35.



you study the figure, you draw on paper, increase the linear size, at least four times,—and twice that amount if you draw on a blackboard. You will then be able to make these characters much more distinctive, and especially to show a greater difference between the dotted and the unbroken lines, which, as formerly, are here taken to represent the Observer's and the Earth's Systems. The line of stars appropriately designates the System of the Heavens. The planes of three Secondaries, one of each System, are here made to coincide, by supposing a time when the Observer has, as in the night figure, the Solstitial Colure coincident with his Meridian; and in no other way could the Poles of the three Systems be in the same (combined) circle, their axes all lying in its plane. On the figure, the Secondary of the Ecliptic—the First of Aries and Libra—is, to prevent confusion, drawn larger than the Secondaries of the other two Systems, which thus appear concentrically within it; but to the Observer, in reference to whom they are drawn, it is precisely the same;—since a thousand concentric circles, drawn on the plane of his Meridian, would in the Heavens occupy to him the same place. With these observations, we believe that any pupil who has followed the course of our instructions, may, by beginning with the Observer's System, and assuming the Observer's latitude, be able to connect first his System with that of the Earth, and then combining with the two the Starry System of the Heavens,—not only construct the figure, but understand it.

The fourth Spherical System which we wish our pupils now, in idea, to add, may be called the Galactic System, from its Great Circle, the Galaxy or Milky Way; or rather from a circle which most nearly conforms to the Galaxy; that being to appearance somewhat irregular, although it is supposed the greatest and most sublime of circles. "This circle," says Sir John Herschel, "is to sidereal motion what the invariable Ecliptic is to planetary Astronomy—a plane of ultimate ground reference—a ground-plane of the Sidereal System." We might name our fourth System, on this authority, the Sidereal System; but we prefer the term Galactic, because it is not equally liable to be misunderstood.

Knowledge to be permanent, must have its isolated facts, systematically connected; and it is worth while for this object, if for no other, to study the stars in connection with the grand scheme of which the two Herschels are the authors, although we have presumed to bring it forward as the fourth System in our peculiar arrangement of Astronography. According to our definitions, all the positions of the Galactic System, and all its intersections with the Systems of the Earth and Heavens, are permanent positions. Sir John Herschel wisely begins by first comparing this System with only that of the Earth. We will then examine the Celestial Globe, and see how the Great Circle and Poles of the Galactic System are situated with regard to the Equinoctial and its Poles. And here, as in the intersections of any two Systems, we shall find a Secondary of each, coinciding with a Secondary of the other; and since every Secondary of a system passes through its poles, this one coincident or combined circle will contain the poles of both. This in the intersections of the Galactic and the Earth's

System will be such a Secondary of the former as coincides with the Equinoctial Colure in the latter. We shall then find the Poles of the Galactic System on the same circle where we began our study of the Heavens, and on which are the three first letters of our sidereal alphabet, Megrez, Cynosura, and Caph. The Galactic Poles are then on this Circle, but on what parts? They are of course everywhere 90° from the great Galactic Circle, and that passes through Cassiopeia, we will suppose, in Caph. Then trace from Caph through Cynosura and Megrez, and on the Circle 30° south of Megrez will be the northern Galactic Pole, 60° from the Pole of the Earth, and 30° north of the Autumnal Equinoctial Point.* The southern Galactic Pole will of course be upon the opposite, or Vernal half of the Equinoctial Colure, as many degrees South of the Equinoctial as its North Pole is North. The Great Circles of these two systems intersect at angles of about 63°. We recommend to our students to study Sir John Herschel's description of the Milky Way, contained in his "Outlines of Astronomy," looking on the Celestial Globe, but not wholly trusting to it, since the Galaxy is in many parts incorrectly laid down. Our next and last Exercise will be connected with the Terrestrial Globe.

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* By referring to Sir John Herschel's description of the Milky Way, it may be seen that he places the North Galactic Pole 3 degrees farther south—that is, having a north polar distance of 63° instead of 60°, and that he places it 47 minutes (less than a degree) east of the Equinoctial Colure; but the subject not admitting of exactness, we have taken the liberty of using numbers nearly approximating to our authority, because they are so easy to remember, especially as taken in connection with our previous instructions; and we think it wise in the instructor to let his scholar first get the easy rule thoroughly into his memory, and afterwards learn the small exceptions.

CHAPTER XXV.

Astronomy as left by Kepler and Newton.—Mathematical Astronomy.—Optical Astronomy.—Bodies added by Discovery to the Solar System.—Aerolites.—Tremendous Shower at Aigle in France.—Meteoric Shower in North America, 1833.—Terrible Appearance at Crema.—Franklin's Discovery.—Morse's Invention.—Changes in the Stars.—Appearance and Disappearance of the great Star in Cassiopeia.—The two Herschels.—Sir W. Herschel's great Plan and Labors in "gauging the Heavens."—Continued by Sir J. Herschel.—The Telescope.—The Discovery of the Southern Heavens.—Great Discoveries of Stars in the Milky Way.—Sublime Hypothesis of Sir W. Herschel concerning the Motion of the Sun.—The Milky Way the paramount Circle of the Heavens.

1. Astronomy may be said to have been left by the labors of Kepler and Newton, a perfect science, yet only in the same sense in which a child may be said to be a perfect human being. Development and expansion were needed, and they have been supplied by a host of astronomers who have since flourished; and who, while adding proof to certainty, concerning the laws taught by Kepler and Newton, have enlarged the boundaries of the science in various directions. The department of Mathematical Astronomy has been successfully pursued by La Place of Paris, in his great work on "Celestial Mechanics." Another French astronomer, Arago, has made wonderful discoveries concerning light; by means of which the distant heavenly bodies tell the astronomer who examines them with the proper glasses, whether they shine by their own inherent light, whether it comes from a luminous

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Chapter XXV.—1. In what sense may the science of Astronomy be said to have been left perfect by Kepler and Newton? What was still lacking, and how supplied? What has been done by La Place? What by Arago?

atmosphere, or whether it is reflected, like the moon's, from some luminous body.

2. Astronomy has, since the time mentioned, been extended by the discovery of two large planets and a number of satellites,—by about twenty asteroids between Mars and Jupiter, and by a great number of comets. The large planet Uranus was discovered, March 13, 1781, by Sir WILLIAM HERSCHEL, who with his son, Sir JOHN HERSCHEL, still living, are the most eminent astronomers who have flourished since the days of Newton. In 1788–9, Sir William Herschel discovered with his colossal telescope the two innermost of Saturn's satellites,—the second from that planet performing its revolution around its primary in less than a day. Of the asteroids, Ceres, discovered in 1801 by Piazzi, a Sicilian astronomer, was the first known, and since that period about twenty others have been discovered. Lastly, as the grand triumph of astronomy, the large planet Neptune was discovered before it was seen, by its perturbing force first pointed out by M. Bouvard, as exercised upon Uranus, by means of which that planet's motions in its orbit were disturbed. Le Verrier, of Paris, and Adams, of Cambridge, England, both announced the existence of a new large planet without the orbit of Uranus, and finally, September, 25, 1846, it was actually seen by Galle.

3. Astronomers have of late paid much attention to AEROLITES, which are the various phenomena designated as falling or *shooting stars*, *fire-balls*, and *meteoric stones*. Shooting or falling stars, also called meteors, when seen singly, are of common occurrence; but showers of meteors, fire-balls, and meteoric stones are rare. For the chrono-

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2. What bodies of the Solar System have been discovered since the days of Newton? By whom and when was the large planet Uranus discovered? What satellites were discovered by the same astronomer? By whom and when was Ceres, the first known of the Asteroids, discovered? What discovery is regarded as the grand triumph of Astronomy? What was the circumstances of this discovery, and who the persons engaged in it?—3. What are Aerolites? Which of these phenomena are of common occurrence? Which are rare?

logical knowledge of the most ancient of Aerolites on record, we are indebted, says Humboldt, "to the industry of the all-registering Chinese," by whom they were observed about 600 years before Christ. The fall of the heated stone at Egos Potamos, whose weight "was equal to a full wagon load," took place 465 years before Christ; and it is remarkable that the hypothesis which Anaxagoras of Clazomene formed to account for its existence, is in its main features still adopted. Meteoric stones are still regarded as not parts of the Earth, but as portions of bodies foreign to it, and revolving either about it or about the Sun, and to this day no other direct proof exists, that bodies foreign to the earth are composed of the same materials. "Meteoric stones," says Humboldt, "appear to be parts of small asteroids, revolving around the Sun, and which coming in contact with the atmosphere of the Earth move in it so swiftly as to ignite by friction, explode, and fall in fragments to the Earth." The matter of which these fragments or meteoric stones are composed, is, in its ultimate elements, oxygen, nitrogen, and other gases, such as the Earth's matter is composed of, but in their compounds they are sometimes different. They have much iron in their composition, mingled with nickel. If therefore meteoric stones are a specimen of the matter contained in the planets and other bodies exterior to the Earth, those bodies will have a general uniformity in this respect with the Earth, while the composition of their masses will show, that nature, with regard to them, will have manifested her usual variety.

4. Until within a few years, many doubted the existence of such foreign masses of matter, notwithstanding well-authenticated accounts of the fall of Meteoric Stones. But

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3. What, in regard to the history of aerolites, is said of the Chinese? When occurred the fall of the Meteoric Stone at Egos Potamos? What is remarkable in the teachings of Anaxagoras concerning this Meteoric Stone? What is Humboldt's definition of Meteoric Stones? What is said of the ultimate elements of the matter which composes them? Of the compounds of these elements?—4. What is said concerning the belief in the existence of Meteoric Stones?

on the 26th of April, 1803, such a tremendous shower occurred, at Aigle, in France, as furnished specimens for personal examination to all philosophers and every museum desirous of possessing them; and from that time forward skepticism on this subject was at an end. The phenomenon commenced by the appearance of a large fire-ball, which was seen to move swiftly over the neighboring towns. The motion of the ball was from S. E. to N. W., the sky being then clear. Near Aigle, it became enveloped in a small black cloud, which was motionless for five minutes, but emitted strange and startling sounds, as of smaller and larger artillery. During these minutes there fell, on an elliptical shaped ground of 6 miles in length, a great number of meteoric stones, some of which weighed 17 pounds. They were smoking and heated, but not to redness. These stones, on being analyzed by different chemists, were found to be composed of matter which, as remarked, was similar to that of the Earth, though differing in some of its combinations.

5. On this Continent, also, many other cases have occurred. Meteoric Stones have, in some instances, been projected from fire-balls with such force as to penetrate 10 or 15 feet into the Earth. One, seen as a fire-ball, fell at Weston, Connecticut, weighing 500 pounds. Although many Meteoric Showers have at different times taken place, yet the most remarkable ever known occurred in North America on the night of Nov. 23d, 1833. It extended throughout the whole of the United States and into Mexico. Its appearance, where the fall of the Meteors was the greatest, was terrific. In the Southern States, to the slaves, awakened at the dead of night, the heavens seemed on fire; and they ran screaming to their masters, that the day of judgment had come. The Meteors seemed like great snow-flakes of fire. Similar phenomena were

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4. When was skepticism at an end, and on what occasion? Describe the shower of aerolites at Aigle? What was their weight, and of what were they composed?—5. When and where have Meteoric Stones fallen on this Continent? Where occurred the most remarkable Meteoric Shower ever known? Describe this Meteoric Shower?

recollected to have been observed at the same season of the year, and the astronomer Olmsted, of New Haven, predicted that similar phenomena would occur at the same time in the years immediately succeeding. This happening to a considerable extent, was regarded as confirmatory of an ingenious theory, by which he explained why the Earth, in this part of her Orbit, should have fallen in with these Meteors. They all appeared to proceed from the same part of the heavens, and are believed to have been contained within a ring or zone, within which they all pursue a common Orbit.

6. Even these terrific appearances fade before a scene which, according to Humboldt, is related by a Latin author as having occurred at Crema, in Italy, on the 4th of September, 1510. At noon-day, it suddenly became dark;—a cloud of appalling blackness overshadowed the heavens. Upon this cloud appeared the semblance of a great peacock of fire flying over the town of Crema. Suddenly it changed its form to a fiery pyramid traversing the heavens. From the intense blackness which succeeded arose awful lightnings, and thunderings indescribable, while there fell upon the plain, rocks, some of which weighed a hundred pounds.* . . . The density of Aerolites is to water generally as 3 to 1.

7. Lightning is, in one sense, a part of our subject, since it comes from the Heavens to the Earth. The American philosopher FRANKLIN, June 15, 1752, proved to the world the identity of the Electric Fluid with Lightning, and thereby taught how, by providing suitable conductors, life and property may be guarded. Another American phi-

* This description occurs in a note in the first volume of the "Cosmos." Humboldt says it may be exaggerated, but of the main facts there is no doubt.

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5. From what circumstances, observed by Professor Olmsted, did he predict the recurrence of a Meteoric Shower at the same season of the year? What is supposed concerning these numerous and small meteors?—6. What terrible appearance is related to have occurred at Crema in Italy? What is the common density of aerolites?—7. What great discovery concerning lightning was made? By whom? When?

losopher, Morse, invented, 1832, the Electro-Magnetic Telegraph, by which Electricity and Magnetism, those subtle and viewless agents of the atmosphere, transmit with their own velocity, man's thoughts over the face of his planetary home.

8. No one race of men, of whatever ability, could have completed the Science of Astronomy. It needs the observations made and recorded of succeeding races. By these it is known that important changes take place among the Fixed Stars. Those which one race alone would have regarded as perfectly motionless, are thus known to have moved. Ptolemy, in the Almagest, enumerates six stars as fiery red, one of which was Sirius, which now shines with a white light. Stars have, therefore, changed their color. There were certain stars whose places were well defined, which are not now seen. Others appear and disappear at certain well-defined periods; and many are now catalogued not formerly known.

9. Of the sudden appearance and disappearance of a heavenly body, bearing all the characters of a fixed star, the most remarkable is that which appeared in the constellation Cassiopeia, on the 8th of November, 1572. Tycho Brahe, who was at the time on one of the Danish islands, says, that as he was walking in the evening, it suddenly broke forth with a brightness which exceeded Sirius, Lyra, or Jupiter, and was equal to Venus when nearest the Earth. Wagoners and common people, in different parts of Europe, hastened to the Astronomers to ask the cause of this unwonted phenomenon. At night, when the sky was partially overcast, so that other stars were hidden, this alone was visible, and even at noon-day it

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7. What other American is famous for a great invention? What is the nature and what the effect of this invention?—8. How does it appear that no one race of men could have perfected the Science of Astronomy? What is now known by comparing the Stars with former recorded observations concerning them? What change in the color of a star is mentioned, and how is it known? What other changes among the Stars have occurred? —9. What is the most remarkable appearance and disappearance of a star on record? By whom was it observed, and when? How is its appearance described by that Astronomer?

could be seen by some. It had none of the character of a Comet, but its light was precisely like that of a fixed star, except that it scintillated more. Thus it blazed for two months; then, in December, its brilliancy began to diminish. Its color, which had at first been white, had changed through yellow to the fiery redness of Mars. Then it faded to the size and color of Aldebaran. Continuing to diminish in size, its white color returned, and finally, in March, 1574, it wholly faded away, and has never reappeared. Some believe this to have been the final conflagration of a world, and suppose it may have been the blaze of the elements at the creation of some new and now dark body. It is believed that such exist, and some of immense size, amidst the luminous fixed stars.

10. That portion of the labors of Sir William Herschel and his son, which have most extended the science of Astronomy, has been made in the region of the Fixed Stars. The contrast of what the Heavens were in respect to these after their discoveries, as compared with the meagerness of former times, will appear by considering that the catalogue of Hipparchus, about 130 B. C., contained only 1080; that of Ptolemy, 250 A. C., 1225; and Tycho Brahe's catalogue did not exceed this number. These catalogues included not the smallest of the visible stars, but all sufficiently distinct to be clearly and minutely described. But as soon as Galileo turned the newly-invented telescope to the Heavens,* stars, before barely visible to the naked eye, shone distinctly, while the invisible now first appeared.

* "It was not," says Humboldt, "till the invention of the telescope, that mankind attained to the possession of the Celestial Sphere of the Cosmos."

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9. Could it have been a Comet? How long before it began to fade? and how long before it finally disappeared? What suppositions are made to account for this remarkable phenomenon? —10. What is said of the labors of the two Herschels? What contrast is shown by examining ancient catalogues of Fixed Stars? How many did that of Hipparchus contain? that of Ptolemy? of Tycho Brahe? What stars were not included in these catalogues, and what were? What change was made by the first telescope? What in regard to the milky-clouded spots or nebulous parts of the Heavens?

He noticed that the milky whiteness of some parts of the sky, by examination with the telescope, became clusters of stars. Huygens discovered the Nebulæ in Orion's Sword. Previous to this period, nothing had been said of those clouded portions of the sky which have since, as nebular phenomena, received so much attention. The southern part of the heavens was unknown until described by the navigators who followed in the track of Columbus, and Pinzon was the first to bring their peculiarities into notice. The two *Magellanic Clouds*, the greater and the lesser collection of Nebulæ, then became known; and also those dark spots called the *Coal Sacks*, one of which is in the Southern Cross, to which the telescope being pointed, the astronomer seems to have looked through creation into the infinitude of space.

11. But previous to the labors of Sir William Herschel, which commenced in 1779, the Fixed Stars were studied without method; and although, after the invention of the telescope, they were supposed to be very numerous, yet in this respect it was left to him to bring wonders to light. Halley and Lacaille had speculated upon Nebulæ, and of these cloudy spots, not more than 2000 had been enumerated. Of *Binary* stars, from which so much has since been learned and conjectured, Sir William Herschel was acquainted with only four at the period when, having provided himself a telescope far exceeding in power any former one, his mind conceived the great idea of examining the Heavens, after a method by which, from successive fields of the azure dome of the Heavens, he could obtain certain information of the stars telescopically visible, and data for calculation, concerning similar parts of the Heavens not actually examined; and that thus a grand calcula-

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10. How did the discovery of Columbus enlarge the field of the Astronomer? By whom were the Southern Heavens first described? What peculiar appearances of the Southern Skies then became known?—11. How was the study of the Fixed Stars pursued previous to the time of Sir William Herschel? What is said concerning the supposed number of the Stars? of the Nebulæ? of Binary stars? What great idea was at this time conceived by Sir William Herschel? and what method pursued?

tion of the Stars and nebulous appearances of the whole Heavens might be made.

12. This immense labor, called "GAUGING THE HEAVENS," Sir William Herschel began, and with the aid of his son and a sister, Miss Herschel, great advances were made during his life-time; and since his decease, the same process has been continued by his son, Sir John Herschel, who transmitted the great telescope to the Cape of Good Hope, where he resided for the examination of the Southern Heavens; and to him we are indebted, not only for continuing, with equal ability, his father's labors, but for giving to the world a complete exposition of the whole science of Astronomy, with the sublime reasonings and conjectures arising from the new facts brought to light. The study of these facts and conjectures, will form an important part of a more advanced course in Astronomy, as one statement alone of Sir John Herschel will suffice to show: "So crowded," says he, "are the stars in some parts of the Milky Way, that, by counting the stars in a single field of his telescope, he (Sir W. Herschel) was led to conclude that 50,000 had passed under his review in a zone two degrees in breadth, during a single hour's observation."

13. Sir William Herschel gave to the world the probable conjecture, that as the Earth, with her Moon, revolves about the Sun, so the Sun, with his attendant Planets and their Satellites, is moving around some vast invisible central body,* with a rate of motion at least as great.

* Mr. Madler, a German astronomer, believes that he has discovered this central body to be Alcyone, the largest of the Pleiades. Sir John Herschel does not favor the idea. Alcyone is not, he says, central to the Milky Way.

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12. What was this method called? By whom was it pursued after the death of Sir William? What was especially done by Sir John Herschel? Concerning the immense number of the stars contained in the Milky Way, what fact is quoted from Sir John Herschel?—13. For what sublime and probable conjecture is the world indebted to Sir William Herschel? What does Mr. Madler suppose he has discovered? and what is Sir John Herschel's opinion concerning it? (See note.) On what is the argument for the Sun's motion based?

The argument for this motion of the Sun is based on the fact that, comparing past descriptions with present appearances, the stars, in a certain part of the Heavens, viz., the Constellation Hercules, are apparently receding from each other, and their distances increasing; a fact not to be accounted for on any other supposition than that our system is advancing in that direction, and that the Earth is nearer those stars now than formerly.

14. With this sublime idea, another is associated. If our family of Planets, in moving around our Sun, keep near the plane of a certain circle, so we may suppose it probable, that if some immense central body, and it may be a dark one, has a host of suns, with attendant worlds encircling it, that they may be moving in orbits varying but little from a plane, and the whole making an immense belt or larger Zodiac. So the Herschels supposed; and they believed that the Milky Way, studded with radiant stars—the interstices filled with Nebulæ, that, as telescopes became enlarged, are more and more resolvable into groups of stars—is the Great Zodiacal Circle, in which thousands of suns, with their attendant planets, are performing their grand era, or year of years. This conjecture is founded upon the fact, elicited by the labors of those two great astronomers, that there are in the Milky Way 30 times as many stars as there are in equal parts of the Heavens at a distance from it, and nearer its poles.*

15. Lord Rosse, of Ireland, has now the largest telescope extant, by which he is able to resolve into single stars Nebulæ which were not thus resolvable by that of the

* So, if the Fixed Stars were invisible, would all the Planets, with their Satellites, appear in the Zodiac except the Asteroids, which would be seen without it, as also the Comets—of which Kepler said there were "as many as of fishes in the sea." They would show themselves in every possible direction.

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14. What other sublime idea is associated with this hypothesis? What is the teaching on this subject of the Herschels? On what fact, and by whom elicited, is this opinion founded concerning the Milky Way, as the paramount circle of the whole Heavens? —15. Has a telescope, larger than that of the Herschels, been made?

Herschels, but their discoveries and opinions have not by this superior telescopic power, been controverted, but rather established. The opinion more and more prevails, that all those whitish cloudy appearances of the sky, whether of the Milky Way, the Magellanic Clouds, or the Smaller Nebulæ, are in reality congeries of stars, distant beyond the power of thought.

EXERCISES.

The scope of our work embraces both Astronomy and Geography, rather descriptively than philosophically treated.*

Our last Exercise referred wholly to Astronomy, and was connected with that great scheme of the Heavens, in which the imagination of two great men had been mingled, with the facts which they had observed and learned,—thus giving to the world a grand single point of view, in which to connect together in one system all astronomical knowledge, and bringing to the mind sublimer views of the Power, the Immensity, and the Majesty of God.

Following this example, we are about to propose for Geography

* When this work was put to press, the author was not fully satisfied with the title written; viz., "Astronomical Geography; or, Astronomy as connected with Geography;" though, on the whole, the best which she could form from actually existing English words. The second line was added, because the first, taking Geography as the subject, and Astronomy as a mere qualifier, did not give sufficient prominence, according to the plan, to Astronomy. Had the second line alone been taken, that would have given too much. Having conversed on the subject with a literary friend, John S. Tyson, Esq., of Maryland, he proposed for a title the word "Astronography," sending a learned dissertation on the Greek derivation of this as of similar words; showing that it differed from Astronomy, as meaning, not the laws, but a description of the stars. Although this was not precisely the scope of my work, yet the word had an English sound, and one word for a title is far better than two. As to the manufacturing of a word, which may be considered in one sense as a proper name which a parent is to give to a child, I felt no qualms of conscience. But if manufactured, I saw no reason why we should go back to ancient languages for the material. The given word, by resemblance of sound, is associated to the minds of all, with the two English words Astronomy and Geography. A girl of thirteen being asked what she should suppose the meaning of the word to be, replied at once, "A mixture of Astronomy and Geography." We adopt the word Astronography, then, not as derived from the two Greek words αϛρον and γραφω, but the two English words; and in the title we add "Astronomical Geography," because the learned might otherwise suppose the book was to be merely a description of the stars; and besides, the greater part of the work (which was already stereotyped) was written before the word Astronography was in existence—and in reference to the term Astronomical Geography.

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15. What effect has a superior telescopic power produced respecting their discoveries? What opinion seems more and more to prevail?

something of a similar nature. Geography regards God in respect to his dealings with man. To account for nations as they are, Geography borrows from History, as History from it; and when the present is combined with the past, imagination, aided by reason, goes forth in Geography as in Astronomy,—into the events of unaccomplished time, as into the regions of unknown space.

Both sacred and profane history testify to the fact that mankind originated in Asia, in the regions near the eastern extremity of the Mediterranean; and Revelation and profane history also teach that there Christianity originated,—that religion which the infidel acknowledges to be suited to the necessities of man—the best he ever had,—and likely, from the present aspect of things, to become, at no very distant day, the religion of the whole Earth. Civilized men have recently been unusually moved on the subject of the unreasonableness and barbarism of war; and PEACE SOCIETIES and congresses of delegates, from all civilized nations, have already begun to assemble to devise measures to insure the permanent harmony of the world.

Let the student here take the Terrestrial Globe, and examine it in reference to this point. Suppose the principal governments now existing, should take up the reasonable and righteous determination, that an authoritative COUNCIL OF PEACE, to settle the differences and quarrels of nations, should be permanently established; to which every people might appeal, and where the weaker might have justice against the stronger—where, in such a case, should this council assemble?

> "Of this vast rule, say where shall be the seat?
> Where, on Earth's face, Earth's delegates shall meet?"

What place would be the most convenient for members and petitioners to assemble from all lands? We believe it will be found, on the strictest examination, to be the same region of the world where God first showed the glories of his power and the wonders of his love, in creation and redemption.

Do not take this assertion on trust, but faithfully examine the globe in reference to it,—keeping in view the improvements made and in progress, in locomotion by steam, both by land and sea. And as you examine, mark how easy it would be for a Congress of all Nations to assemble near the eastern shore of the Mediterranean; reckoning from the capitals of the several nations now existing. Put Jerusalem into the upper vertex of the globe. Imagine the Holy City to be the place where the grand *Council of Peace* shall assemble—there being a railroad to connect it with the coast of the Mediterranean—and suppose yourself an Observer. Now apply to the Globe the same system of Almacantars as formerly at New York, and then take a rapid view of the land and water contained severally in the six belts. The first and second will be nearly all land, while their opposites, the fourth and sixth, will be nearly all water. The two on each side of the Horizon will contain most of the Western Continent. But the inhabitants are mostly on the eastern side. The capitals of the greatest nations of the Western Continent, Washington and Rio Janeiro, are, the first above and the last scarce below the Horizon, and of course each but about 6000 miles distant from Jerusalem. In South America mark how narrow is the strip of land along the Pacific coast, west of the Andes; and how the great streams, rising in their summits and gathering by a thousand navigable affluents into three great rivers, discharge themselves on the eastern coast into the Atlantic Ocean, on an arm of which is the Holy Land. As to North America, on the eastern shore stands the capital of its Great Republic, and the remotest west will soon be connected to it by a railroad. The inhabitants of the British dominions also gather to their provincial capitals on the east. The region in which Jerusalem is situated is, therefore, the place where the inhabitants of the world could the most conveniently assemble.

To give interest to this peculiar examination of the geographical position of every nation of the globe, let us now examine a few of the proofs that such a Council is actually to be held hereafter, and to be held not merely in that region, but actually at Jerusalem itself.—Mankind, as they become more enlightened, must more and more see a truth apparent to an intelligent child, that war is a great detriment to the human race; wicked, when, being appealed to from ambition, strong nations thus affright and injure the weak, until the grieved and unwilling people are obliged to relinquish their territories or their nationality; or, if appealed to by the oppressed, it is but a hopeless and delusive remedy; it is but to wade—like the Poles and the Hungarians—through blood to greater degradation; or, if war be resorted to, as in the present case of England and France against Russia, the strong against the strong, the mutual injury is certain,—the result is subject to the casualties of storms at sea, of blight and pestilence on land, as well as to the chances of battle.

Even statesmen who make war, and brave men who fight battles, alike bear testimony that war is a detriment to mankind, and only justifiable in self-defence, or because there is no other more rational resort against ambitious aggression.

Such a tribunal as we have supposed, is a means, and the only human means, to prevent war. The greatest king of France, Henry IV., had the wisdom and the benevolence to plan for Europe, such a confederation as is here supposed, to exist among all nations; and the greatest and wisest of ministers, Sully, believed his plan to be feasible, and began actual operations. The thirty nations of the Republic of America, are by such a confederation kept in peace, amidst the most exciting differences of political institutions, and of religious opinions. The nations will then, sooner or later, seek Peace by a similar confederacy, which shall leave to each its own peculiar government. But a meeting of nations would naturally promote the interests of all, by making the wants of each known to those who wish to supply them, and by diffusing the knowledge of all improvements.

And we believe, as confidently as the astronomer believes that the Milky Way is the Zodiac of Zodiacs, that the world is destined to be ruled, in matters of national law, by a government of governments; and we believe that this tribunal will have its terrestrial seat at Jerusalem. For the nations who even now bear sway in the world are Christian nations; and whatever may be the religious belief of their rulers, they know that to the hearts of their people, there is on the face of the earth, no place like Jerusalem,—no hills like those of Sion and Calvary, and no gardens like those of Gethsemane and Joseph of Arimathea. Few believe that either Nicholas of Russia or Napoleon III. have been actuated by personal feeling in the late contest concerning the Holy Places—but that they seek for popularity, being aware of the power of these sacred associations over the hearts of the people. None of the more powerful nations would be permitted by the others to become the metropolis of the world; nor would any existing government be willing to give itself, within its own territory, what would, in some respects, be its superior. The Holy Land might be obtained for this purpose, as the District of Columbia for the general government of the United States of America. The Jews now have the wealth and the desire to purchase Palestine, and surely they would rejoice that their beloved city should, as foretold by their prophets, have "the glory of all lands flow into her."

With the ships which brought the Gentile delegates to the port of Jerusalem, its ancient people, who for nearly 2000 years have shown the single example of a nation without a place, would naturally return there, believing that the Author of Christianity had been proved the Restorer of their Nation. The riches of the world would concentrate; and soon would arise in splendor, a "New Jerusalem."

> Nor war nor waste her borders more shall see,
> And the whole Earth her happy borders be.*

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* The concluding lines of a poem on the same subject, written and published by the author in 1820.

CHAPTER XXVI.

Atheism Unphilosophical.—God is especially Manifested in Adaptations.—Man is adapted to the Earth, the Air, and the Sun, and they to him.—Man's dignified Position—His Immortality—His high Moral and Religious Duties Illustrated by Gravitation.

1. Heaven and Earth are full of the Majesty of God's glory. Of this, if any of our young learners are not now more fully convinced than before they studied this book, then, to them, has it been comparatively useless; for they will have missed the most valuable of its intended benefits. But if this work shall have led them to join the glorious company of those who delight in praise to God, then will it have achieved a nobler task than that of the proudest astronomical philosopher, who, with vast learning, writes Systems of the worlds, taking no note of their Maker—the self-existent God—the all-pervading Spirit of the Universe.

2. We know that efforts, like those we are now about to make, to show "the Eternal Power and Godhead, by the things which are made," are apt to be looked upon by such writers with cold contempt, as wholly unphilosophical. We not only repel such a charge, but we return it. Would he who should write a treatise on Man, and make no mention of his Mind, be truly logical and philosophical? As little so, is he who writes a system of the visible Universe, and makes no mention of its God.

Chapter XXVI.—1. With what assertion does the Chapter commence? In what case would your author regard her work as comparatively useless? In a contrary case, how would she compare the effect of her labors with some of those who are her superiors in learning?—2. What does your author say of certain views of such writers? How would she receive such a charge concerning her own work? What two things does she compare, regarding them as equally illogical and unphilosophical?

3. The great mathematical astronomer, La Place, as if to show that Creation itself might have been but the undesigning action of inanimate matter, has produced a grand theory by which he undertakes to show, that if we grant the existence of a mighty mass of matter, equal in quantity to that contained in the whole Solar System, already having received the form of a ring or rings, similar in shape to those of Saturn, endued with gravitation, and already whirling with a given centrifugal force, then, that such a ring or rings might, by their gyrations, throw off such bodies as the Planets of our System, and still have sufficient remaining for a great body to occupy the centre. Suppose this theory—which can never be proved, and which would be perfectly useless if it were—suppose it to be true; and what then? Atheism gains nothing by it. If such was the best way to make the worlds, it was no doubt the method by which God made them. But for the possession and balancing of forces, by which action should be given to such immense masses, and for such sublimely intelligent ends, from whence did these unintelligent collections of atoms receive it? In the language of the poet Young, we ask:

> "Who, Motion, foreign to the smallest grain,
> Shot through vast masses of enormous weight?"

And how—if the worlds were chance-directed—how comes it that they have taken their places in such magnificent ORDER—that though the Heavens are studded with worlds sweeping circuits beyond the reach of thought, yet System never interferes with System, nor world with world?

4. But should any be so irrational as to maintain that dead matter, in its great masses, is self-endued with the centripetal and centrifugal forces, and that by these the

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3. For what purpose does La Place seem to have introduced his theory of worlds? What are we to take for granted in this theory? And what is the supposed consequence, or what might then happen, according to this theory? Suppose this theory true, what then? Is it credible that such a collection of unintelligent atoms should, of themselves and by chance, produce worlds and set them in such harmonious motion?

Planets have been thrown off from a great gyrating ring, and set to rolling and revolving in harmonious order—whence, we ask again—whence are the LIVING FORMS, vegetable and animal, which adorn and people the earth? What is there in all dead matter, even if endued with these blind forces, that could have produced the lowliest plant which creeps beneath the oak of the forest? And WHO, then, made the oak? WHO made the strong lion under its foliage, and the melodious bird, whose nest is in its branches? And more than all, WHO made MAN, with his majestic form and godlike faculties,—beneath whose intelligent eye the monarch of the forest quails, and acknowledges him the regent of this lower world—the chief inhabitant, and the intelligent Ruler of the Earth?

5. There is in our day a fashionable kind of Atheism which professes to find a Divinity in *Nature*. But what is Nature? A mere word expressing effects. It does not imply an intelligent, designing Cause. But ONE GREAT DESIGNING FIRST CAUSE of all things *there must be;* planning, with INFINITE BENEVOLENCE, to bring forth the greatest good; devising, with INFINITE WISDOM, the best means, and executing them with INFINITE POWER.

6. The ADAPTATION of all things one to another, no less than Creation itself, proves the Existence, the Unity, and the Attributes of GOD. Let us take a single example, MAN; and let us observe how he is suited to other things, and they to him. When he is first ushered into the world, there is the dormant spark of life residing in his lungs; but it must, at the instant, and during every instant of his life, be rekindled and revivified by an external sub-

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4. But suppose that any should be so irrational as to maintain that great masses of matter might be self-endued with innate forces, what questions might then be asked?—5. What is here said of Nature? What does the term Nature not imply? Since we produce evidences of design, what must there be? Which of the terms used expresses the Unity of God? What three terms in the sentence express the infinite attributes of God?—6. What, equally with Creation, proves the existence, unity, and attributes of God? What example is chosen, and what are we to observe? What has man when first ushered into the world? How must this be revivified?

stance constantly brought in contact with it. Is this external substance made, and at hand, and has the infant been provided with a proper physical organization to draw it inwards to the lungs? All has been well done. The substance, without which he immediately dies, is the atmosphere which surrounds the globe, and which, from its pressure in all directions, must ever envelop him.

7. By his physical organization Man is not only enabled, but *compelled* to receive air into his lungs, and to retain it until it has imparted the needful oxygen, and then to expel the hurtful residuum. Man's bony frame, his muscles, and his nerves, are all arranged with the special object of producing this effect. His ribs are so articulated to his spine as to rise—the muscles being made to conspire—giving breadth to the chest, and thus producing a vacuum, which irresistibly draws in the air; and then the same ribs fall, narrowing the chest, and forcing out the unwholesome carbonic gas, which remains after the oxygen of the inspired air has been imparted to the carbon of the blood. And thus is the fire of life, every moment while life lasts, rekindled and revivified at the lungs; and thus is shown the adaptation of Man to the Air, and of the Air to Man.

8. There is another portion of this vital process of breathing—Man's first and last act—by which is equally shown that he is designedly adapted to the Earth and the Earth to him. In the animal combustion—which, as we have seen, must be constantly kept up by respiration—there must be *carbon to be burned, as well as oxygen in which to burn it.* And whence comes this carbon-fuel? From the Earth. To furnish it was the special object for which the vegetable world was created. Plants are either man's im-

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6. What questions are here asked? How are they answered? —7. What parts of man's body are arranged with special reference to his breathing? In what way are his ribs articulated or joined to his backbone? and what is every moment accomplished by this? What is thus shown?—8. What is here incidentally asserted of breathing? What does your author now propose to show? What is said concerning the animal combustion which the oxygen of the air supports? Whence comes this carbon-fuel?

mediate aliment, or they are that of the animals on which he feeds. And Water to dilute this food, and furnish the substratum of the blood into which it must be formed, before it can be taken to the lungs by the pipes prepared to convey it—water is no less a necessary to man than food; and liberally is the Earth prepared to furnish it. Next to the air, it is the freest and most abundant thing on the surface of the globe. And is man's physical system so made that he can receive, and reduce to its proper state for breathing, this necessary but unprepared carbon? Expressly is the physical man formed for eating, drinking, and digestion. Then as you observe his mouth, his teeth, his stomach, and other organs of digestion, and at the same time look abroad upon the waving bread-fields of the Earth, devoutly say that man was formed for them, as they for him, by the SAME INFINITE INTELLIGENCE.

9. Man's designed adaptedness to the things around him, is as clearly shown by his INSTINCTS as by his physical frame. Had it been left to his discretion and judgment whether he would choose to breathe or not, in vain might God have made the lungs and the air. But to make sure of his purpose, he has added the irresistible *instinct of respiration*, which compels Man to breathe, so that he cannot, if he would, shut that door of his life. He is obliged to take water by the *instinct of thirst*, and food by that of *hunger*. And the benevolence of the Deity has added the instincts of pleasure, by which man is invited to take his necessary aliment, to those of pain, by which he is compelled.

10. And equally are the wisdom and goodness of God indicated by the *instinct of warmth*. By this we mean the sense of comfort in warmth, and of pain in coldness. Man does not live to breathe: he breathes to live. The great function of life to which breathing is subservi-

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8. What is said of water? For what is the physical man expressly formed? What should we then observe together, and what conclusion form?—9. By what besides his physical frame is man's adaptedness to the things around him shown? What instincts are first mentioned?—10. What is meant by the instinct of warmth?

ent, is the Circulation of the Blood. By this, sustenance is carried to every part of the body, to supply the waste, or increase the growth. If circulation fails, death ensues. But it must fail, unless there is kept up a DUE BALANCE between that interior heat, which is caused by animal combustion at the lungs, and that exterior coldness, which is caused by the conducting of the heat from the surface of the body by the atmosphere. A due balance is indicated by a medium temperature of 98° Fahrenheit, which must be preserved by all races of men in all climates of the Earth. This delicate balance must be rightly adjusted, or circulation stops, and man dies. But how is this balance to be preserved? Has Man within him a hidden thermometer by which it is adjusted? God has given him one which will never deceive him. It is his instinctive genial pleasure in a just degree of warmth, and a sense of discomfort in coldness, as soon as it becomes hurtful, and of intolerable pain when it is destructive.

11. It is by this instinct of warmth that Man is both invited and compelled to clothe himself; and the more heavily as his climate grows the more cold: threatening otherwise to carry off the heat of his body; so as to destroy the necessary balance. For the same reason, he is obliged to build houses for himself and his children. But fear not: he who is the Author of Man's necessities is the same who provides for their supply. See, for his clothing, the flax, the cotton, the wool, and the fur; and to construct his dwelling, behold the trees of the forest, the iron of the mine, and the stones of the quarry.

12. But clothe and shelter himself as he may, Man, in very high latitudes, breathes a condensed air, containing

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10. What does your author consider to be the great function of life to which breathing is subservient? What is the use of the circulation of the blood? But in what case must the circulation fail? What is said of the medium temperature of the human body? What questions are here put concerning the due balance of heat and coldness? How are they answered?—11. What is further said of the instinct of warmth? Will man find provision for these great necessities?—12. But how will it be with the inhabitants of high latitudes in regard to the proper balance of heat and cold?

much oxygen; and sharp cold comes to him externally. But here his instincts lead him to seek such aliment, as the inhabitant of the Equator would loathe; and hence he feeds on oily matters, yielding to the blood much carbon—to meet at the lungs the extra quantity of oxygen; thus keeping up a glowing fire at the centre,—balancing the intense cold without, and keeping up the normal temperature.

13. Thus we see, that not only has the Deity wrought a general adaptation of Man and the things around him, but, as if to manifest that he works by no necessity, but by an intelligent choice, he makes SPECIAL ADAPTATIONS, by which he varies his general plans to suit particular circumstances. Thus, while the dweller in the Frigid Zone has an appetite for tallow, the inhabitants of the Torrid desires nothing but the cooling fruits which his climate alone produces. These afford all the carbon needed to meet the small quantity of oxygen afforded to the lungs by his sun-expanded atmosphere. If the fire of life burns feebly within, there is no intense cold without; nay, there is too little external cold for the circulation; and, by more copious perspiration, which takes heat from the surface of the body to convert it into vapor, the Almighty makes another special provision to keep up, in warm climates, the due healthful balance.

14. The exterior organs of respiration are also varied in the different races to receive a greater or less bulk of air, according to its expansion by heat or condensation by cold, in the different regions which they are formed to inhabit. The white race, made for the Temperate Zones, inspire through slender noses, bending downwards, but a small bulk of air compared with the negro, who spreads the broad unobstructed nostril to the heat-attenuated breeze; while he is furnished with a skin, which, by its porous tex-

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13. What do *Special Adaptations* manifest respecting the Deity? In these how does he vary his general plans? By what arrangements is the healthful balance kept up in the Torrid regions?—14. What is said of the special adaptedness of the exterior organs of respiration to the climate of particular races of men?

ture, freely exudes in perspiration the water of the blood, thus furnishing the material to keep up a constant coolness on the surface of the body by evaporation.

15. Thus man, in every breath which he draws, shows that his Maker has adapted him to the Earth and the air, and that they are made expressly for him; and our Science carries us farther. It shows us that Man was made for the Sun, and the Sun for him. It is by means of the Sun that the Earth brings forth his food, that liquid water flows, and that the atmosphere is sufficiently warmed and expanded for man's respiration. But man has an organ which unmistakably connects him with the Sun. It is the EYE—the eye, which is the gem of the animal creation. It was made for light, and light emanating from the Sun was made for the eye.

16. And with this more delicate organ our indulgent Father has connected higher and finer instincts,—*the sense of beauty, and the love of knowledge.* And how gloriously has he wrought to supply these desires, and to make them the means of virtue and enjoyment to his sentient and rational children! How beautiful and how sublime has he made the forms of external things! He has connected man with the Starry Heavens as well as with the Sun, by his desire to know them, and his perception of their beauty; and ever, when he becomes wearied amidst the glare of day, the Earth shall turn upon her axis, and bring him, with the starry night, repose in sleep: sleep—that emblem of death, from which he shall, in the morning, have a resurrection to renewed existence. And can we look at these facts, and not believe in ONE, DESIGNING, WISE, AND BENEVOLENT GOD? And shall we call it philosophy to stand and doubt? And must we be called credulous who believe? As well call him credulous who, seeing an infant wrapped and asleep in his cradle,

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15. What is here said of the Sun in reference to Man? How is it proved that the Sun was made for man, and man for the Sun?—16. What instincts has our indulgent Father connected with the Eye? How has God wrought to supply these desires? What arrangement is made that man may sleep? What questions are here asked? How are they answered?

believes that the child has an intelligent mother, who has done for him what he was not able to do for himself;—and as well may we call that logic and philosophy, which, not having seen the mother, denies that there is one, and laughs at the idea, that the cradle was designed expressly for the babe.

17. Man is the child of God. His nutrition, and his vestments are derived from that Earth which God has made for his use. And he cannot be shaken from her maternal embrace, because of that part of the law of gravitation by which nearness binds more closely than quantity of matter; while, by the other portion of the same law, the great mass of matter which, by the Almighty, is placed in the central body of the Solar System, so binds the Earth with the other Planets, that they cannot wander from their spheres.

18. God has made the Earth for man. Is the house regarded by the Father who has built it, as of more value than the child who inhabits it, and for whom it was made? And will He keep the house and not preserve the child? It cannot be. And if man, in the wise use of that agency by which he is ennobled, shall become a co-worker with God for good, then shall he be preserved, though his body shall all perish, except that germ of immortality which the Lord, according to his Word, will keep from destruction, raise from the dead, and to which he will give such a body as shall please Himself.

19. Let Man, then, appreciate his own dignified and responsible position in the Universe. Let him study his Maker's will. To this end, let him yield a profound attention to the great lesson taught him by the connection which

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17. How does it appear that man is the child of God? What does Astronomy teach which shows that man cannot be shaken from the Earth? what which shows that the Earth cannot wander from her sphere and deprive man of the light and warmth of the Sun?—18. This paragraph contains an argument for the immortality, especially of those who make themselves co-workers with God for good:—can you state the argument, with the conclusion?—19. What should man do in reference to his position in the Universe?

the Author of Nature has established between Time, Space, and Motion. The Sun apparently passing over 15° in an hour, and in 24 completing his daily circle—what is it but a great diurnal clock? And what is the Ecliptic but a grand annual Chronometer, where the Sun describes, with invariable regularity, his twelve star-marked periods, and which, as the last is completed, strikes the knell of another of those yearly courses which, to man, divides Time from Eternity? And shall the Sun, the Earth, and the Planets each have its revolution to perform in Time and in Space, and shall Man complain that he "hath his daily work of body or mind appointed?" or shall he alone be a laggard in his sphere?

20. There is a Moral Gravitation, as well as a natural. It is beautifully recognized in our SAVIOUR's summary of the great *Law of Love*. Intelligent beings are by this to gravitate first towards the CREATOR, himself infinitely greater in all perfections than all his creatures combined. But as the Earth and the Moon, influenced by the gravity of nearness, revolve around their common centre of union, yet cease not to move together around the Sun, so may the good, allied by consanguinity or friendship, revolve around each other, so they never violate that higher moral attraction, which binds them to God.

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19. What lesson has our Science taught him to which he should pay profound attention? Recite the succeeding passage respecting Time, Space, and Motion.—20. Recite the concluding passage in which your author illustrates the two branches of the great law of love to God and love to man by the two parts of the law of natural gravitation.

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division or discovery engraved at short notice, and feel safe in assuring the public that no other Globe of its size in market is so full and complete.

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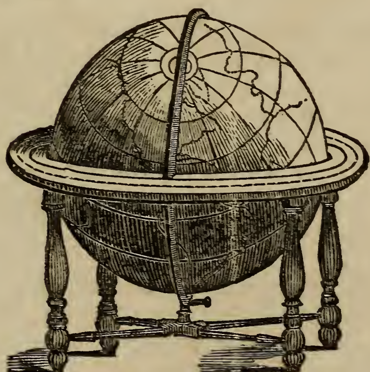

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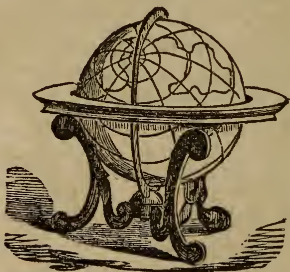

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We subjoin the remarks of an influential daily paper (Times) on the Globe and its uses, which we commend to the attention of all interested in education, to the general reader, and to the literary of all ages and both sexes:

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From S. B. Woolworth, Principal of the State Normal School, Albany, N. Y.

STATE NORMAL SCHOOL, Jan. 14, 1853.

I have examined with considerable care a pair of ten-inch Globes constructed by Messrs. Merriam, Moore & Co., of Troy, and have been much pleased with the convenience and beauty of the mounting, and the apparent correctness of the delineations. I cheerfully recommend these Globes to the confidence of those who may have occasion to procure for schools this indispensable aid to correct instruction in Geography, as among the best which I have examined.

S. B. WOOLWORTH.

From Thomas W. Valentine, of Albany, Resident Editor of the New York Teacher.

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I have carefully examined your "Franklin Globes," and can truly say that I consider them in all respects fully equal, and in some points *superior* to any that I have ever seen. They combine durability with cheapness—the mechanical execution of them being evidently of the very first order. I find, moreover, that all the recent discoveries, down to the latest dates, are given, and that all the delineations are correctly and faithfully made. But one of the best improvements you have made, is the means provided for their preservation. Being put in substantial cases, they are fully protected from the dust and accidents of the school-room—which an experience of many years in the use of globes, convinces me, is a very great *desideratum*. I would, therefore, cordially recommend your Globes to all teachers, confidently believing that wherever they shall be introduced, they will give the best satisfaction. Very truly yours,

THOMAS W. VALENTINE.

THE IMPORTANCE OF THE USE OF THE GLOBE.

We believe the use of the Globe in teaching has been undervalued. To say nothing of its use in the higher branches of study, its importance as an aid in teaching Geography, can hardly be over-estimated. To prove this, it is only necessary for teachers or parents to revert to their own school days, and ask themselves how many months or years of study they passed through before they acquired so correct an idea of the form of the earth, or the relative positions and distances of places, as would be acquired by a single day's study of the Globe. For example, many scholars get the idea from the map that Australia and New Zealand are at the two extremes of the earth, instead of learning that they are near neighbors, no farther distant than New York and Cuba; that New York is much farther from England than from Liberia, instead of learning that it is many hundred miles nearer. Many other equally erroneous ideas are gained,—and these ideas are sometimes hardly corrected in a lifetime. The use of the Globe instead of the Map, or in connection with it, would give to the eye of the pupil correct ideas in regard to those things in which the map tends to mislead; and this is the more important because such error once fixed in the mind, the impression remains there long after the understanding learns that it is error; and we believe that in no way can the same expense be more profitably incurred for a school, than in the purchase of a pair of Globes of sufficient size and fulness to be thoroughly available for the pupil in the study of Geography.

Impressed with the importance of this, the publishers of the Franklin Globes have secured the services of Mrs. Emma Willard, so well known for her efficient and successful labors in the cause of education, to prepare a work of the following title:

ASTRONOGRAPHY:

OR

ASTRONOMICAL GEOGRAPHY,

FOR READING AND STUDY IN SCHOOLS,

TAUGHT BY THE USE OF THE GLOBES.

We invite the attention of teachers to this work. From the time and labor that have been spent in preparing the work, by Mrs. Willard, as well as from the very favorable opinions of eminent educationists who have examined portions of the work, it is believed that it will be found to be far superior to any work heretofore published on the use of the Globes.