MATHEMATICAL GEOGRAPHY.

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A TREATISE

ON

THE CONSTRUCTION OF MAPS:

COMPREHENDING AN INQUIRY INTO THE PRINCIPLES OF

MATHEMATICAL GEOGRAPHY

AND

THE RELATIONS OF GEOGRAPHY TO ASTRONOMY:

WITH RULES FOR THE FORMATION OF

MAP-PROJECTIONS.

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PREFACE.

In the present volume, the first edition of which was published in 1843, the author has aimed at supplying an obvious want in our schools and colleges; that, namely, of a clear and easily intelligible treatise on Maps, and the mathematical principles involved in their construction. It had always appeared to him that in works referring to this subject, one or other of the following defects of treatment was commonly found to prevail. Either they are too completely theoretical, and afford an insufficient explanation of the practical difficulties which occur to the student; or they possess the contrary defect of being merely indicative of manual operations, without inquiring into the principles upon which those operations are dependent, or showing *why* they should be pursued: in other words, they do not combine an explanation of the principles of mathematical science upon which the theory of Map-projections depends, with a sufficiently practical description of the method to be followed in applying them to the actual construction of Maps. These requisite elements he has accordingly endeavoured to combine in the following pages, which lay claim to little merit beyond that of systematic treatment of a subject which the writer's pursuits have led him to examine from the most varied points of view, and which has assumed to his own mind the simplicity, as well as the attractiveness, which is engendered by a lengthened course of familiar experience. And though he should fail in imparting to those who may consult his pages any share in the latter portion of the feeling here expressed, he will regard it as ample recompense if their claim to utility be allowed.

It will be observed that the merits of the stereographic and the conical projections are brought prominently forward in the ninth and tenth chapters of this volume, and their claims to more extensive use strongly urged. In so far as the author's knowledge extends, the application of purely conical projections to the construction of Maps of Europe and other divisions of the globe, in the manner illustrated in the present work, had not hitherto been employed by geographers; nor is he aware that the method herein adopted for determining the distance of the centres (Art. 99, note) had appeared in print, previous to the first publication of this treatise.

To the problems given in the former edition, the author has here added the projection of a Map of Palestine. A brief notice is also taken of the laws and uses of the gnomonic projection of the sphere. An additional chapter, forming a kind of supplement to the more strictly scientific portion of the work, and devoted to a few suggestions on the practice of Map-drawing, with remarks on the various uses of Maps, will probably be welcomed as an improvement calculated to render the volume of more especial service, both in the class-room and to the private student.

It remains for the author to express his gratification at receiving, in the course of last year, a copy of a translation of the former edition of this work into the Oordoo or Hindustanee language, made by the principal native master in the Civil Engineering College established under the direction of the British Government at Roorkee, in India, and executed expressly for the use of the students in that institution:—an approving testimony in favour of an earnest (though humble) effort in the cause of education, and one to which additional value is imparted by the high sanction of the authority whence it has proceeded.

W. H.

London: 1852.

Some further additions have been made to the present edition. Among these will be found a reference to Sir John Herschel's suggested development of the sphere on the section of a circle, and to Sir Henry James's projection of two-thirds of the spherical surface on a plane. Additional illustration has also been given of the projection of the sphere upon the horizon of any particular place. The text has, besides, undergone careful revision throughout.

London: 1864.

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MATHEMATICAL GEOGRAPHY.

CHAPTER I.

RELATIONS OF THE SUBJECT TO OTHER BRANCHES OF GEOGRAPHY, AND TO SCIENCE IN GENERAL—RELATIVE POSITION, FIGURE, AND DIMENSIONS, OF THE EARTH.

(1) There is no branch of science of which the pursuit more fully exemplifies the intimate alliance subsisting between all departments of knowledge than that to which our present subject belongs—Geography. Depending on the Mathematical Sciences and on the aid of Astronomy for a knowledge of the form and dimensions of the globe, of the place which it holds in the system of the universe, and of the means of ascertaining and registering with accuracy the situations occupied by different places on its surface;—looking to the Physical Sciences for assistance in inquiring into the various properties of the land, the water, and the atmosphere, into the laws by which those properties are regulated, and into the numerous forms of organisation of which they are the seat;—and deriving essential aid from History and from the Mental and Moral Sciences in investigating the religious, civil, and political condition of the inhabitants of the different countries of the earth;—Geography, in its most extensive sense, may be justly regarded as embracing a circle of knowledge of the most varied and interesting description.

Although the present work is intended to illustrate but a small portion of the extensive range of subjects here indicated, yet it seems desirable to bring this brief review of their relations before the mind of the reader. For it is this affinity between all branches of mental inquiry which gives science its chief value, since it is by the possession of this property that it becomes practically beneficial to mankind, and serviceable in the promotion of human happiness. As, in the harmony which subsists among the agencies operating around us in the natural world, we perceive one thing blending into another, and one object serving to promote the accomplishment of the purposes of another;—so, in the mental world, the inquiry after *truth*—however abstruse and removed from the ordinary purposes of life the subject particularly aimed at may at first appear—yet has its bearings upon the simplest and most common relations of daily life. The calculations of the mathematician form the necessary foundation for the practical operations of the engineer, and their results enter in a thousand ways into the ordinary pursuits of commercial and social existence. The researches of the astronomer, abstracted from the passing world and immersed in the lore of science, supply the means by which the navigator may guide in safety through the ocean the vessel which is the medium for supplying the mutual wants of inhabitants of opposite sides of the globe, and for exchanging the expression of sympathies by which the common heart of humanity links together those dwelling in the most distant regions.

(2) The appearances presented by the heavens during the succession of day and night have from the earliest ages made it evident to man that the earth which he inhabits is only one among the number of bodies that constitute the

universe. An inquiry into the laws which govern the motions of these bodies forms the subject of Astronomy. The most important of them are the Sun and Moon. The former of these always presents to us the appearance of a circular, luminous disc; while the latter is constantly going through a variety of changes, or *phases*, being sometimes invisible, at others exhibiting a portion of an enlightened circle, and sometimes presenting to view the whole luminous circumference. Most of the other luminous bodies which cover the surface of the heavens present invariably the same appearance to the naked eye—that of a number of bright points, shining with a greater or less degree of brilliancy. The successive return of day and night exhibits the whole of these bodies as appearing to move round the heavens in a direction from east to west in a space of about twenty-four hours, and this *apparent* motion always seems to be performed, in our latitude, about a fixed point in the northern part of the sky. If a spectator go farther toward the south, this point descends lower in the heavens, and, if he advance far enough, it entirely disappears and sinks below the reach of his vision; while a similar point in the southern part of the sky, round which the heavens appear to revolve in the same manner, rises in a position exactly opposite to the former. These two points constitute the *North* and *South Poles* of the heavens, and an imaginary line joining them represents the *Axis* of their apparent motion.

(3) The greater number of the luminous bodies which are visible every clear night appear always to remain in the same positions with respect to one another, and, excepting the *apparent* daily motion which they have in common with the whole heavens, to continue from age to age in the same places: they are therefore denominated

Fixed Stars. About three thousand of these are visible to the naked eye, but with the aid of the telescope many thousands more may be distinguished. They are divided by astronomers into classes, or *magnitudes*, according to their apparent brightness; those which shine with the greatest brilliancy being called stars of the first magnitude, those so much less bright as to present a marked distinction being classed in the second, and so diminishing gradually down to the sixth, which comprises the smallest stars visible to the naked eye on a clear dark night. The stars are observed to be unequally distributed over the heavens, and to be disposed in certain groups, to which the name of *Constellations* has been given. These constellations have from very early ages received distinct names, which are employed to facilitate the description of the heavens, and a reference to any particular star.

The names of the principal Constellations, with, in some cases, those of a conspicuous star or stars in each, are given in the following table. The names of the stars are distinguished by italic letters. Their respective positions will be found marked upon the artificial celestial globe. Attentive observation of the aspect of the heavens, on successive starlight nights, will best familiarise the student with the respective places of those of them that are visible from the particular point of observation,—a condition which varies with the latitude of the observer, in the same manner that the place of the pole rises or sinks in the sky according as a spectator travels to the northward or southward. Thus, constellations which in the latitude of London are visible only on the verge of the southern horizon are seen at a greater altitude by a resident on the shore of the Mediterranean, and rise still higher as the equator is more nearly approached; while, at the same time, the stars that circle round the northern pole, in near proximity to it, sink lower and lower in the heavens. Again, as the observer travels to the southward, fresh constellations (those belonging to the southern half of the sky) come successively into view. To an observer within the Northern hemisphere, the constellation known as the Southern Cross does not become wholly visible until the parallel of 28° N. latitude is reached, and is then only seen on the extreme edge of the southern horizon. By an observer at the equator, it is seen (when on the meridian) at an altitude of 28° above the horizon. To a resident at Sydney its correspondent altitude is 62°, and to a person under the 60th parallel of S. latitude it would appear, when at the greatest altitude of its apparent diurnal course, in the zenith. The artificial globe supplies the best means of illustrating these changes to the learner.

I.—Constellations of the Zodiac.[1]

Aries.	Cancer.	Scorpio (*Antares*).
Taurus (*Aldebaran: Pleiades*).	Leo (*Regulus*).	Sagittarius.
Gemini (*Castor*: *Pollux*).	Virgo (*Spica Virginis*).	Capricornus.
	Libra.	Aquarius.
		Pisces.

II. Northern Constellations.

Andromeda(*Alpherat*).	Cygnus (*Deneb*).	Pegasus.
Aquila.	Delphinus.	Perseus.
Auriga (*Capella*).	Draco.	Serpens.
Bootes (*Arcturus*).	Hercules.	Ursa Major (*Dubhe*).
Cassiopeia.	Leo Minor.	Ursa Minor (*a Polaris, or the Pole Star*).
Cepheus.	Lynx.	
Corona Borealis.	Lyra (*Vega*).	

[1] The Zodiac is the belt of the sky within which the apparent path of the Sun, in its annual circuit of the heavens, is confined. The exact line of the apparent solar path is called the Ecliptic: this intersects the Celestial Equator at an angle of 23° 28'. (See p. 20).

III.—SOUTHERN CONSTELLATIONS.

Argo Navis (*Canopus*).	Corvus.	Orion (*Betelgueux : Rigel : Bellatrix*).
Canis Major (*Sirius*).	Crater.	Pavo.
Canis Minor (*Procyon*).	Crux.	Phœnix.
Centaurus.	Eridanus (*Achernar*).	Piscis Australis.
Cetus.	Hydra (*Cor Hydræ*).	
Corona Australis.	Hydrus.	
	Ophiuchus.	

(4) Others of the heavenly bodies are distinguished from the fixed stars by the circumstance of their changing the places which they occupy in the sky, or, in other words, by their appearing to move *among* the fixed stars. Thus, the Sun, when carefully observed from day to day, appears to move through the heavens in a direction from west to east; that is, he is seen one day in front of a different group of stars from that before which he seemed to be placed the preceding day, and each day he changes his position among them, until, at the end of 365 days, 6 hours, 9 minutes, he is found to have made a complete revolution of the heavens. In a similar manner the Moon describes a circle round the heavens from west to east in the space of 27 days, 7 hours, and 43 minutes.

(5) Besides the Sun and Moon, some of the brightest among the stars are observed, when attentively watched from night to night, to change their relative positions among the rest; these are called *Planets*. Five of them, viz., Mercury, Venus, Mars, Jupiter, and Saturn, have been known and observed from remote antiquity, and a great number of others have been discovered in modern times—most of them within a very recent date. Two of these—Uranus and Neptune—are of considerable size, and rank, with the five above-mentioned, and the Earth, which is also a planet, amongst the larger members of the Solar

System. The remainder are of greatly inferior size, and are known as Asteroids. All of these bodies are found, by attentive observation of their changing positions relatively to the fixed stars, to move in elliptical paths, or *orbits*, round the sun, which is their common centre.

The planets vary considerably in magnitude, and in their respective distances from the sun: they also perform their revolutions round that body in different intervals of time, and with different degrees of velocity. The names of the larger planets, arranged in order of succession from the sun towards the outer borders of the system, are as follow: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.[1]

Four of the above planets, Venus, Mars, Jupiter, and Saturn, are visible as large and brilliant stars: Mercury is sometimes visible to the naked eye as a large star, but from its proximity to the sun, is most frequently lost amidst the rays of that luminary; Uranus is barely discernible without the aid of a telescope. Neptune is only seen by aid of the telescope; as likewise are the asteroids.

The smaller planets, or *asteroids*, at present known (1864), are seventy-eight in number. The orbits of all of them lie intermediate between the orbits of Mars and Jupiter. Four of the asteroids—Ceres, Pallas, Juno, and Vesta—were discovered early in the present century (1801–7): all the

[1] The larger planets are denoted by the following symbols: Mercury ☿, Venus ♀, the Earth ⊕, Mars ♂, Jupiter ♃, Saturn ♄, Uranus ♅, and Neptune ♆. Uranus was discovered by Sir William Herschel, in 1781: Neptune as the result of calculations made nearly at the same time by Adams and Le Verrier, in 1846. It is the peculiarity of the planet Neptune, and the triumph of modern astronomical and mathematical research, that its place in the heavens was fixed by calculation, *before* it was actually seen or looked for. Observed irregularities in the motion of the planet Uranus led to this result.

remainder are due to much more recent observation, from the year 1845 downwards, and their number is of course liable to increase. A complete list of the asteroids is given in a succeeding page.

Some of the planets have smaller bodies, called *Satellites*, or *Secondary Planets*, revolving round them, in a manner similar to that in which the moon revolves around the earth. The sun and planets, with their satellites, constitute the SOLAR SYSTEM. A Table of the Elements of the Solar System, exhibiting the size, distances from the sun, and periods of revolution, of the larger planets and their satellites, is given at the end of the volume.

(6) There are other luminous bodies called *Comets*, which are also observed to change their place among the fixed stars: they are distinguished from the planets by being visible only for a short time and then disappearing, not returning until after a considerable interval. Considerably more than a hundred of these have been accurately observed, and portions of their orbits calculated. Of a few of the number the entire orbits are known, and their return is hence capable of being predicted with certainty. The cometary orbits are ellipses, of great elongation. As, however, these bodies, concerning the nature and constitution of which little is known, are of no importance to geography, it is needless to do more than mention them.

(7) Of all the bodies which constitute the universe, it is with the Earth alone that geography is directly concerned; and a knowledge of its form and dimensions constitutes the most important element in that science. The first impressions of the senses are insufficient to give a correct idea of the figure of the earth: to a spectator placed on an open plain it seems to present the appearance of a flat or plane surface, equally extended in every direction, and terminated

by a line (called the *Horizon*) in which the heavens appear to touch the earth—resting on it like a concave sphere. This, however, is illusory, and the shape of the earth has long been known to be that of a round body, or globe. The globular or spherical shape of the earth is the foundation of Mathematical Geography: it is established by the following proofs.

I. To a person going from north to south the appearance of the heavens is continually changing: the stars, indeed, retain the same relative position among themselves, but those which were near the horizon towards the north when he set out, sink below it as he advances;—those which were at first vertically over his head, descend lower in the heavens towards the same quarter;—those which previously reached their greatest elevation in the sky to the south of him, pass gradually over his head, and at length appear, when highest, to the north;—and numerous other stars come gradually into view, rising above the horizon to the south. Similar appearances, but in the opposite direction, are observed by a person advancing from south to north. This succession of appearances clearly indicates that the line along which he has advanced is not a straight line, but a curve, or arc of a circle, and proves the earth to be at least spherical from north to south; for, if it were a flat surface, the stars which were above the horizon in one place would remain so in all parts of it. Similarly, as the sun is observed to rise earlier to those places eastward of others, and later in proportion as they are situated towards the west, the earth is proved to be spherical from east to west; for, were it a plane in this direction, the sun would begin to enlighten the whole of one side of it at the same time. It is, then, shown to be circular in all directions—that is, to be a globe or sphere.

II. Astronomical observations have long since shown that eclipses of the moon are caused by the shadow of the earth being thrown upon the moon's face or disc. Now in all cases the section of the earth's shadow thus visible on the moon is found to be an arc of a circle. A body which in all positions casts a circular shadow must itself be circular, and the earth is thus again proved to be of a spherical figure.

III. The convexity of the surface of the earth is evident to a spectator who observes any object approaching him from a distance, or receding from him. A person standing on the sea-shore, for instance, and observing the approach of a vessel, sees first the masts and upper parts of the rigging, next the lower parts, and last of all the hull comes into view; and, similarly, if the vessel be receding from the shore, the body of it disappears first, while the highest parts remain longest in view. Or if a traveller, in an extensive and perfectly open plain, slowly retires from distant objects, he first loses sight of their bases or lowest parts, gradually of their middle portions, and, lastly, of their summits. These appearances, manifested in all parts of the earth and in all directions, can only arise from the *curved* surface of the earth being interposed between the spectator and the objects; for, if these were situated on a flat surface, they would only increase or diminish in size as they became more or less near, but all parts of them would do so in the same proportion, without any part being hidden while the rest remained visible.

IV. A proof of the earth's sphericity is derived from the voyages of navigators. The horizon, or distant line which seems to bound the ocean, recedes as we advance towards it; so that a vessel which continues to sail in the same general direction (merely deviating from it so far as the intervening land renders necessary) will eventually arrive at the same point from which it started,—thus describing a circle round the earth. This practical proof of the rotundity of the earth was first afforded by Fernando de Magellan, a Portuguese, who in 1519 sailed westward from the shores of Spain, and whose vessel, by continually holding a westerly course, after an absence of three years and fourteen days, returned to the port whence it had started. This circumnavigation of the earth was soon repeated. The first Englishman to accomplish it was Drake (1577–80), and to him succeeded, a few years later, Cavendish, or Candish (1586–8). Such an achievement has long ceased to attract any special regard, and is in the present day a thing of merely ordinary performance.

Finally, in sailing round the earth in high latitudes of the southern hemisphere (a similar voyage in the neighbourhood of the northern pole is forbidden by intervening tracts of land), it is uniformly found that the distance round the earth is diminished in proportion as the course taken advances nearer to the pole.

(8) Observation and experience thus combine so clearly to indicate the spherical form of the earth as no longer to leave room for any reasonable doubts on the subject, and we must therefore learn to regard the body we inhabit as *an immense globe*, isolated in space. Next to the figure of the earth, the knowledge of its magnitude is of the greatest importance. In a subsequent chapter will be explained the principles on which the measurement of its exact dimensions depends: it is sufficient here to state the result of these investigations. It is ascertained that the mean diameter of the earth is about 7,916 miles, and its circumference about 24,870 miles.

(9) A learner may perhaps object that the various elevations of the land in different parts of the earth should

prevent us from regarding its figure as being round. But this difficulty disappears when we consider the relative proportion which these elevations bear to the whole size of the globe. The highest measured elevation on the earth, Mount Everest, in the Himalaya chain, is 29,000 feet, or five and a half English miles, in height; and yet, stupendous as this is, so small a proportion does it bear to the diameter of the earth, that its representation on a globe of eighteen inches in diameter would be equal only to the 80th part of an inch! Thus it appears that the greatest irregularities on the surface of the earth are too insignificant to be regarded as in any way interfering with the general sphericity of its form, from which they detract far less than do the roughnesses on the rind of an orange from the rotundity of its whole figure.

CHAPTER II.

DIURNAL ROTATION OF THE EARTH—DEFINITIONS.

(10) We have already spoken of the apparent motion by which the entire heavens seem to be carried round the earth in the space of a day and night, in a direction from east to west. There are two ways in which this apparent diurnal motion may be explained:—1st, by supposing the whole heavens and their contents to be really carried round the earth while that body remains at rest in the centre;—or, 2nd, by supposing the heavens to be at rest while the earth revolves in an opposite direction, that is, from west to east. The appearances presented to us would evidently be the same, whether the earth on which we are placed remain at rest while we see every part of the heavens as they are carried in succession round us,—or whether, while they remain fixed, the earth turn round with us in the contrary direction, so as to place each part of them successively before us. The latter of these hypotheses—which supposes the earth, a single body, to revolve—is far more probable than the other, which supposes a great number of bodies, of different magnitudes and placed at different distances, to have motions so adjusted that each of them shall perform a revolution round the earth in exactly the same space of time, as on this supposition they must do in order to preserve the same relative position among themselves. The latter supposition is, accordingly, that

which is adopted by the Copernican system of Astronomy, and the truth of which is now universally admitted.

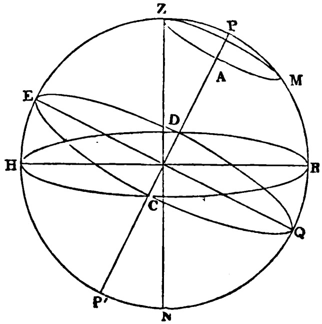
It is true that we at first experience some difficulty in conceiving the whole earth, with ourselves and everything on its surface, to be revolving with a motion sufficiently rapid to carry round a globe upwards of 24,000 miles in circumference in the space of twenty-four hours. This difficulty, however, disappears when we consider that in being carried along from one place to another our senses are easily deceived as to the nature of the motion: to the traveller in a railway carriage, or in the cabin of a vessel, the objects at which he gazes appear to be really moving past while he himself is at rest, and it is only by the jerks or inequalities in the motion of the conveyance that he is made sensible of his advance, which is the less perceptible in proportion to its steadiness. It is thus with the diurnal rotation of the earth;—carried round with it, along with all the objects by which we are surrounded, with a perfectly uniform and steady motion, our progress is imperceptible to the senses, and is only rendered manifest by the exercise of the reflective faculties.

We must, then, regard the earth as a globe revolving from west to east about a line which corresponds with the axis (Art. 2) of the apparent diurnal motion of the heavens. Upon the spherical surface of the earth various lines are supposed to be drawn for the purpose of enabling us to refer any place on it to a certain and fixed position, and to state its bearing with reference to other places; and, as the heavens present the appearance of a concave sphere, of which the earth seems to occupy the centre, similar lines, corresponding exactly with those traced on the earth, are also supposed to be marked on their internal surface. It is necessary to describe the nature of these lines, and to explain some other geographical definitions of frequent occurrence.

(11) The line about which the earth revolves from west to east, and which constitutes one of its diameters, is called its *Axis*. Its position is shown in the annexed diagram by the line P P′.

(12) The *Poles* of the earth are the points in which its axis meets the surface — corresponding to the Poles of the heavens, or the points around which their apparent diurnal motion is made. Of these, P is the North and P′ the South Pole.

Fig. 1.



(13) A circle, E C Q D, drawn round the globe at an equal distance from the poles, and dividing it into two hemispheres,—a northern and a southern,—is called the *Equator:* the *plane* of this circle passes through the centre of the globe, and is at right angles to its axis. A circle in the heavens corresponding to that on the earth, and marked out by the indefinite extension of its plane, is called the *Celestial Equator*, or the *Equinoctial*. The equator, and all circles drawn on the globe of which the planes pass through the centre, are called *great* circles; all others are known as *small* circles.

(14) A great circle, such as P E P′ Q, which passes through both the poles of the earth, and the plane of which

coincides with the earth's axis, is called a *Meridian.* When its plane is extended to the sphere of the heavens, it marks out a corresponding line called a *Celestial Meridian.* A circle of this kind passing through any place on the earth is called the meridian of that place, because, when the sun is on the corresponding celestial meridian, it is mid-day or noon at that place. As such a circle may be drawn through any point on the globe, it is obvious that every place has it own meridian. The equator cuts all the meridians at right angles, so that with the poles it divides them all into four equal parts, or *Quadrants,* as E P, P Q, Q P′, P′ E.

(15) A point in the sphere of the heavens vertically over the head of a spectator in any place on the earth is called the *Zenith* of that place : it is directly over the extremity of a line drawn from the centre of the earth to the place. A corresponding point in the opposite hemisphere of the heavens, vertically beneath the spectator, is called the *Nadir.*

(16) The extremities of a plane passing through any place on the earth's surface, and perpendicular to a line joining the zenith and nadir of that place, constitute the *Visible* or *Sensible Horizon,* which is, therefore, the circle that bounds in every direction the view of a spectator, and at which the heavens and earth appear to meet. The plane of a circle parallel to the visible horizon, and passing through the centre of the earth, prolonged until it meets the sphere of the heavens, is called the *Rational Horizon.*

(17) The points in which the meridian of any place intersects the horizon are called the *North* and *South* points; and those in which a circle perpendicular to the meridian (and the plane of which passes through the zenith) inter-

sects the horizon, the *East* and *West* points. These four constitute the *Cardinal Points* of the compass. They divide the horizon into four equal parts.

(18) All circles, great or small, are divided into 360 equal parts, called *Degrees*; every degree is divided into 60 equal parts, called *Minutes*, and every minute into 60 equal parts, called *Seconds*: these parts are indicated by the signs ° ′ ″; thus 20° 14′ 26″ signify twenty degrees, fourteen minutes, twenty-six seconds. Each quadrant, or quarter of a meridian, therefore, contains 90 degrees.

(19) The distance of any place on the earth's surface from the equator towards either pole, measured in degrees on the meridian passing through that place, is called its *Latitude*: if towards the north pole, it is called *North Latitude*, and if towards the south pole, *South Latitude*. Thus, E Z is the latitude of the place Z. As that portion of the meridian which fills the interval between the equator and either pole is a quarter of a circle, it is evident that the greatest latitude which a place can have, north or south of the equator, is 90 degrees. Small circles on the globe, parallel to the equator, and intersecting the meridians at right angles, as Z A M, are called *Parallels of Latitude*. Every place through which the same parallel of latitude passes has the same latitude.

(20) The distance of a place, measured in degrees of the equator, from the meridian of any place which is chosen as a *first meridian*, is called its *Longitude*: thus E C is the longitude of the place C from the meridian P E P′. It is called east or west longitude, according as the place is on the east or west side of the circle chosen as a first meridian, and is reckoned on either side halfway round the globe to the opposite side of that meridian. The greatest longitude which a place can have east or west of any

meridian is thus 180 degrees, or half the circumference of the globe. The choice of a meridional circle as a first meridian from which to reckon is arbitrary, the people of each country generally making use of that which passes through their national observatory: thus English geographers use the meridian passing through the Observatory at Greenwich.

The meridians most extensively used (next to that of Greenwich) as first meridians, from which to measure longitude, are those of Paris and of Ferro, the westernmost island of the Canary group. The latter was universally adopted by the ancients, since it represented the most westerly portion of the world as known to them. It is still used by some modern nations, and is frequently referred to by geographers of all countries. The meridian of Paris is 2° 20′ 24″ east of Greenwich. The actual longitude of Ferro is 18° west of Greenwich, but the meridian conventionally understood as that of Ferro is only 17° 40′ to the west of Greenwich. A place lying 5° west of Greenwich is hence 7° 20′ 24″ west of Paris, and 12° 40′ east of Ferro. Similarly, a place situated 5° east of Greenwich is 2° 39′ 36″ east of Paris, and 22° 40′ east of Ferro. The people of the United States use the meridian passing through Washington, situated 77° 2′ to the west of Greenwich, as a first meridian.

It has frequently been proposed to obviate the inconvenience arising from the use of different meridians by various nations, by the general adoption of some *one* such line as an universal first meridian, from which all nations might reckon their longitudes.

(21) In Astronomy, the terms *Declination* and *Right Ascension* correspond to the latitude and longitude of terrestrial measure. Declination (applied to the distance of a star or other body from the line of the celestial equator)

is measured from the equator in the direction either of north or south, towards the Pole. Right Ascension is measured eastward, from the first point of Aries, round the entire globe.

(22) The distance of any object from the east or west point of the horizon, measured in degrees upon the horizon, is called its *Amplitude.* Distance from the north or south point of the horizon is called *Azimuth.* Imaginary circles passing (at any place) through the zenith and nadir—and therefore cutting the horizon at right angles—are called *Azimuth Circles.* An arc of the horizon contained between the azimuth circle of any star or other object, and the north or south point of the horizon, expresses the azimuth distance of that object. The *Altitude* of any object is its height above the horizon, expressed in degrees of a circle supposed to pass vertically through the object.

CHAPTER III.

ANNUAL MOTION OF THE EARTH—THE SEASONS—ZONES.

(23) It has been already observed, that besides the apparent diurnal motion round the earth in which the sun participates with all the other heavenly bodies, he appears also to move in an easterly direction among the fixed stars, and to make a complete revolution of the heavens in the course of a year. The sun is also observed to reach at mid-day a higher position in the heavens on the meridian of any place, or, in other words, to attain a greater *meridian altitude*, at some seasons of the year than at others, thus moving backwards and forwards in a north and south direction. By observing attentively from day to day this meridian altitude of the sun, and also noting successively his increasing distance eastward from the meridian passing through any particular star, we are enabled to trace out his apparent motion, both in the direction of the meridian and in that of a circle parallel to the equator. The path which the sun thus appears to follow is found to intersect the equator in two opposite points, and to make with it an angle of 23° 28′; so that he is at one time of the year at that distance north, and at another at the same distance south, of the equator. The circle thus traced by the sun on the concave sphere of the heavens is called the *Ecliptic*, and where the plane of this circle meets the earth, it of course

marks out a similar circle on it. This circle is represented in fig. 1 by the line H C R D.

(24) The points in which the ecliptic intersects the equator (C D, fig. 1,) are called the *Equinoctial Points*: that in which the sun passes from the south to the north side of the equator is called the *Vernal* or *Spring Equinox*, and the other the *Autumnal Equinox*. The points at which the sun attains his greatest distance north or south of the equator are called the *Solstitial Points*; that to the north, R, is distinguished as the *Summer*, that to the south, H, as the *Winter Solstice*. A circle drawn on the globe, parallel to the equator, through the point of the northern or summer solstice, is called the *Tropic of Cancer*; and a similar circle drawn through the point of the southern or winter solstice, the *Tropic of Capricorn*. The Tropic of Cancer is therefore at a distance of 23° 28′ to the north of the equator, and the Tropic of Capricorn at a similar distance to the south of that line.

(25) Astronomy, however, teaches us that this motion of the sun is only apparent, and that it consists in a *real* motion of the earth around that luminary. As the magnitude of the sun is ascertained to be upwards of a million times greater than that of the earth, it is surely more probable to suppose that the latter body should be carried round it, than that a body so enormously greater in bulk should revolve round one of so much smaller dimensions; nor can the observed movements of the planets *amongst* the other stars be well made to consort with any other theory. For an explanation of these movements, however, the student must be referred to works directly treating of Astronomy. We have already mentioned (Art. 5) that the planets are found to revolve in orbits round the sun as a common centre, and we must regard the earth as a body

of similar nature to them. The ecliptic is really the path which the earth, in common with the other planets, describes annually round the sun. The orbit of the earth is situated between those of Venus and Mars. Mercury and Venus, being nearer to the sun than the earth is, are called *inferior* planets; the others, which are exterior to the earth's orbit, *superior* planets.

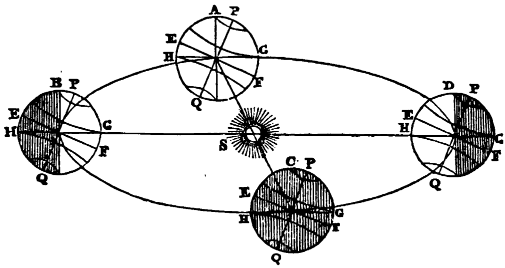
We must, then, reject as erroneous the notions which appearances at first suggest respecting the system of the world. The globe which we inhabit, instead of being at rest in the centre of the universe, is in reality performing a double motion—that around its own axis, and that around the sun. In regarding it under this aspect all the appearances of the heavens are explained in the most simple manner, the laws which regulate their movements appear uniform, and an analogy is preserved throughout the whole of them. Like some of the other planets, the earth is accompanied by a satellite—the moon; and like them, it receives its light from the body round which it revolves. This system of the world, taught by some of the ancients but afterwards neglected, is called the *Copernican System*, from Copernicus, by whom it was revived in the early part of the sixteenth century.[1]

(26) In this annual motion of the earth, its axis always preserves the same direction; that is to say, in whatever part of its orbit the earth may be situated, its axis is always

[1] For the sake of simplicity of conception, it is a frequent practice to speak of the earth and other planets as describing *circles* round the sun. When accurately traced out, however, their paths are found not to be circles, but *ellipses*, which have the sun in one of their *foci*. The orbits of the secondary planets round their respective primaries, as that of the moon round the earth, are also *elliptic*. This universal ellipticity is a consequence of the law of *Universal Gravitation*.

parallel to its direction when in any other part. As the ecliptic is inclined to the equator at an angle of 23° 28′, it follows that the angle which the axis of the earth makes with the plane of its annual motion will be 66° 32′. It is this obliquity of the ecliptic and parallelism of the earth's axis which occasion the variety of *the Seasons*, as illustrated in the diagram, fig. 2.

Fig. 2.



Let S represent the sun, and A B C D four positions of the earth in its orbit, viz.: A, that which it has on the 21st of March; B, its position on the 21st of June; C, that of the 21st of September; and D, that of the 21st of December. In each of these positions let P Q represent the axis of the earth, about which it performs its daily rotation, independent of its annual motion in its orbit. Since, then, the sun can only enlighten at the same time that half of the surface which is turned towards it, the shaded portion of the circles will represent the dark, and the bright portion the enlightened, halves of the earth's surface in each of these positions.

Now, in the positions A and C, the sun is vertically over the intersection of the equator E F and the ecliptic H G, or in one of the equinoxes. In this position the poles P, Q, both fall on the extreme edges of the enlightened half, and it is therefore day over half the northern and half the southern hemisphere at once. As the earth revolves on its axis, every part of it describes, in these positions, half its diurnal course in light and half in darkness; in other words, the duration of day and night is then equal over the whole globe: hence the term *equinox*.

Again, B is the position of the earth at the time of the northern or summer solstice. Here the north pole, P, and a considerable portion of the earth around it, as far as B, are situated *within* the enlightened half. As the earth turns on its axis in this position, the whole of this portion remains constantly enlightened: at this part of the earth's orbit, therefore, it is continual day at the north pole, and in all that region which encircles it as far as B,—that is, to the distance of 23° 28′. On the other hand, the opposite, or south pole, Q, with all the region comprised within a distance of 23° 28′ from it, is involved at this time in darkness during the whole of the earth's diurnal rotation, so that it is there continual night. When the earth is at D, which is its position at the time of the southern or winter solstice, similar phenomena will occur, but in the opposite direction; the north pole and a space extending 23° 28′ round it being then immersed in darkness, while an equal extent round the south pole falls entirely within the enlightened half. Circles parallel to the equator, drawn through points marking the limits of that portion of the globe which, in either of these positions, is involved in continual light, or in continual darkness, are called *Polar Circles*; that round the north pole being distinguished as the *Arctic*, and that round the south pole as the *Antarctic Circle*. They are at a distance from the equator equal to the angle which the axis of the earth makes with the plane of its orbit, or 66° 32′.

It is evident that when the earth is at B, the nearer any place on it comprehended between the arctic and antarctic circles is to the north pole, the larger will be the portion of its diurnal course comprised within the light, and the smaller that comprised within the dark, hemisphere; or, in other words, the *longer* will be its day, and the *shorter* its night. Every place north of the equator will have a day of more, and a night of less, than twelve hours' length, and every place south of the equator the reverse. Similarly, when the earth is at D, the days will be longer and the nights shorter in proportion as a place is nearer to the south pole.

Now, the temperature of any part of the earth depends chiefly on its exposure to the sun's rays, since when the sun is above the horizon of any place, that place is receiving heat; and in proportion as the sun's rays fall more vertically, so is the amount of heat which they communicate increased. It is only to that part of the earth which is between the tropics that the sun is ever entirely vertical; and hence his rays, falling perpendicularly, produce in those regions the greatest heat. In those parts which are between the tropics and the polar circles, the sun's rays fall with a degree of obliquity which increases in proportion as a place is nearer to the arctic or antarctic circles, and the heat is therefore less there than in the parts within the tropics; while in the polar regions the most intense cold is experienced, on account of the great obliquity with which the rays of the sun fall, and the length of time during which they are successively involved in darkness. As the quantity of heat received is also greater in proportion to the length of time the sun is above the horizon, it follows that as the earth moves from A, at which the days and nights are equal in length, and the temperature of the earth is at its mean state, to B, the days growing longer and the nights shorter in the northern hemisphere, the temperature of every part of that hemisphere increases, and its inhabitants pass from spring to summer; while at the same time the reverse takes place in the southern hemisphere. As the earth passes from B to C, the days and nights again approach to equality; and when it reaches the autumnal equinox, C, the mean state of temperature is again attained all over the globe. From thence to the winter solstice, D, and finally round again to the vernal equinox, A, it is obvious that all the same phenomena will recur in the reverse order, it being then winter in the northern and summer in the southern hemisphere.

(27) The tropics and polar circles serve to mark out five divisions on the surface of the globe, which are known by the name of *Zones*. That portion of the globe included between the tropics is called the *Torrid Zone*: the spaces comprised between the Tropic of Cancer and the Arctic Circle, and between the Tropic of Capricorn and the Antarctic Circle, are named respectively the *North* and *South Temperate Zones*; and the regions included within the Arctic and Antarctic Circles, the *North* and *South Frigid Zones*.

(28) The circles on the globe which have been explained serve to distinguish three positions of the sphere. The sphere is said to be *right* when the horizon coincides with a meridian, and therefore cuts the equator and all circles parallel to it at right angles: it is thus placed with regard to an inhabitant at the equator, to whom one of the poles occupies the north and the other the south point of the horizon. As his horizon divides all the parallels of latitude

into two equal parts, it is obvious that it divides the courses of all the heavenly bodies into two equal portions.

When the horizon coincides with the equator, the sphere is said to be *parallel*, because all circles parallel to the equator are also parallel to the horizon: the globe would occupy this position to a person situated at either pole, who would see the sun continually for six months of the year, and to whom all the heavenly bodies would appear to describe circles parallel to the horizon.

In all other positions of the sphere it is called *oblique*, because the equator and parallels of latitude all intersect the horizon obliquely, or are inclined to it at an angle differing from a right angle: it occupies this situation relatively to all persons dwelling between the equator and the poles, to whom the courses of the heavenly bodies above and below the horizon are divided into unequal portions.

CHAPTER IV.

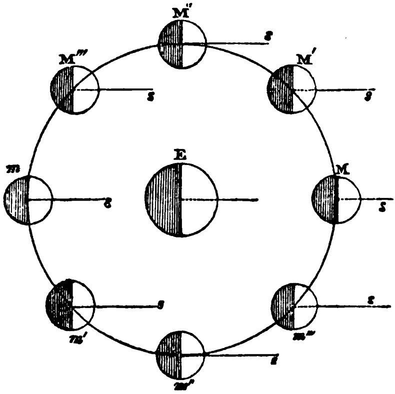
MOTION AND PHASES OF THE MOON—ECLIPSES OF THE SUN AND MOON.

(29) It has already been observed (Art. 4) that the moon, like the sun, appears to describe a circle in the heavens among the stars, but in a much shorter period, being carried entirely round in an easterly direction in 27 days, 7 hours, and 43 minutes, or a *periodical month*, and returning in that time to a position among the stars nearly coinciding with that which it had before. When this apparent motion is accurately traced out, it is found that the moon performs a monthly revolution round the earth in a path or orbit which is inclined to the plane of the ecliptic (or apparent path of the sun) at an angle of 5° 8′ 48″. The points in which the moon's orbit intersects the ecliptic are called its *Nodes*, the *ascending node* being that in which the moon passes from the southern to the northern side of the ecliptic, and the *descending* the reverse. In the course of this period the moon presents a succession of different appearances, or phases, which may be thus explained.

(30) As the moon is an opaque or solid body, receiving, like the earth, her light from the sun, it is only by reflecting his light that she is rendered visible to us. In figure 3, let E represent the earth; M, M′, &c., the moon in different parts of her orbit; and the parallel lines *s s*,

&c., the direction of rays of light propagated by the sun; for since the sun's distance from the earth is four hundred times greater than that of the moon, it is obvious that all lines drawn from the former to any part of the moon's orbit may be regarded as parallel. The half of the moon turned in the direction of the sun will therefore be enlightened, and the opposite half dark, in whatever part of her orbit she may be. When she comes to the meridian at about the same time as the sun, or is on the same side of the earth as that luminary, as at M, her dark side is entirely turned towards the earth, and her bright side from it. In this position, then, the moon is not seen, and it is said to be *new* moon. When she has passed through a quarter of her orbit, and arrived at M″, half her light and half her dark sides are presented to the earth: she is then said to be in her *first quarter*. When she reaches *m*, the whole of her light side is towards the earth, and all her darker side from it; we then see the entire circle of light, and it is called *full* moon: and again at *m″* her position corresponds with that at M″, an equal portion of her light and dark sides being towards the earth: she is then in her *third quarter*. In the intermediate positions,

FIG. 3.



M$'$, M$'''$, m', and m''', the portion of the enlightened side turned towards the earth will at first be less than half the visible surface, then greater, and afterwards less again, until it entirely disappears as she comes round to M: when at M$'$ she appears in the form of a crescent, with the convex side turned towards the sun; at M$'''$ more than half of her enlightened disc is visible, and she is said to be *gibbous*; she is again gibbous at m', and at m''' presents a second time the appearance of a crescent.

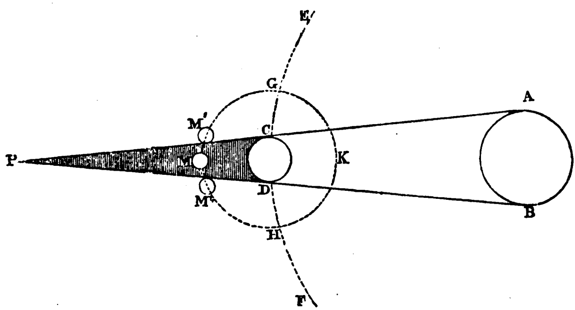
When the moon is new, she is said to be in *conjunction* with the sun; and when full, in *opposition*. The period that elapses between one new moon and another is called a *lunation* or *lunar month*: it consists of 29 days, 12 hours, 44 minutes. Its excess over the periodical month is owing to the continual advance of the earth in the ecliptic in the same direction as the moon's motion; so that the moon has to perform *more* than a complete revolution round the earth in order to return again to the same position with regard to the sun, and will therefore occupy a longer time in it.

(31) The explanation of the lunar phases leads to that of eclipses. As the moon is a solid body, it is obvious that if in her passage round the earth she be so placed at any time as to be directly *between* that body and the sun, she will intercept the light which the earth receives from the sun, and thus cause that luminary to be obscured: such a phenomenon is called an *eclipse of the sun*, and is either *total* or *partial* according as she covers the whole or a part only of the sun's disc. It is equally obvious that if she be so situated as that the earth is directly *between* her and the sun, the earth, similarly intercepting from her a part or the whole of the sun's rays, will cast a shadow on her, and thereby involve her in darkness: such an occur-

rence is called an *eclipse of the moon.*[1] Now, as the moon passes entirely round the earth in the space of a month, *if the plane of her orbit coincided with that of the ecliptic* she would be successively in each of these conditions during that period; but as her orbit is inclined to the ecliptic at an angle of more than five degrees, it follows that the required conditions can only be fulfilled when her conjunction or opposition takes place at the time when she is in or near her nodes (Art. 29); for it is only then that the sun, moon, and earth, are placed in a straight line with one another.

(32) To illustrate, first, the general phenomena of lunar eclipses, let E G H F (fig. 4) represent a portion of the earth's orbit round the sun, and the circle G M H K

Fig. 4.



the orbit of the moon round the earth: suppose A B to be the sun, and C D the earth illumined by it; if we join the

[1] The former of these phenomena can only happen when the sun and moon are in conjunction, or at the time of *new moon,* when both those bodies are on the same side of the heavens; the latter only when they are in opposition, or at *full moon,* when the sun and moon are on opposite sides of the heavens.

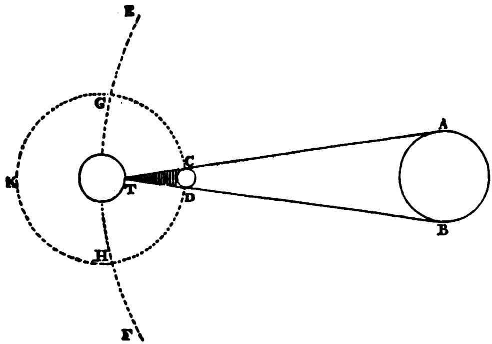
points A C, B D, and prolong the lines joining them until they meet in the point P, there will be a total shadow cast by the earth within the conical space C P D, within which a spectator would be unable to see any part of the sun's disc.

In the above figure, then, if we suppose M to represent the moon, it is obvious that if, when she arrives at the point M′ of her orbit, she be in her node (that is, if she be in that point of the plane of her orbit which intersects the plane of the earth's orbit), she will enter the shadow of the earth: at M she will be entirely immersed in its shadow, so that to a spectator on the earth she will be totally eclipsed: as she advances, she will gradually emerge from the shadow, which she will entirely leave at M″. The moment at which she enters the shadow will be the commencement, and that at which she leaves it the termination, of the eclipse; or the times of her *immersion* and *emersion.* If at the time of her opposition she be not in, but only near, her node, the eclipse will be only partial. In most cases, however, owing to the inclination of her orbit to the ecliptic, she passes (at the time of her conjunction) either *above* or *below* the shadow of the earth, so that she is not deprived of the sun's light, and therefore not eclipsed. The greatest length of time during which the moon can be totally eclipsed is nearly two hours.

(33) In illustration of solar eclipses, let E G H F (fig. 5) represent, as before, a portion of the earth's orbit, and G K H D C the orbit of the moon: suppose also A B to be the sun, C D the moon, and T the earth. If we then join the points A C, B D, and prolong the lines till they meet in the point T, the conical space T C D, representing the moon's shadow, will be involved in total darkness. At the point T, where the vertex of this shadow touches the earth,

the moon will appear for a moment to a spectator situated there to *just* cover the sun, or to eclipse it, while in other

FIG. 5.



parts of the earth the moon will obscure a portion only of the sun's disc. Owing to a slight variation in the distances of the sun and moon from the earth (arising from the ellipticity of their orbits), the vertex of the shadow sometimes falls short of the surface of the earth, in which case there will be no total eclipse on any part of the earth; but a spectator so situated as to be in or near a line corresponding with the prolonged axis of the cone will see the whole disc of the moon on the face of the sun, which, as the figure of the moon will not be large enough to cover it, will present the appearance of an *annular* eclipse: that is, the central parts of the sun's disc will be obscured, but a bright ring will be left visible round the dark body of the moon. Either of these phenomena can only occur when the moon is in or near one of her nodes at the time of conjunction with the sun, or at new moon. Owing to the small size of the moon compared to that of the sun, the section of her shadow on the earth's surface is so near the vertex that the portion of the sun's disc which is covered by it is never very extensive; so that a total eclipse of the sun cannot in any place last longer than 7 minutes 58 seconds.

(34) The time at which solar and lunar eclipses will happen, and the circumstances under which they will occur, may be computed from the laws which regulate the motions of the sun and moon. To do this with perfect accuracy requires many refined astronomical calculations, and is attended with considerable labour; but it has been known from remote antiquity that in 223 *lunations*, or 18 years and 10 days, the moon returns *nearly* to the same position with regard to the sun and to the position of her nodes; so that at the end of that period eclipses will return in nearly the same order and circumstances. By a knowledge of this fact, the Chaldeans and other nations of antiquity were enabled to predict eclipses with tolerable accuracy.

The greatest number of lunar and solar eclipses which can happen in the course of a year is seven,—five of the sun, and two of the moon: there never can be less than two eclipses of the sun every year, although there may be no eclipse of the moon in that period. But though more solar eclipses happen than lunar, fewer of the former than of the latter are visible from any particular place, because a lunar eclipse is visible from every part of the hemisphere turned towards the moon during its continuance; but in a solar eclipse the sun continues to be seen over a considerable portion of the hemisphere turned towards him.

In the earlier ages of mankind, as among ignorant and barbarous nations at the present day, the phenomena of eclipses awakened feelings of mingled awe and astonishment on the part of beholders, whose superstitious fears were not unnaturally excited by the strange spectacle of a temporary abstraction of the sun's or moon's light, due to a cause which they were wholly unable to comprehend. And though science has long since banished the vague terrors by which these feelings were accompanied, yet the solar and lunar eclipses—and more especially the former, in those cases in which either the whole or the larger portion of the diurnal luminary is for the time obscured—are (independently of their scientific importance) occurrences of the highest interest, and possess a striking power over the mind. The influence of a total eclipse of the sun over the lower members of the animal creation, during the strange and apparently unnatural kind of darkness by which it is for the time attended, is also highly curious and instructive.

(35) In a similar manner to that in which the moon passes over the face of the sun in an eclipse of that luminary, she is continually passing over, and thereby *occulting* or eclipsing, some one or other of the stars or planets among which her course in the heavens is situated. Such of the planets as are attended by satellites also eclipse those bodies whenever the latter pass behind them, and are thereby prevented from receiving the light of the sun. The use made in geography of the occultations of the fixed stars by the moon, and of the eclipses of Jupiter's satellites, will be seen in the next chapter.

CHAPTER V.

METHOD OF DRAWING A MERIDIAN LINE—DETERMINATION OF LATITUDE AND LONGITUDE.

(36) It has been explained (Arts. 19, 20) that the latitude of a place is its distance in degrees from the equator towards either pole, and its longitude the number of degrees which it is situated east or west of some one of the meridian lines chosen as a first meridian. By knowing the latitude and longitude of any place, we fix its absolute position, and its situation relatively to others already known. The determination of these elements is therefore of the utmost importance to *exact* geography.

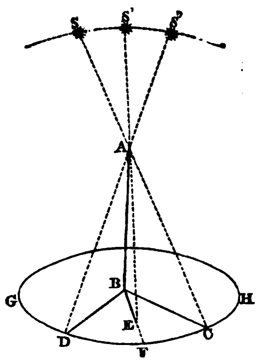
The modes of solving the problems intended to be treated of in this chapter depend entirely upon the application to Geography of the theory and practice of Astronomy. While simple in principle, and easy in performance, if very minute accuracy be not required, their *exact* solution requires the aid of the most careful observations, and of the most refined mathematical calculations. It is needless, in a work of this kind, to do more than explain the general nature of the principles on which they rest; for fuller details respecting them the student must be referred to works professedly treating of Astronomy and Navigation—subjects to which it would be impossible to do justice in the space here devoted to those topics.

(37) The various methods of determining latitude and

longitude all require the observer to know *the direction of the meridian*, or the line in which the true north and south points lie, at the place where he is: hence we indicate the way in which this may be ascertained, before proceeding to explain the modes of solving those problems.

All the heavenly bodies have their greatest diurnal altitude, that is, occupy their highest position in the heavens, when they are on the plane of the meridian; and those which do not sensibly vary in their *declination* (or distance north or south of the equinoctial) in the course of a day, have the same apparent altitude at equal intervals of time *before* and *after* they pass the meridian. About the time of the summer and winter solstices (Art. 22) the sun changes his declination very little in the course of a day, so that at those times his altitude above the horizon at one or two hours *before* noon is equal to his altitude at the same time *after* noon. Let an observer, then, on or near the 21st of June or the 21st of December, plant a rod or wire, A B (fig 6), perpendicular to the horizon at an hour or two before the sun reaches his greatest altitude in the heavens, for instance, at 11 o'clock in the morning, and mark accurately the extremity, C, of the shadow, B C, thrown by the rod; then from the base, B, of the rod as a centre, and with the radius B C, the length of the shadow, let him describe a circle, G H, upon the ground;—as the sun, S, gradually advances

FIG. 6.



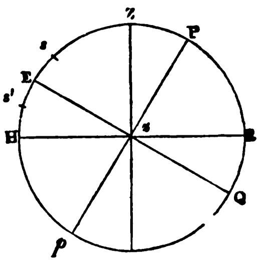
towards his greatest altitude, s′, the shadow of the rod will gradually become shorter, and will fall *within* the circumference of the circle which has been traced. The shadow will be at its shortest, B E, when the sun is at his greatest height, or when he is on the meridian of the place, which is the moment of noon; after this, as the sun gradually becomes lower, the shadow of the rod will become longer and longer; until at last, when he is at s″, it will again reach the circumference of the circle, in the point D, at which time in the afternoon the sun will have the same altitude as he had when the shadow of the rod was of the same length, B C, before noon. As, in the equal times which have elapsed before and after his passage of the meridian, the sun has gone over equal spaces in the heavens, the middle point of the whole space described by the sun in the sum of these times will be that point in the heavens which he occupied at the moment of noon, at which time he was on the meridian. If, therefore, the observer divide into two equal parts the whole arc, C D, of the circle he has traced, and join the central point F and the base of the rod, the line B F, joining these two points, will coincide with the shadow of the rod at noon, and will be the direction of the meridian line.

Such is the simplest method of ascertaining the meridian, —a method of easy and ready adoption. For purposes which require minute accuracy, however, the moment at which some particular star will pass the meridian is ascertained by previous calculation, and a telescope is then directed so that at *that moment* the star may be in the axis of (or in a line with) the telescope, which will then represent the direction of the meridian line at the place of observation.

(38) We now turn to the consideration of *latitude*. In

fig. 7, let P E *p* Q represent a meridian on the surface of the earth, passing through the place Z, of which the latitude is required to be known. Let P *p* be the north and south poles, and E Q the plane of the equator. H R will then represent the rational horizon of an observer at Z. The distance from E to Z will consequently be an arc of the meridian which measures the latitude of the place Z. Now because the arc E P, the distance of the pole from the equator, and Z R, the distance of the zenith from the horizon, are each a quarter of the circumference of the earth, or 90°, they are equal to one another; and, consequently, if we take away the arc Z P, common to both, the remaining arcs, E Z and P R, are also equal. But E Z is the latitude of the place Z, and P R is the elevation of the pole above the horizon; it therefore appears that the *altitude* or *height of the pole is equal to the latitude of the place of observation.*

FIG. 7.



(39) It was stated, in explaining the use of the imaginary circles drawn on the globe (Art. 10), that circles of a similar nature, corresponding to those drawn on the earth, were supposed to be marked out on the concave sphere of the heavens. Now the distance of the fixed stars from the earth is so immensely great, that it is immaterial whether we regard them as viewed from the surface or from the centre of the earth; or, in other words, the radius of the earth is, in regard to them, insensible, so that no change in their apparent positions would be caused by viewing them

from either extremity of it. We may, therefore, in reference to the stars, regard the earth simply as a *point* in the centre of the sphere in which they appear fixed. If, then, in the same diagram (fig. 7), we now suppose P E *p* Q to represent a meridian in the concave surface of the heavens, corresponding with the terrestrial meridian of an observer at the place *z* in the centre, and E Q and H R to be the planes of the celestial circles answering to those which they before represented on the earth, then will P *p* be the poles of the heavens, and Z the zenith of the observer at *z*. It is obvious that the celestial arcs E Z and P R will measure distances equivalent in length to the arcs of the terrestrial circles to which they correspond; so that the observer at *z*, by ascertaining the altitude of the celestial pole above the rational horizon, will in fact *measure in degrees the latitude of the place of observation.*

It is by different applications of this principle that the latitudes of places are determined. If the star which we call the pole star were situated exactly at the pole, it would be sufficient to measure its elevation above the horizon in order to ascertain the latitude of any place to the north of the equator; but since it does not really occupy the place of the celestial pole, but is 1° 24′ distant from it, it is necessary to have recourse to other means. In the course of twenty-four hours every star passes the meridian twice, at equal distances from the pole, and on opposite sides of it. In reference to those stars which do not sink below the horizon, when any particular star passes the meridian below the pole—that is, between the pole and the horizon—its altitude is the *least* possible; and when it crosses the meridian *above* the pole, or between the pole and the zenith, its distance from the north point of the horizon will be the *greatest* possible. If, therefore, with a *quadrant* (an instrument for measuring angles) we ascertain the star's altitude when it is least, and also when it is greatest, it is manifest that half the sum of these elevations will be the altitude of the pole (or the latitude of the place) where the observations were made. A slight correction of the altitude thus measured is requisite, in consequence of the *refractive power* of the atmosphere, a property which has the effect of raising bodies *above* their true position, and in a proportion which increases as the body observed is nearer the horizon. The amount of this undue elevation is computed for various altitudes, and must be deducted from the *observed* altitude.

Again, referring to the diagram (fig. 7), it is obvious that the arc H E is the *co-latitude* of the place Z,—that is, the complement of the latitude, or the difference between the arc which measures the latitude and the entire quadrant. But H E is the elevation of the plane of the equator above the horizon: if, therefore, we can in any way ascertain the measure of this arc, we have the means of ascertaining the latitude. Now the observed altitude of any of the heavenly bodies *when on the meridian* will enable us to accomplish this, provided we know how many degrees distant they are from the plane of the equator at the moment of observation, that is, what is their *declination.* Thus supposing *s*, *s′* to represent the positions of the sun when in north and south declination respectively, if the meridian altitude of that luminary be measured when in the former of these positions, then the arc H *s* will have to be diminished by the arc E *s* (the amount of declination) in order to give the measure of H E, or the co-latitude of the place of observation. If the sun be at *s′*, then the declination (*s′* E) will, on the other hand, require to be added to the observed altitude H *s′*, in order to give the co-latitude. Or, in other words (supposing the observation to be made in the northern hemisphere), the declination of the sun or other body will have to be *subtracted* from the observed altitude if it be in north declination, and to be *added* to it if its declination be south, in order to obtain the arc which measures the co-latitude; and the reverse, if the observer be situated to the southward of the equator.

It is this method of finding the latitude that is most commonly employed, as being the most simple in practice, since it requires only a single observation to be made. The observed altitude of one of the fixed stars is frequently employed for the purpose on land, that of either the sun or the moon (most frequently the former) at sea. The declination of the sun and moon for every day in the year is given in the Nautical Almanac, and the distance of the fixed stars from the plane of the equator is also well-known, so that the observer can readily make the due allowance for declination, and obtain the co-latitude (or the difference between the latitude and 90°) accordingly.

But the observations thus made require in all cases to be corrected for refraction; and in the case of either the sun or moon, a correction has also to be applied for the amount of *parallax*—that is, for the difference between the *observed* altitude as seen from the surface of the earth, and the true altitude above the celestial horizon as it would appear from the earth's centre.[1] A third correction has also, in the case of an observation taken at sea, to be made for the height of the observer above the surface of the sea, which tends to depress the horizon, and consequently to

[1] This difference, as already stated, becomes insensible in regard to the fixed stars, owing to their immense distance, but in regard to bodies situated so comparatively near to the earth as either the sun or the moon, it requires to be allowed for.

give the observed object a greater apparent altitude than it really possesses. All these corrections are readily applied by means of Tables calculated for the purpose, and to be found in works treating especially of Navigation and Nautical Astronomy.[1]

(40) The determination of the *longitude* of any place, although possessing equal or greater simplicity in principle than the preceding problem, is attended with much greater difficulty in practice, owing to the imperfection of our instruments and modes of observation.

The difference of longitude between any two places is simply the difference of *time* between them, expressed in degrees and parts of a degree, instead of hours, minutes, and seconds. To a person who has never reflected on the subject, it appears at first difficult to conceive that *at the same moment* there can be any difference in the time at different places. He should, however, consider that although time is in the abstract indivisible, so that the same instant of *absolute time* is common to the whole universe, the local time of any place is merely a measure of the interval which elapses between the recurrence at that place of certain known phenomena. The succession of day and night, caused by the motion of the earth round its axis, is the most obvious of such recurring phenomena, and is accordingly that which has been chosen as a measure of time. The interval which elapses between a certain star's being on the meridian of any place, and its return, after appearing to move round the heavens, to the same meridian, measures the time occupied by the earth in its diurnal revolution, and is called a *sidereal day*. This is always

[1] See 'Treatise on Navigation,' &c., by Edward Riddle; Lieut. Raper's 'Navigation and Nautical Astronomy,' &c. &c.

exactly of the same length of 23 hours, 56 minutes, and 4 seconds. The interval between the sun's being upon the meridian of a place and his return to the same meridian, called a *solar day*, is longer than this; for if upon any day the sun and any fixed star be observed to be upon the meridian of a place together, the star will on the following day return to the meridian a few minutes before the sun. This difference is caused by the apparent annual motion of the sun in the ecliptic in a direction *contrary* to that by which he is brought successively to the meridian, so that the star, which has only the daily motion common to the whole heavens, appears on the meridian before the sun. This solar day is, moreover, not always of the same length, for the intervals between two successive arrivals of the sun on the meridian are sometimes greater, sometimes less, than 24 hours. About the 21st of December, for example, it is half a minute *longer*, and about the 21st of September nearly half a minute *shorter*, than its average duration; and, as it is essential that a standard measure of time should be a fixed and invariable quantity, we make use of an artificial *mean solar day*, which is an average of all the *apparent* solar days throughout the year, and is always of 24 hours in length.

The difference between the length of the *apparent* and the *mean* solar day is called the *equation of time*; the exact amount of this difference being calculated for every day in the year, the mean solar time may be ascertained from the apparent solar time by either adding to or subtracting from the latter the equation of time, according as the apparent time is behind or in advance of the mean time. It is to the length of this *mean solar day* that our clocks are regulated: a sun-dial shows the hour of *apparent* solar time. When the sun is exactly on the meridian of any place, it is apparent noon at all places situated under that meridian.

(41) As in the apparent daily path of the sun from east to west he passes in succession over the meridian of every place on the earth, it follows that it is mid-day or noon in succession to every place as he comes to its meridian; so that when he is on the meridian of any place, London for example, it is *past* the hour of noon at all places to the *east* of London, over the meridians of which the sun has already passed, and *before* that hour at all places to the *west* of London, at the meridians of which he has not yet arrived.

In 24 hours the sun passes in this manner over the whole 360 degrees into which the earth's circumference (in common with all circles) is divided; dividing 360 by 24, we find that he moves at the rate of 15 degrees in every hour of time. When, therefore, the sun is on the meridian of Greenwich, so that it is 12 o'clock at that place, he will, in the course of an hour, have reached the meridian of a place 15° to the west of Greenwich; in two hours he will have advanced 30° to the west, at which times it will be successively at Greenwich 1 and 2 o'clock in the afternoon, and 12 o'clock at the places west of it as the sun arrives at their meridians. When in this way he reaches 180° west of Greenwich, it will be 12 hours later, or midnight, at Greenwich, while it is mid-day on the opposite side of the globe.

Similarly, as the sun arrives at the meridian of a place to the east of Greenwich *before* he reaches the meridian of the latter place, when it is noon at a place 15° to the east of Greenwich it will yet *want* an hour of noon at Greenwich; or, in other words, as the sun has yet to travel 15° to reach the meridian of the latter place, it will there be only 11 o'clock in the morning: in a like manner, when it is noon at a place 30° east of Greenwich, it will be only 10 o'clock at Greenwich, and so on for the whole 180° eastward of that meridian.

The various methods of finding the longitude are merely so many different applications of these principles, since, if an observer in any place can ascertain the difference between the local time of *that place* and that of *Greenwich*, he may, by turning the difference of time into degrees at the rate of 15° to an hour, find the difference of longitude between the places. If, for instance, he finds that when it is 12 o'clock at Greenwich it is three hours *later*, or 3 in the afternoon, at some other place, knowing that the sun passes over 15° of longitude in an hour, and multiplying 15° by 3, he will ascertain his longitude to be 45° *east* of Greenwich. If, on the contrary, the time at the place where he is situated be three hours *earlier* than that of Greenwich, the sun will have to traverse 45° from the meridian of Greenwich to the meridian of the observer, and he will therefore be 45° *west* of Greenwich. For *parts* of an hour of time, similar proportional parts of 15° must of course be reckoned: thus half an hour of time will be equivalent to $7\frac{1}{2}°$ of longitude, 10 minutes of time to $2\frac{1}{2}°$, four minutes of time to 1°, and one minute of time to 15′ of longitude.

(42) All, therefore, that is requisite for the purpose of finding the longitude of a place from Greenwich is to ascertain,—1st, the hour of *mean time* at the place of which we wish to know the longitude; and, secondly, the corresponding hour of *mean time* at Greenwich. Now the hour of *apparent time* at any place may always be found by means of an observed altitude of the sun, or by the meridian-passage of any star of which the right ascension

is previously known; and the hour of *mean time* may be obtained from the other by adding to or subtracting from it the equation of time, as given in the Nautical Almanac. The corresponding mean time at Greenwich may then be ascertained by a good watch or chronometer (*time measurer*), regulated to Greenwich time.

As an instance of the application of this principle, if a traveller leaving London carry with him a good watch regulated to Greenwich time, and proceed to Paris, he will find the local time there to be 9 minutes 21·6 seconds *later* than that shown by his watch; converting this difference into degrees at the rate of 15° to an hour, he may conclude that Paris is situated 2° 20′ 24″ *eastward* of the meridian of Greenwich. If he go from London to Dublin, he will find the local time there to be 25 minutes 8 seconds *earlier* than that shown by his watch; he will, therefore, by a similar process, find the difference of longitude between them to be 6° 17′; and as at Dublin the local time is earlier than at Greenwich, it is of course to the *west* of the latter place. If, therefore, a chronometer could be made sufficiently perfect to go always without error, or if its error in going were always the same, so that the *rate* at which it either lost or gained, being uniform, might be exactly ascertained, the longitude of places might be correctly found by a chronometer.

(43) This object, however, has not been attained, and chronometers, although constructed with very considerable accuracy, are still too much influenced by changes of climate and other causes to be relied on implicitly. It is necessary, therefore, to resort to other means of ascertaining the difference between the local time of one station, taken as a first meridian or point from whence to start, and the local times of other places of which the longitudes are

wanted. The changes of appearance and position which take place from time to time among the heavenly bodies afford such means. The time at Greenwich at which certain phenomena in the heavens will occur being carefully computed beforehand, and set down in the Nautical Almanac, if an observer in any part of the earth ascertain the *local* time of the place *where he is situated* when these phenomena are observed there, and, comparing it with the computed *Greenwich time*, note the difference between them, he will be in possession of the necessary information for determining his longitude.

It will be sufficient to mention here the various astronomical phenomena used for this purpose. The longitude may be ascertained, 1st, by observing the difference of time at which *eclipses of the moon* occur at different places: 2nd, by *eclipses of Jupiter's satellites:* 3rd, by observing the *distance of the moon from particular fixed stars, or from the sun:* 4th, by *occultations* (Art. 35) *of fixed stars by the moon:* 5th, by *eclipses of the sun:* and 6th, by the *transit or passage of the moon over the meridian compared with that of the sun or of some of the fixed stars near the moon.* The fourth and fifth of these methods require a correction to be applied to the observations taken on account of their not being observed at all places at the same instant of absolute time, or, in other words, on account of a small portion of time elapsing between their being visible at two different parts of the earth.

The third of the above methods, or that of *lunar observations*, is the one most commonly employed for ascertaining the longitude at sea. The distances of the moon from the sun, from four of the planets, and from some of the principal fixed stars lying near the plane of direction in which she moves, are calculated for several years beforehand, for every three hours of mean Greenwich time, and are published in the Nautical Almanac. By measuring, with a sextant, any of these lunar distances, the observer at any place can therefore correctly obtain the mean *Greenwich* time at the moment of observation, and by comparison of this with his own local time (obtained by taking the altitude of the sun or of some particular star), he can ascertain the difference of time between the two meridians, —in other words, the difference of longitude.

(44) Small differences of longitude may also be accurately determined by means of any signal, as a rocket fired from an elevated spot, which is visible to an observer at each of two given stations; the difference of time between the two places, as noted by each observer when he sees the explosion, giving the difference of longitude. If two places at any distance apart be connected by a chain of intermediate stations near enough to each other to admit of a signal being seen between each two adjoining stations, the difference of longitude between them may be ascertained in a similar manner, by taking the sum of the successive differences, which will of course give the difference between the extreme places. On a similar principle, the difference of longitude between any two or more places connected by the wires of the electric telegraph, may be computed from the different local times at which the same electric shock (communicated *instantaneously* throughout the entire line) is experienced at each. This last method has, indeed, been employed with advantage in many recent instances.

CHAPTER VI.

EXACT FIGURE AND DIMENSIONS OF THE EARTH—GRAVITATION —MEASUREMENT OF DEGREES ON THE EARTH'S SURFACE.

(45) In speaking of the figure of the earth we have hitherto proceeded on the supposition of its being that of a perfect sphere: it has, however, been ascertained to differ slightly from this form. Since, in explaining the methods by which its exact figure and dimensions are ascertained, we shall have occasion to speak of the power called *Gravitation*, it is necessary briefly to notice the nature of this power.

(46) Gravity, considered merely in reference to the earth, is the power by which all bodies, when raised in any way into the air and abandoned, return to the surface of the earth; as a ball or stone thrown from the hand, when the impetus which gives it its upward course is weakened and at length destroyed, falls again to the ground. If the body be quietly abandoned in the air, it descends perpendicularly to that part of the surface of the earth which is immediately beneath it. This descent is owing to the *attraction* which the earth exerts upon all bodies on or near its surface. The force with which it thus attracts them is found to be proportional to the *mass* of the body attracted, since a heavy and a light body would fall to the ground from the same height in the same amount of time if it

were not for the resistance opposed to them by the atmosphere, as is easily shown by experiment in the vacuum formed within the receiver of an air-pump.

(47) It is to Sir Isaac Newton that we owe the first clear conception of the idea that the force which causes bodies to descend to the earth is the same which regulates the motions of the heavenly bodies, which causes the moon to revolve round the earth, and the earth and other members of the solar system to revolve in orbits round the sun. By the aid of calculations which cannot be entered into here, and which involve the most abstruse doctrines of mathematical and physical astronomy, he was enabled to *prove* these forces to be identical, and to ascertain that the proportion according to which the force of gravity acts upon distinct bodies is *inversely as the square of their distances.* This force is exerted by all the bodies in the universe, which mutually attract one another, and by the action which they thus exert give rise to all the celestial phenomena. *Universal Gravitation* is, then, the principle that "*every particle of matter in the universe attracts every other particle, with a force which is inversely poportional to the square of the distance between them,*" or, in other words, with a force which *diminishes* as the square of the distance between the particles *increases.* The cause of this force, or in what it consists, is unknown to us; we are only able to observe the effects produced by it, and to ascertain it to be the one universal law prevailing throughout the material world.

(48) Although it may appear at first view difficult to measure the size of a body which bears so vast a proportion to ourselves as does the globe which we inhabit, yet, on the supposition of the earth being a perfect sphere, the principle on which it is done is exceedingly simple, and

has been practised from very early ages. Since the circumference of the globe is measured by a great circle drawn on it, and every circle is divided into 360 parts or degrees, it follows that if we *measure* the exact length of *one* degree of a great circle on the earth, and multiply this length by 360, we shall have the length of the whole circle, or the circumference of the earth. As the proportion which the circumference of a circle bears to its diameter is known to be 3·1416 to 1, we can easily compute the one of these quantities from the other, and thus learn also the length of the earth's diameter. If, instead of *one* degree, we measure the length of *several* degrees, still, by knowing the exact proportion which they bear to the whole circle, the same result may be attained. To illustrate this more clearly, let P E *p* Q, in fig. 7 (p. 39), represent as before a meridian of the earth. If the part of this meridian contained between E and *s* be supposed to be 5°, it is obvious that if by measurement we ascertain it to be equal to a certain number of miles, and then multiply it by the number of times which 5 is contained in 360, that is, by 72, we shall have the number of miles contained in the entire circle. To insure accuracy we must be certain that the extreme stations between which our measurement is to be made are exactly in the direction of a great circle, and also know exactly the number of degrees or parts of a degree contained between them. Since every meridian is a great circle of the globe, the former of these requisites may be attained by constantly ascertaining the direction of the meridian, as explained in Art. 37; and although we may be obliged by local causes to deviate from it in our measurement, yet if an exact account of these deviations be kept, they may be allowed for, and the actual measurement be thus reduced to its *meridional* value. The exact number of degrees between the stations may be known by observing the latitude of each (Art. 39). On the supposition of the earth being a perfect sphere, its dimensions are then easily ascertained.

(49) In the measurement of the arc of the meridian which it is decided to take, the inequalities of the ground and other causes present too many difficulties for an *actual* and *mechanical* measurement to be made in such a manner as to be relied on.[1] The method usually adopted, therefore, is similar to that used in a trigonometrical survey: this consists in measuring with rigid care a *base line*, and from this calculating (by a series of triangles) the distances between intermediate stations, and finally reducing them to the distance between the extreme stations in the direction of the meridian, from which the sides of the intermediate triangles are, in fact, so many temporary *deviations*. The details of this kind of measurement may be found in any work treating of plane trigonometry, and need not be entered into here.

[1] This method has, however, been adopted in two instances,—one, that of Norwood, who in 1635 measured mechanically the actual length of the meridional arc comprehended between London and York; and the other, that of Mason and Dixon, who about the middle of last century made a similar measurement upon the American continent, within the state of Pennsylvania. In these cases, the distance between the extreme points of the arc selected was first actually measured, and the turnings and windings of the road, with its ascents and descents, were afterwards allowed for. The result of Norwood's measurement has been found to differ but little from the length of the similar arc deduced from calculation. It has been suggested that the surface of a line of railway running in, or nearly in, the same general direction as the meridian (and the deviations of which from a straight line, as well as its gradients, or departures from uniformity of level, are all *ascertained* quantities) might more accurately serve such a purpose.

(50) For the purpose, therefore, of finding the size (and also the exact figure) of the earth, arcs of the meridian have been measured in different countries with the most extreme care, and the result of these measures shows that the length of a degree is not the same in different latitudes, but *increases*, though not quite in a regular ratio, in going from the equator towards the poles. This will be evident by inspecting the following Table,[1] which shows the length, in English miles, of a degree of the meridian as measured in different latitudes.

Country in which the measurement was made	Latitude of the middle of the arc			Length of the degree concluded
	°	′	″	
Peru	1	31	0	68·700
India . . .	9	34	43	68·718
India . . .	12	32	21	6 ·731
India . . .	13	2	54	68·734
India . . .	16	34	42	68·755
India . . .	19	34	34	68·776
India . . .	22	36	32	68·800
France and Spain .	40	0	52	68·983
France and Spain .	42	17	21	69·010
France . . .	44	41	48	69·039
France . . .	47	30	46	69·073
France . . .	49	56	29	69·102
France and England	51	15	24	69·117
England . .	51	25	18	69·119
Germany . .	52	32	17	69·132
England . .	52	50	30	69·135
England . .	54	0	56	69·149
Russia . .	57	26	26	69·187
Russia . .	59	13	58	69·206
Sweden . .	66	20	11	69·274

(51) It is, then, obvious that a meridian of the earth

[1] Derived from the 'Encyc. Brit.,' 8th Edition, Art. Figure of the Earth;—the measurements there given in feet having been converted into English miles.

cannot be exactly a circle, and consequently that the earth is not a perfect sphere. On considering what must be the shape of the meridian in order to cause this progressive increase in the length of a degree from the equator towards the poles, the only supposition which will accord with the ascertained facts is that its figure is nearly that of an *ellipse*, having the axis or polar diameter of the earth for its shorter, and the equatorial diameter for its longer, axis. The shape of the earth must therefore be nearly that of an *ellipsoid*, or *oblate spheroid*, a figure formed by the revolution of an ellipse about its shorter diameter, possessing greater curvature at the equator, and being flattened at the poles. We say *nearly*, because, since the ratio in which the degrees increase with the latitude is not exactly the same throughout, and as this discordance is greater than can fairly be attributed to errors of measurement, it seems probable that the earth does not possess any exact geometrical figure: the deviation from the elliptic form is, however, so trifling that it may be disregarded.

From the known geometrical properties of the ellipse, we are enabled to ascertain what must be the proportionate length of its diameters in order to correspond to a certain rate of variation in its curvature, and thus to fix upon the absolute lengths of the earth's diameters corresponding to any assigned length of the degree in a given latitude. The difference between the lengths of the earth's diameters at the poles and at the equator, or the amount of its *polar compression*, is differently estimated, according to the various elements which have been used in computing it; but the result which agrees best with the most satisfactory measurements is, that the excess of the equatorial over the polar diameter is $\frac{1}{299}$th, or a little more than $\frac{1}{300}$th, part of the former. The greater or equatorial diameter of the earth is equal to 7925·65, and the lesser or polar diameter, 7899·17 English miles, so that there is a difference of 26·48 miles between them. The circumference of the earth at the equator is thence deduced to be 24·899 English miles.

(52) Before, however, measurements of degrees on the earth's surface had been made with sufficient accuracy or in sufficient number to enable its figure and dimensions to be deduced from them, its depression at the poles had already been conjectured, and its amount assigned, from other considerations. One of these was the revolution of the earth on its axis, and the other the diminished weight (or gravity) of bodies at or near the equator. As the earth revolves on its axis in the space of 23 hours 56 minutes, those parts of it which are under the equator are being carried round with a velocity of more than 1000 miles per hour, while other parts move with less velocity in proportion to their distance from the equator, or their proximity towards the poles. This rotation must obviously generate a tendency in bodies on the earth to *recede* from its axis, the centre of their motion; as a stone when whirled round in a sling endeavours to fly off from the hand which moves the sling. Such a tendency of bodies to fly off or recede from the centre of their motion is called a *centrifugal* force.

If the globe were entirely covered with an ocean, this centrifugal force (being greatest at the equator, where the motion is most rapid, and diminishing towards the poles) would cause the waters near the equator to be raised considerably *above* the general level, and those portions nearer the poles to flow *towards* it, in order to attain a state of equilibrium, thus swelling out the water in that part of the globe, and diminishing it at the poles. If the motion were sufficiently rapid, it would actually *throw off* the water from its surface, in the same way that water placed on a top while spinning is thrown from its surface. Now, although the solid particles of land, owing to their cohesion, are much less influenced in this respect than fluids, still the *tendency* to assume this form is the same in either case. From the action of this force, produced by the rotation of the earth, Sir Isaac Newton deduced the elliptic form of the earth, to which he assigned an excess in the equatorial over the polar diameter of $\frac{1}{230}$th. This is more than the result obtained from the measurement of degrees, but the difference is owing to the increase of density towards the centre of the earth, whereas Newton assumed its density to be uniform.

(53) The other circumstance from which the elliptic form of the earth has been deduced, viz. the diminution of gravity at the equator, is consequent on the preceding. The centrifugal force obviously acts in a direction *contrary* to that of gravity, which tends to draw all bodies *towards* the earth, the centre of attraction to all smaller bodies near it. The centrifugal force, on the other hand, has a tendency to counteract the force of gravity; and, as the former is greatest at the equator, it follows that gravity will be most diminished there, and less in proportion towards the poles: or, in other words, that the weight of the same bodies (which is the same thing as their *downward tendency* or gravity) will be different in different latitudes, being least at the equator and greatest at the poles. The fact of its being so was first made obvious by the pendulum of a clock swinging backwards and forwards, or *oscillating*, more slowly at Cayenne, near the equator, than it did at Paris, in 48° 50′ N. lat., so that it occupied a longer time in performing the same number of vibrations at the former

than at the latter place. Now the force which causes a pendulum, when moved out of a vertical or perpendicular direction, to descend, is gravity; and if, owing to the centrifugal force, gravity be *less* near the equator than in a higher latitude, it is obvious that the pendulum will there occupy a longer time in its descent. It is thus found that the same pendulum, which, under the equator, makes 86,400 vibrations in a *mean solar day* (Art. 40), makes, when transported to London, 86,535 vibrations in the same time. Experiments of this kind have been made with the greatest care in different parts of the earth, and the results uniformly agree in showing this diminution in the force of gravity from the equator towards the poles. The different intensities of this force, calculated from the number of oscillations made by a pendulum in the same amount of time at different places, give a degree of ellipticity to the earth which nearly corresponds with that obtained from the actual measurement of degrees.

CHAPTER VII.

REPRESENTATIONS OF THE EARTH—THE ARTIFICIAL GLOBE—DEGREES OF LATITUDE AND LONGITUDE.

(54) In vain would the ingenuity of man be exerted in determining the form and magnitude of the earth, and the positions occupied by different places upon it, if he were unable to adopt some method of making these observations apparent to the senses, by displaying to view the various parts of the earth in their correct proportions and relations to one another,—to contrive something which might constitute a record to which he could refer for past information, and serve as a register for future observations. Representations of the earth in the form of a Globe, and Maps, are intended to serve such purposes.

The *artificial terrestrial globe* is obviously the most simple and natural of such representations, besides being the only one which can preserve the true relative situations and sizes of the various parts of the earth. A person who wishes to make himself thoroughly acquainted with Geography cannot, indeed, bestow too much study and attention upon a well-constructed globe. In the elementary stages of geographical tuition, its use is indispensable, nor can anything else supply the place which (under the guidance of a judicious teacher) it is capable of filling in the conceptions of the learner, in every portion of his progress. Few things, indeed, afford a more instructive theme of study, or one more fruitful of matter for reflection. Placing before the view an image of our planet *as a whole*, and freeing the mind from the more confined ideas with which we are apt to regard representations of particular localities, we may see at once the great features of nature impressed upon its surface,—its broad and spreading lands,—its lengthened chains of mountains,—its widely-extended oceans, spotted with their numberless islands, or presenting an open expanse of water which man once thought interminable,—its inland seas, lakes, and rivers;—and, in connection with these, the political limits which divide one country and tribe of men from another, and the localities of towns which human industry has everywhere called into existence. The phenomena of currents, the correspondent movements of the air, the great lines of volcanic action, and the numerous other conditions of physical geography, may be best illustrated by its aid.

(55) The Artificial Globe is a hollow sphere, the outside of which represents the surface of the earth, and on which are marked those imaginary circles traced on the earth which were described in Chapter I. Since the earth is not really a sphere, but an oblate spheroid, of which one diameter is 26 miles longer than the other, a globe does not (strictly speaking) exactly represent its form; but as the difference only amounts to $\frac{1}{300}$th part of the whole diameter,—a quantity quite imperceptible on a globe of the largest dimensions ever employed—it is of course entirely disregarded in the construction of such an instrument. In addition to the equator, the tropics, and polar circles—the parallels of latitude at intervals of 10° apart, and the meridians at similar intervals, or sometimes at 15° apart, are marked on globes of moderate dimensions. The meridians are numbered at

their intersection with the equator, from each side of that which is taken as a first meridian (which in our country is the meridian passing through Greenwich); these numbers, which respectively measure *east* or *west* longitude, extend on either side to 180°, or round half the globe. The parallels of latitude are numbered at the points where they intersect the first meridian, the reckoning commencing at the equator, and extending to each pole, or to 90°. The ecliptic, or line of the sun's apparent annual course, is also marked on globes.

(56) The poles, or extremities of the axis about which the artificial globe turns, are fixed to a circle of brass which surrounds the globe. Since, on turning the globe, every place on it passes under this circle, it serves as a *general meridian*, and is so called. Upon this meridian the degrees of latitude, divided into minutes, are also marked, commencing from that point of it which is exactly over the equator. Upon turning the globe so as to bring any place represented on it to the edge of this general meridian, its latitude is therefore seen.

(57) The frame-work of the instrument supports a broad circular band of wood, called the *Horizon*, which divides the globe, in whatever position it may be placed, into two hemispheres; it thus represents the rational horizon (Art. 16) of any place which may be placed in the zenith. Several circles are usually traced on its upper surface. The innermost of these is generally a great circle, divided into degrees, with a double reckoning, one of the reckonings starting from the east and west points of the horizon, the other from the north and south points. The former serves for amplitude: the latter for azimuth (Art. 22). To these succeed circles showing, successively, the points of the compass, the signs of the Zodiac, and the

months and days of the year. The last named of these is so graduated that each day of the year is brought against the correspondent sign and degree of the Zodiac throughout the latter. Thus the place of the sun in the Zodiac, for every day of the year (a necessary condition for working astronomical problems), is at once seen. This is also shown by the line of the ecliptic marked on the globe itself, along the upper and lower edges of which a double graduation —the one corresponding to the signs and degrees of the Zodiac, the other to the months and days—is given.

(58) The *Quadrant of Altitude* appended to globes is a thin strip of metal, attached to the general meridian by means of a nut and screw, so as to admit of its being moved in any direction, and divided into 90 degrees, corresponding to those on the general meridian. Round each pole is fixed a small brazen *Horary* or *Hour Circle*, divided into the 24 hours of the day. This is movable, so that, by turning, any hour can be brought to the line of a given meridian. At the foot of the globe is usually fixed a *Mariner's Compass*, that is, a card showing the thirty-two points of the compass, in the centre of which is a pivot bearing a magnetic needle, which turns freely upon it.

(59) The *parallels of latitude*, being circles parallel to the equator, necessarily diminish as they approach the poles, at which they vanish. The *circles of longitude*, or *meridians*, extending from pole to pole, are all equal to one another. The *degrees of latitude*, being each $\frac{1}{360}$th part of a meridian, or an arc of it intercepted between two parallels of latitude, are all of equal length (since we neglect on the artificial globe the ellipticity of the earth). The *degrees of longitude*, being each $\frac{1}{360}$th part of a parallel of latitude, or an arc of it intercepted between two meridians, are equal at the equator to the degrees of latitude, but thence continue to *diminish* in proportion

as they approach the poles, at which the meridians all meet, so that at the poles there is no longer any difference of longitude.

(60) We have mentioned the *Mariner's Compass*: the following Table exhibits the 32 points of which it consists, and also the number of degrees corresponding to each point, reckoning eastward from the north point, which is taken as unity.

Names	Degrees		Names	Degrees	
NORTH (N.) . . .	0°	0′	SOUTH (S.) . .	180°	0′
N. by E. . . .	11	15	S. by W. . . .	191	15
N. N. E. . . .	22	30	S. S. W. . . .	202	30
N. E. by N. . .	33	45	S. W. by S. . .	213	45
North-East (N.E.)	45	0	*South-West* (S.W.)	225	0
N. E. by E. . .	56	15	S. W. by W. . . .	236	15
E. N. E. . . .	67	30	W. S. W. . . .	247	30
E. by N. . . .	78	45	W. by S. . . .	258	45
EAST (E.) . . .	90	0	WEST (W.) . .	270	0
E. by S. . . .	101	15	W. by N. . . .	281	15
E. S. E. . . .	112	30	W. N. W. . . .	292	30
S. E. by E. . .	123	45	N. W. by W. . .	303	45
South-East (S.E.)	135	0	*North-West* (N.W.)	315	0
S. E. by S. . .	146	15	N. W. by N. . .	326	15
S. S. E.	157	30	N. N. W. . . .	337	30
S. by E. . . .	168	45	N. by W. . . .	348	45
SOUTH (S.) . .	180	0	NORTH (N.) . .	360	0

(61) It is not intended to specify here the various elementary questions, or *problems*, which are commonly solved by means of the artificial globe. Few of them possess sufficient practical utility to be regarded otherwise than as matters of amusement, and exact solutions of any of them can only be attained by the aid of calculation. The more popular among them may be found in most elementary books on geography. We shall, however, notice a few of the most important uses to which the globe may be put.

(62) The first of these is to determine the direct distance between one place and another. The shortest distance between any two points on a sphere is the arc of a great circle which passes through them, and, as all great circles are equal, if we measure with a pair of compasses the length of the arc between the two points by placing the extremity of one leg of the compasses on each, and then apply the arc so measured either to the equator or the general meridian, we shall see the number of degrees comprised between them. The number of degrees thus found may be converted into any itinerary measure which we desire, by multiplying it by the number of times which that measure is contained in a degree of latitude. Thus, since a degree of latitude contains 60 *geographical miles*, we must multiply the number of degrees by 60 if we wish to know the distance in geographical miles. If we are desirous of knowing the number of *English* miles between two places, we must multiply the number of degrees by 69·12, the number of English statute miles contained in a degree of latitude. The distance between London and New York, measured in this way, is 49° 30′; multiplying this by 69·12, we have 3,421 English miles as the direct distance between those places. If either of the places be brought to the general meridian, and the quadrant of altitude screwed over it, and then turned so that its graduated edge shall touch the other place, it will answer the same purpose, by showing the number of degrees intercepted between them.

If the two places be situated on the same meridian, the difference of their latitudes will of course be the number of degrees contained between them. The shortest distance between two places on the same parallel of latitude will not, however, be measured by the parallel which passes through them, for the parallels of latitude are small circles (Art. 13), and therefore do not measure the shortest distance, on account of their excess of curvature over great circles, owing to their having a shorter radius than the latter. The distance between two places not on the same meridian can, however, be found with *minute* accuracy only by regarding the arc of a great circle joining them as the side of a spherical triangle, and ascertaining its length by the aid of spherical trigonometry.

(63) To know on what point of the compass one place is situated with respect to another, we must *rectify* the globe for the latter place; that is, elevate the nearest pole as many degrees above the horizon as are equal to its latitude, and turn the globe until the place is brought under the edge of the brass meridian. The place itself will then be in the zenith, and the horizon will occupy with respect to it the position which its rational horizon occupies on the earth. If we then screw the quadrant of altitude over the zenith-point, and turn its edge so as to make it pass by any place of which the bearing is required, it will show at its intersection with the horizon on what point of the compass the latter lies with regard to the other, and also the measure of the angle which a great circle joining the two places makes with the meridian.

(64) The hour circles serve to show roughly the difference of time between any two places:—thus, suppose it be required to know the hour at Vienna when it is 12 o'clock at London, if the latter place be brought to the general or brass meridian, and the hour circle so placed that the hour of 12 is exactly under the line of the meridian, upon turning the globe until Vienna comes to the meridian, the time shown by the hour circle (at its *then* point of contact with the meridian) will be the time at Vienna corresponding to 12 o'clock at London. It is obvious, however, that

this may be ascertained more accurately by converting the difference of longitude between the places into time, allowing one hour of time for 15° of longitude, upon the principle already explained (Art. 41).

(65) It has been mentioned (Art. 59) that the degrees of longitude progressively diminish in length from the equator towards the poles; this diminution is rendered sensible to the eye by observation of the globe.

In order to find the length of a degree of longitude in different latitudes, it is requisite to know the proportion in which the diminution takes place;—on the supposition of the earth being a sphere, this is as follows: *the length of a degree of latitude is to a degree of longitude at any place as the radius of a great circle of the globe is to the cosine of the latitude of the place.* This will be evident from the diagram, fig. 8, in which let A represent the pole, and A C the radius of the earth, A *e* E, A *b* B, two quadrants of the meridian, E Q the equator, and the arc *e b* part of a parallel of latitude; joining E C, B C, these lines will be radii of the equator; and if we draw *e c*, *b c*, perpendicular to the radius A C, they will be radii of the parallel *e b*. Now the arc E B: the arc *e b*: : E C: *e c* (which is the cosine of E *e* = the latitude of *e*); but the length of a degree of the equator E B is equal to a degree of latitude, since at the equator the degrees of longitude and latitude are equal, and the length of a degree of the circle *e b* is a degree of longitude at *e*. Therefore a degree of latitude : a degree of longitude : : E C, the radius of a great circle : *e c*, the cosine of the latitude.

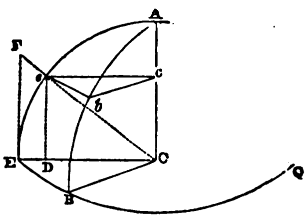


Fig. 8.

Further, since in the similar triangles C D *e*, C E F, radius C E : cosine *c e* = C D : : secant C F : radius C *e*, it follows that a degree of latitude : a degree of longitude : : secant of latitude : radius of equator.

By either of these proportions we can, with the help of the logarithmic Tables, ascertain easily the length of a degree of longitude corresponding to any parallel of latitude. Thus, suppose we wish to know how many geographical miles are equivalent to a degree of longitude under the parallel of 50°; we find by a Table of logarithms that the logarithmic cosine of 50° is 9·80807, and the logarithm of 60 (the number of geographical miles in a degree of latitude, is 1·77815: we have then the following proportion; 10 (radius) : 9·80807 : : 1·77815 : 1·58622, the whole number corresponding to which is 38·57, which is, therefore, the number of geographical miles contained in a degree of longitude under the assumed parallel. In this manner is calculated the Table given at the end of the volume (No. II.), which shows the number of geographical miles contained in a degree of longitude under every parallel of latitude, from the equator to the poles. It is obvious that the same formula will enable us to find the number of English miles, or any other itinerary measure which may be taken as an element in the proportion.

(66) If great accuracy be not required, the length of a degree of longitude corresponding to any latitude may be *measured* mechanically by dividing the line E C (fig. 8), assumed to represent the length of a degree of latitude, into 60 equal parts, and at any latitude, as *e*, at which the correspondent degree of longitude is required, letting fall a perpendicular *e c* on the radius A C : then, since the length of the required degree is proportional to *e c* (the cosine of *e*), the number of parts of E C which are contained in *e c*

will be the length required; and similarly for any other latitude.

(67) In the remarks in this chapter we have considered the earth as represented by the figure of a perfect sphere, on which the degrees of latitude are equal to one another; and, in so far as the artificial globe is concerned, no perceptible error results from doing so. In the Construction of Maps (which will be investigated in the next Chapter), the scale on which they are drawn is rarely sufficiently large to render it necessary to regard the ellipticity of the earth; but if the scale be very large, this becomes an element which should not be disregarded by the careful geographer. We have accordingly inserted a Table (No. III.), which shows the length in geographical miles of a degree of longitude, under each parallel of latitude, as computed on the supposition of the Earth's being an oblate spheroid, with a compression of the polar diameter equal to $\frac{1}{304}$th.

CHAPTER VIII.

REPRESENTATIONS OF THE EARTH (*continued*)—MAPS.

(68) Artificial globes, as they are generally made, are not sufficiently large, nor sufficiently convenient in shape, to answer the numerous purposes for which Geography requires an image of the earth and its parts; and it becomes necessary, therefore, to adopt some other mode of obtaining such a representation. This purpose is answered by *Maps*, which are representations on a plane surface either of the whole or any particular part of the surface of the globe.

Now, as it is impossible to make a *spherical* surface coincide exactly with a *flat* surface without tearing or folding over some portion of it, it is obvious that no representation of the earth on a plane can exhibit all its parts in their true magnitudes and relative positions. In the construction of maps it is therefore necessary to adopt such a method of tracing or laying down the parts which it is intended to represent as will best fulfil the particular purpose for which they may be required, and at the same time preserve as little general error as will be consistent with this object. The various methods adopted for this purpose are called *Projections*: some of these are *perspective* representations of the earth as it would appear to an eye placed in certain positions with regard to its surface; others are *developments* of portions of it, which preserve certain geometrical relations to the true figure of the parts represented, and which have more or less of error according to the method adopted. The former are chiefly used for Maps of the World, or *Hemispheres*, which exhibit the globe as divided into two portions, each embracing the half of its surface. We shall first describe the principal of these.

(69) The perspective representation of an object will be different according to the position which the eye, or *point of projection*, occupies with regard to the object, and to the *plane of projection*, or surface on which the representation is to be made. In drawing hemispheres the plane of projection always corresponds with a great circle of the sphere, over which the point of projection is supposed to be vertically situated: according to the distance at which this point is assumed to be placed, the projection may be either *Orthographic*, *Stereographic*, or *Globular*.

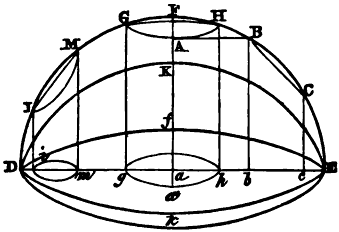
(70) I. *The Orthographic Projection.* In this projection the point of view is assumed to be at an *infinite* distance from the object, so that all lines drawn to it may be regarded as parallel. If, then, from every point on the surface of the sphere lines be drawn perpendicular to the plane of a circle passing through its centre, their points of intersection with this plane will be an orthographic representation of the globe.

The following are the principal laws of this projection:—

1st. A straight line which is either parallel or oblique to the plane of projection is projected into a straight line; if parallel, into a line equal to itself,—if oblique, into one less than itself: thus, in fig. 9, the line A B is orthographically represented on the plane D *f* E by the equal line *a b*, and the line B C by the shorter line *b c*.

2nd. The projection of a circle or semicircle perpendicular to the plane of projection will be a straight line, equal to its diameter; thus the semicircle D F E is represented by its diameter D E. Equal arcs of such a circle will also be projected into *unequal* straight lines, as the arcs B C, C E, are represented by *b c*, *c* E.

Fig. 9.



3rd. A circle parallel to the place of projection is projected into an equal circle. This will be evident by considering that as all the *diameters* of such a circle are straight lines parallel to the plane of projection, they will be projected into *equal* straight lines; and a curvilinear figure, of which all the diameters are equal, can only be a circle: thus the small circle, G A H, will be represented by the circle *g a′ h*.

4th. A circle oblique to the plane of projection will be projected into an ellipse. This is equally obvious if we reflect that one of the diameters of such a circle is a straight line parallel to the plane of projection, while that at right angles to it is oblique to this plane, so that their representations will be lines of unequal length; and a curvilinear figure of which one diameter is longer than the other is an ellipse. Thus the circle I M will be projected into the ellipsis *i m*, and the semicircle D K E into the elliptic curve D *k* E.

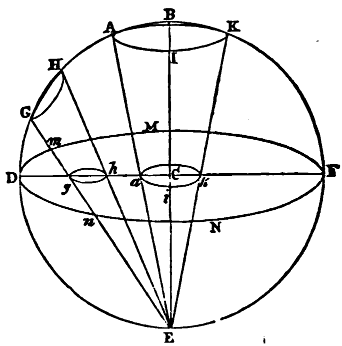
(71) From the properties of this projection, it is obvious that *equal* parts upon the surface of the sphere are not in all cases represented on the plane by parts either *equal*

or *similar*; but that they diminish progressively from the centre towards the circumference. In applying it to the construction of maps, therefore, the central parts are exhibited nearly in their true proportions, while the parts distant from the centre are greatly distorted in form and diminished in magnitude.

(72) II. *The Stereographic Projection.* The eye, or point of projection, is here supposed to be placed on the surface of the globe, and to be vertically over the centre of the plane of projection, or every way 90° distant from it. If the globe were transparent, the eye would then see the inside or concave surface of the hemisphere *opposite* to it. If straight lines were then drawn from the eye to each point of this hemisphere, their intersection with the plane of projection would be its stereographic projection.

The principal properties of this projection are as follow: 1st. Every great circle the plane of which passes through the point of projection is projected into a straight line. Thus, in fig. 10, let E D B F represent a great circle of the globe, D M F N the plane of projection, and E the position of the eye: then the circle D B F will be projected into the straight line D F. Equal arcs of such a circle will be represented by unequal distances on the projected line; thus the equal arcs, D G,

FIG. 10.



G H, H A, A B, are represented by unequal spaces on the radius D C.

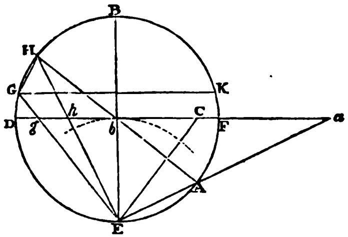
Also, every circle, great or small, any portion of which passes through the point of projection, will be projected into a straight line. Thus, the projection of part of a circle, the plane of which is coincident with the line E G, will be the line *m g n*.

2nd. The projection of a circle parallel to the plane of projection will be a circle; for if straight lines be drawn from the point E to every part of the circle A I K (fig. 10), they will form the superficies of a cone of which that circle is the base;—now the intersection of a cone by a plane parallel to its base will be a figure similar to its base, and therefore A I K will be represented by the similar circle *a i k*.

3rd. The projection of a circle which is oblique to the plane of projection will also be a circle. Thus the circle G H (fig. 10) will be projected into the circle *g h*.[1] And

[1] Let G H (fig. 11) represent the diameter of such a circle, then will E G H be the section of an oblique cone, having that circle for its base. Draw G K parallel to D F, then, because the arcs E D G and E F K are equal, the angle E H G is equal to the angle E G K; or, since G K is parallel to D F, the angle E H G is equal to the angle E *g h*. Now the intersection of an oblique cone by a plane at an angle equal to its base will be a figure similar to that base, and since G H is the diameter of a circle, *g h* will be the diameter of a circle also.

FIG. 11.



For the second part of the proposition, the line *g h* is the projected diameter of the circle G H: now the line *b g* is the tangent of the

the projected diameter of such a circle, situated wholly on one side of the pole of projection, will be equal to the difference of the semi-tangents of that circle's greatest and least distance from the said pole.

4th. The projection of an arc of a great circle passing through the point of projection will be a straight line equal to the tangent of half that arc.[1]

5th. The distance of the centre of the projection of any oblique great circle from the centre of the plane of projection is equal to the tangent of the angle at which the circle is inclined to the plane of projection; and its radius is equal to the secant of the same angle.[2] Also, the distances of the projected extremities of the diameter of any

angle G E B, or the semi-tangent of G B, the *greatest* distance of the circle G H from the pole of projection B; and the line *b h* is the tangent of H E B, or the semi-tangent of H B, the *least* distance of the same circle from the pole of projection B. The line *g h* is the difference between the two semi-tangents.

[1] Thus, in fig. 11, *h b* is the projection of the arc H B; but *h b* is the tangent of the angle *h* E *b*, or H E B, which (Euclid, Bk. III. Pr. 20) is equal to half the angle H *b* B, the measure of the arc H B.

[2] In fig. 11, let H A represent the diameter of a circle inclined to the plane of projection D F. The projection of the points H and A will be *h* and *a*, so that *h a* will be the projected diameter: bisect this in C, which will then be the centre, and C E the radius, of the projected circle. Now it is shown (*Keith's Trigon.* Bk. III. Chap. ii. Pr. 1 & 2) that the angle C E *b* is equal to the angle H *b* D, the inclination of the circle to the plane of projection, and it is obvious that C *b*, the distance of the centre of the projected circle from the centre of the plane of projection, is the tangent of this angle, and C E, the radius of the projected circle, its secant.

For the second part of the proposition: *h b*, the distance of the point *h* from the centre of the plane of projection, is the tangent of H E B, or semi-tangent of H B, the least distance of H A from the pole B; and *b a* is the tangent of B E A, or semi-tangent of B A, the greatest distance of H A from the pole.

circle inclined to the plane of projection, from the centre of that plane, are equal to the semi-tangents of the circle's least and greatest distances from the pole of projection.

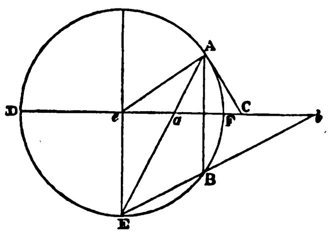
6th. Small circles perpendicular to the plane of projection will be projected into circles, the distance of the centres of which from the centre of the plane of projection will be equal to the secants of their distances from their own pole, and the radii of which will be equal to the tangents of those distances.[1]

7th. The angles made by circles intersecting each other on the plane of projection are always equal to the angles made by the circles on the surface of the sphere which they respectively represent.

(73) From the foregoing properties, it results that, although the Stereographic Projection does not give equal representations of equal arcs of the great circles which are perpendicular to the plane of projection, yet it represents

[1] The first part of this proposition is evident on reflecting that lines drawn to such circles form oblique cones, intersected by a plane at an angle equal to the obliquity of the base, and therefore projected into circles: for the remaining parts, it will be seen by fig. 12, that if A B represent the diameter of a circle perpendicular to the plane of projection D F, the line *a b* will be its projection, the half of this (C *a*) its radius, and C *e* the distance of the centre of the projected circle from the centre of the plane of projection. Now it may be shown that C A *e* is a right angle (*Keith's Trigon.* Bk. III. Chap. ii. Pr. 4), and therefore C A (= C *a*) is the tangent of the arc A F, the distance of A B from its pole F, and C *e* is the secant of the same arc.

FIG. 12.



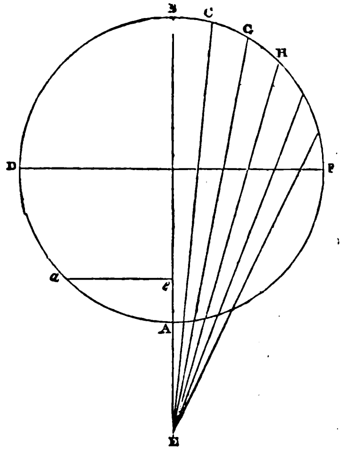
all parts of the sphere by figures *similar* to those on the surface of the sphere itself. The spaces in it diminish from the circumference towards the centre, in the contrary direction to those in the orthographic projection: so that in maps constructed on it the central parts are unduly contracted in proportion to the extremities.

(74) In the two preceding projections we have seen that equal arcs of a circle perpendicular to the plane of projection are projected into unequal spaces; so that if such a circle represent the equator, arcs of it which are either ten or any other assumed number of degrees apart will not be equal to one another on the projection: we see also that the direction of their increase or diminution differs according as the point of projection is assumed to be at an infinite distance, or on the surface of the sphere. Hence it is obvious that by placing the point of projection at an *intermediate* distance, we may expect to diminish this inequality, so as to obtain on the diameter of the plane of projection an equal, or nearly equal, representation of equal arcs of the great circle which it represents: this is effected by the projection about to be described.

(75) III. *The Globular (or Equi-distant) Projection.* The point of view is here assumed to be vertically over the centre of the plane of projection, and at a distance from the surface of the sphere equal to the sine of 45° of one of its great circles: if straight lines be then drawn from the point of view to the interior surface of the opposite hemisphere, their intersection with the plane of projection will be a perspective representation of it.

In this projection, as in the preceding, great circles perpendicular to the central plane are projected into straight lines; but it is to be observed that the inequality of the spaces representing equal arcs of such circles is here very considerably diminished.

Fig. 13.



In fig. 13, if we produce the diameter B A to E, so that A E is equal to *a e*, the sine of 45°, and then, dividing either of the opposite quadrants, as B F, into any number of equal parts, as B C, C G, &c., draw lines from E to each of these divisions, we find that the spaces intercepted between them on D F are very nearly equal; the difference between them is in fact scarcely perceptible when the projection is made on a small scale.

Circles parallel to the plane of projection are also, in this case, as in the two former instances, represented by circles; but all circles not belonging to either of the above classes are projected into ellipses, since, when lines are drawn to them from the point of view, they form the bases of oblique cones which are intersected by a plane at angles *unequal* to those of the base, and the section is therefore a dissimilar figure. As the degree of ellipticity in the applications usually made of this kind of projection is very trifling, it is generally disregarded, and all circles on the sphere, excepting great circles perpendicular to the plane of projection, are represented by circles: a map thus constructed ceases, however, to be a true perspective representation of the globe.

Finally, the angles made by circles intersecting each other on a globular projection are not equal to the angles made by the circles on the globe which they represent.

It hence appears, that as equal arcs of the great circles perpendicular to the plane of projection are projected into parts of a straight line which are nearly equal to one another, the equality of size in the spaces intercepted between similar parallels and meridians is better preserved in the case of the so-called 'globular' than in either of the preceding projections, and the *relative dimensions* of the objects delineated more nearly correspond to those on the globe. It is from this property that the term equidistant is sometimes bestowed upon the present projection. But as the rectangular intersections of the meridians and parallels, instead of being preserved on the projection, are represented by angles differing more from right angles as they approach the circumference of the map, it does not exhibit figures *similar* to those on the globe, and therefore *distorts the shape* of the countries represented. In this important particular the globular projection is inferior to the stereographic, though its greater facility of construction causes it (or, rather, a modification of it) to be of much more frequent usage than the latter.

(76) Each of these projections may be variously applied, according to that circle of the sphere which is taken as the plane of projection. In the next Chapter we shall describe the different modes of using them.

(77) *Gnomonic Projection.* In the methods of projection above described, the eye, or point of projection, is in each case supposed to occupy a position *exterior* to the sphere, and the plan of projection is made to coincide with a great circle of the globe. But there is a fourth and wholly different

kind of projection—termed the *gnomonic*—which, though rarely used for geographical purposes, is employed with advantage in drawing maps to represent the aspect of the heavens.

The gnomonic projection supposes the eye to occupy the *centre* of the sphere, and the sphere itself to be enclosed within a circumscribing cube, upon the six equal faces (or planes) of which the projection is supposed to be made. If straight lines be drawn from the eye to every point upon the surface of the sphere, and prolonged until they meet the planes of the circumscribing cube, the points at which they meet those planes will be the projections of the correspondent points on the sphere.

In this projection the whole sphere is represented on six equal planes—each embracing a sixth part of the entire spherical surface. A great circle is represented by a straight line on the projection. Small circles are variously represented, according as they are parallel or oblique in their position with regard to the plane of projection. If parallel, they are represented by similar figures, or circles: if oblique, their projection becomes either an ellipse, a parabola, or an hyperbola, according as they are variously placed with reference to the centre and the plane of projection.

The advantage in the use of the gnomonic projection in the construction of maps of the heavens consists in the fact that a straight line joining any two stars (within the limits of either one of the projected planes) represents the apparent shortest distance between them, so that *all the stars which appear on the same line in the heavens are found on the same line in the map.* And, as each map contains a sixth part of the entire sphere, the most important groups generally fall within the limits of the same map. In the case of every such group, therefore, the exact figure which is marked out by the stars themselves in the sky is preserved in the map.[1]

[1] See for further details on this projection, 'An Explanation of the Gnomonic Projection of the Sphere,' by A. de Morgan. London, 1836. The 'Maps of the Stars,' included within the Atlas originally published under the superintendence of the Society for the Diffusion of Useful Knowledge, are drawn on this projection. The same series of maps includes also a gnomonic projection of the terrestrial sphere.

CHAPTER IX.

DIFFERENT CONSTRUCTIONS OF MAPS OF THE WORLD.

(78) Maps of the world, or planispheres, are drawn to exhibit the globe in the positions either of a right, a parallel, or an oblique, sphere (Art. 28): in the first of these cases the projection is made on the plane of a meridian, in the second on that of the equator, and in the third on the plane of a great circle which forms the horizon of any place (London, for example,) which we may wish to exhibit in certain relations to other parts of the globe.

(79) The orthographic projection may accordingly be made on either of these planes; but although of considerable use for astronomical purposes, as in the construction of the Analemma (a projection showing the time of sunrise and sunset, the duration of twilight, &c., at any place, for every day in the year), the distortion which it produces towards its exterior parts in the images and dimensions of objects delineated is so great that it is scarcely ever applied to geographical maps. We shall accordingly confine ourselves to a brief explanation of the mode of employing this projection, on the Plane of a Meridian, or of the Equator. An example of each of these is shown in figs. 1 and 2 (Plate I.), to which the two following paragraphs refer. The references to the preceding propositions exhibit the principles on which the methods of drawing them depend.

(80) *To project the Sphere orthographically on the Plane of a Meridian.* Describe a circle N E S Q (of any size which it may be desired to construct the map) to represent a meridian, and draw two diameters, N C S, E C Q, at right angles to each other; E C Q will then be the projection of the equator, and N C S that of a meridian (termed the *axis meridian*) 90° degrees distant from the meridian N E S Q (Art. 70, pr. 2). Divide each quadrant of the circle N E S Q into nine equal parts, each of which divisions will represent 10° of a great circle, which should be numbered from the equator towards the poles, 10, 20, 30, &c.: straight lines drawn between the corresponding numbers on each side of the equator will then represent the *parallels of latitude*, drawn to every tenth degree (Art. 70, pr. 2). The tropics will be represented by straight lines drawn between corresponding arcs of the quadrant at the respective distances of 23½° north and south of the equator, and the arctic and antarctic circles by similar lines between arcs 23½° from either pole. If perpendiculars be drawn from the divisions of either quadrant to the equator E Q, as 10 *a*, 20 *b*, &c., the points *a*, *b*, in which they meet it, will be the points through which the meridians must pass. Then ellipses described through N *a* S, N *b* S, &c., with N S as a common tranverse axis, and C *a*, C *b*, &c., as half their conjugate axis, will be the projection of *meridians* at every tenth degree from that chosen as the plane of projection (Art. 70, pr. 4). Any of these being assumed as a first meridian, and the others numbered 10, 20, &c., east and west of it, along the equator, the countries may be delineated on the map according to the respective latitudes and longitudes of the places which they contain.

(81) *To project the Sphere orthographically on the Plane of the Equator.* Fig. 2, Plate I., represents this projection,

which is thus constructed:—About any point, C, as a centre, with a radius C A, of any required length, describe the circle A B E D, to represent the equator, and draw diameters A C E, B C D, at right angles to each other; the point C will be the projection of the pole, and A C E, B C D, the projections of meridians at 90° apart. Divide each quadrant into nine equal parts, each of which, will, as before, contain 10° of a great circle; then the points in which perpendiculars, as 80 *a*, 70 *b*, &c., drawn from these divisions on either quadrant to one of the radii, as A C, meet that radius, will be the points through which the *parallels of latitude* must pass. The points in which similar lines drawn from arcs respectively distant $23\frac{1}{2}°$ from D towards A, and from A towards D, intersect the radius C A, will be the points through which circles representing one of the polar circles and one of the tropics should be drawn. Circles drawn from the common centre C, and with the radii C *a*, C *b*, &c., will therefore be the projections of the parallels, drawn to every tenth degree (Art. 70, pr. 3). Diameters of the circle A B E D, drawn through the centre C and the opposite divisions of each quadrant, as from 10 to 170, from 20 to 160, &c., will be the projections of the *meridians* at 10° apart (Art 70, pr. 2). These must be numbered 10, 20, &c. round the equator to 180° on each side of that assumed as a first meridian, and upon which the parallels should be similarly numbered from the equator towards the pole. The projection is then complete.

(82) By inspecting these two projections, the inequality in the representation of similar spaces on the globe, which has already been noticed (Art. 71), will be at once apparent. It is obvious that no scale of measurement can be applied to such maps.

The orthographic projection may likewise be made on the plane of the horizon of any place; its construction, however, presents some technical difficulties, in consequence of the lines being all ellipses, and it is besides of little geographical use.

(83) *To project the Sphere stereographically on the Plane of a Meridian.* Describe a circle N E S Q (fig. 3, Plate I.), to represent any meridian, and draw two diameters, N C S, E C Q, perpendicular to each other; N will then represent the north, S the south, pole; E C Q will be the projection of the equator, and N C S that of a meridian of which the plane passes through the projecting point, and which is 90° distant from the plane of projection (Art. 72, pr. 1). Divide each quadrant of the circle N E S Q into nine equal parts, and number them 10, 20, &c., from the equator towards the poles; also mark divisions at $23\frac{1}{2}°$ north and south of the equator, and at the same distances from the north and south poles, for the tropics and polar circles.

Since the parallels of latitude are small circles of the sphere perpendicular to the plane of projection, they will be represented by circles drawn between correspondent divisions of the semicircles north and south of the equator (Art. 72, pr. 6). The points in which they will pass through N C S, the axis meridian, will be found by drawing straight lines from E to the divisions of the opposite quadrant north of the equator: the intersections of these lines with N C, as *a b c*, &c., will be the points required.[1] They may be found in a similar manner for those south of the equator, or

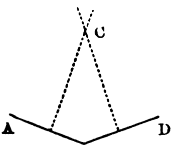
[1] Since the spaces intercepted on the axis meridian and equator between the parallels and meridians, being arcs of great circles which pass through the point of projection, are represented on the plane by the tangents of half their arcs (Art. 72, pr. 4), the points in which they will intersect these lines may be found by setting off from the point C

transferred to C S from those already obtained. Circles described through 10 *a* 10, 20 *b* 20, &c., will then represent the *parallels of latitude* for every tenth degree, and those through the points 23½° and 66½° north and south of the equator, the tropics and polar circles. The centres of these circles will all be in the prolongation of the line N S, and may be found by the well-known rule for describing a circle through any three points.[1]

spaces equal to those tangents. Thus, N *x*, the tangent of 5°, set off from C towards N, E, S, Q, will give the points through which the parallels and meridians 10° distant from the equator and axis meridian will respectively pass;—the tangent of 10° those for 20°, and so on for the rest. The division of the diameters N S, E Q, may thus be made without the aid of lines drawn from E and S to the divisions of the opposite quadrant: in the projection next described (Art. 84), the diameter may be divided in the same way. It will be requisite, however, to use great care in setting off the tangents correctly from the point C, and the method of finding the required points by means of intersecting lines, as given in the text, will no doubt be preferred.

[1] To describe a circle through three given points, as A B D (fig. 14), join A B and B D by straight lines, bisect these lines and at each of the bisecting points erect a perpendicular. The point C in which these perpendiculars intersect one another, will be the required centre.

FIG. 14.



Since, in the projection exemplified above, the distances of the centres of the parallels from C are equal to the secants of their distances from the pole (Art. 72, pr. 6), they may be determined by drawing lines from C through each division of one of the quadrants, as N Q, to the line N E′ perpendicular to N S, which will thus become a line of tangents, and the lines drawn from C to N E′ will be the secants of those distances: thus C *y* will be the secant of 10° (the distance of the parallel of 80° from the pole), C *z* of 20° (the polar distance of 70°), &c. These secants being then transferred by arcs, of which C is the centre, to the prolongation of the diameter N S, will give the centres required.

Or, if we divide one of the radii of the primitive circle N E S Q into

The meridians will be represented by circles drawn from N to S (Art. 72, pr. 3). The points in which they intersect the equator will be found by lines drawn from N or S to the divisions 10, 20, &c., of one of the opposite quadrants, as N E; then circles described through the three points N 10 S, N 0 S, &c., will be the projections of the *meridians* passing through every tenth degree.[1] These should be numbered along the equator, 10, 20, &c., on either side (if necessary) of that chosen as a first meridian, and the projection is then complete. If the meridian which forms the plane of projection be assumed as 20° west from London, the map will embrace nearly the whole of the old world or eastern hemisphere, and the correspondent projection the new world or western hemisphere.

90 equal parts, the value of the distance of the centres in these parts may be found by the aid of the Trigonometrical Tables. Thus, if we take the parallel of 60°, for example, we have the following proportion; radius : 90 : : secant of 30° (the distance of the parallel of 60° from the pole): the required distance; or, taking the logarithms of these quantities, 10·00000 : 1·95424 : : 10·06247 : 2·01671 = 103·9 of those parts of which the radius contains 90. This distance, set off from C, will be the centre of the parallel of 60°; and the centres of the others may be found in a similar manner. Although the student will probably prefer describing the parallels through the three given points by the rule given above, these instances will be of service in illustrating the principles on which the projection depends.

[1] The centres of the meridians will, of course, be in the line E Q, or its prolongation. Since their distances from the centre C of the primitive circle are equal to the tangents, and their radii to the secants, of their inclination to that circle (Art. 72, pr. 5), these distances may be measured on a line of tangents (as described in note 1, p. 84) and set off on the equator: thus N *y*, the tangent of 10°, set off from C towards Q, would give the centre of the circle N 10 S, which is inclined 10° to the plane of the primitive meridian N E S Q, and C *y*, the secant of 10°, would be equal to the radius of the same circle. Or these distances may be found by the Trigonometrical Tables, in the way illustrated in the preceding note.

(84) *To project the Sphere stereographically on the Plane of the Equator.* About the point C describe a circle, A B E D (fig. 4, Plate I.), to represent the equator, and draw diameters A C E, B C D, perpendicular to each other: C will represent the pole, and A C E, B C D, meridians 90° distant from one another. Divide each quadrant into nine equal parts, each of which will be 10° apart, and lay off arcs of $23\frac{1}{2}$° and $66\frac{1}{2}$° from A towards B. From the divisions of the quadrant A B, draw straight lines to the point E, intersecting the radius B C in the points 10, 20, 30, &c.; then, with C as a centre, describe circles passing through these points. These circles will be the projections of the *parallels of latitude* for every ten degrees, and of one of the tropics and polar circles. Straight lines drawn through the centre C, between the opposite divisions of each quadrant, will represent the *meridians* passing through every tenth degree of the equator. The parallels should be numbered 10, 20, &c., from the equator towards the pole, and the meridians from 0° to 180° on each side of that assumed as a first meridian.

(85) We have dwelt at some length on the two preceding projections, because the properties which they possess seem to us to give them considerable superiority over all the other projections employed for the construction of Planispheres, and to make it a matter of regret that they are so rarely used in drawing Maps of the World. As the meridians and parallels all intersect one another at *right angles*, like the intersections of the same lines on the sphere (Art. 72, pr. 7), diagonal lines measured across any one of the spaces contained between them in any part of the map are always *equal*, and therefore a similarity in shape to the objects on the surface of the globe is preserved in them; so that they do *not distort* the figures of the countries, &c., which are

represented. This is a property which more than balances the advantage possessed over them by the Equidistant or so-called Globular Projection in the more equal representation throughout of spaces of equal dimensions. For the erroneous impressions resulting to students from the undue increase from the centre towards the circumference may be in a great measure corrected by using *both* the projections described,—that on the plane of a meridian, and that on the equator,—since the enlargement in the one affects the opposite regions to that which it does in the other, the errors thus counterbalancing one another; while nothing can compensate for the distortions occasioned in the globular projection. The diameters of a map stereographically projected which represent either the equator or a meridian, by being graduated according to the proper ratio of increase from the centre outwards, constitute a scale which may be employed to measure distances either *along those lines*, or in any direction from the centre towards the circumference. We shall see an interesting application of this principle in the projection next to be described.[1]

(86) *To project the Sphere stereographically on the Plane of the Horizon of London.* In this case, London will occupy the position of the zenith, and the eye, or point of projection, that of the nadir. Assume any point, C, for the situation of London, and describe about it, with any required radius, the circle W N E S (fig. 5, Pl. I.): draw the

[1] The difficulty experienced in the stereographic projection in finding the exact latitudes and longitudes of places, owing to the unequal extent of the spaces, would be considerably diminished by graduating several of the meridians and parallels to every fifth, or, if the map be on a sufficiently large scale, to every second or even to each degree. This might be done without creating confusion, or in any way impairing the utility of the map.

diameter N S at right angles to a line joining W E: the line N S will be the projection of the meridian passing through London, and N, S, W, E, will be the north, south, east, and west points of the horizon with respect to that place.

Since the elevation of the pole above the horizon is equal to the latitude of the place (Art. 38), set off from N towards E the arc N P′$=51\frac{1}{2}°$ (the latitude of London), and a similar arc, E Q′, from E towards S; the arc P′ Q′ will then be equal to a quadrant of the primitive circle W N E S: then draw straight lines from W to P′ and Q′, and the intersections, P, Q, of these lines with N S will be the projections of the north pole, P, and of the point, Q, in which the equator passes through the meridian of London. Divide a quadrant of the circle W N E S into nine equal parts, each of which will contain 10°, and mark off on *each side* of P′, towards W and S, as many of these divisions as there are parallels at 10° apart between the north pole and the south point of the horizon, which in the present case is twelve, as *a a′*, *b b′*, &c.: then draw lines from W to each of these divisions, and the intersections of these lines with the diameter N S, or its prolongation, will give the diameters of the equator, and of the parallels of latitude respectively distant 10°, 20°, &c. from the pole: thus the distance between 80, 80, on each side of P, will be the diameter of the parallel of 80°, from 70 to 70 that of the parallel of 70°, and so on for the rest. The centres of the equator and parallels will be found by bisecting their diameters, and circles described from these centres through the points 80, 80,—70, 70, &c., will represent the equator and the *parallels of latitude* for every tenth degree. In the same way, if arcs of $23\frac{1}{2}°$ be set off on each side of Q′, or of $66\frac{1}{2}°$ and $113\frac{1}{2}°$ from P′ towards W, for the tropics, and arcs of $23\frac{1}{2}°$ on each side of

P′ for the arctic circle, and lines drawn to them from W, the intersections of these lines with N S will mark the diameters of those circles, which may of course be described from a point bisecting their diameters. In order to avoid confusion, they are not marked on the diagram (fig. 5) which exhibits the construction, but are shown on the correspondent fig. 6.[1]

To draw the Meridians. Since one pole of the globe is always as much depressed below the horizon as the other is elevated above it, if from P′ we draw through C the diameter P′ *p′*, and then draw a straight line from W through *p′* to meet the prolongation of N S in *p*, the point *p* will be the projection of the south pole: the projections of all the meridians will therefore pass through the points P *p*, the north and south poles. Bisect the line P *p* in F, and from F as a centre, describe with the radius F P the circle D P G *p*, passing through W and E, the east and west points of the circle W N E S, and representing a meridian 90° distant from the meridian N S. If on the circle D P G *p* we then project stereographically the meridians for every tenth degree, as previously described (Art. 83), and, in drawing them, continue them *beyond* the point P until they meet the semicircle W N E, they will represent on the circle W N E S the meridians drawn through every tenth degree of longitude; their

[1] The diameter, in the case of each circle, will be equal to the difference of the semi-tangents of that circle's greatest and least distance from the pole of projection (Art. 72, pr. 3): and the distances of the extremities of the diameter from the centre of the plane of projection will be equal to those semi-tangents (pr. 5). The required points through which to draw the parallels, on the prolongation of the line N S, may of course be thus obtained geometrically, though the method of construction shown on the diagram will probably be more generally followed.

centres will be in the line D G or its prolongation. Thus the meridian *p* 1 P must be continued until it meets the semicircle W N E in 1′, *p* 2 P to 2′, and so on for the others. The projection will then be complete.

It is almost needless to say that the lines of construction, which are shown in our diagram by dotted lines, should in all cases be drawn only in pencil, so that they may be erased when the projection is complete. As the great number required in that now under consideration renders them likely to confuse the student, we have added another figure, No. 6, which exhibits this projection in its perfect state. The parallels of latitude should be numbered 10, 20, &c. on the central meridian, from the equator towards the poles, and the meridians 10, 20, &c. on each side of the same meridian round half the circumference of the circle, or to 180°:—the one half measuring east, the other west, longitude.

(87) *To project the Sphere stereographically upon the horizon of any place.* The principles applied in the above example, that of London, are of course applicable to any other spot upon the surface of the earth, regarded as in the position of an oblique sphere. In the case of London, all the circles of latitude requiring to be represented lie either in part or altogether upon one side of the pole of projection, and their centres hence fall throughout in the same direction from the centre of the plane of projection—i. e. on the same side (or to the northward) of the point C. This, however, will not always be the case, as the following example will show.

Suppose the place selected to be *in the latitude of* 30° *north.* In this case (fig. 5, pl. IV.), the place of the pole P on the line N S will be found by setting off 30° on the primitive circle, from N towards E, and drawing a straight line from W to the extremity of this arc, the intersection of this line with N S being the required point. Similarly, a line drawn from W to the extremity of an arc of 30° set off from E towards S will give the place of the equator. Divisions of a quadrant of the primitive circle, each equal to 10°, must then be set off upon either side of the point P, as many of them being required as there are parallels at 10° apart comprehended between the north pole and the south point of the horizon—i. e. in the present case, fourteen. These, as in the preceding case, should be distinguished by corresponding letters on either side of the pole, and the points of intersection with N S, by lines drawn to them from the point W, should also be similarly numbered upon the line N S, as 80, 80; 70, 70, &c., upon either side of the point P, the place of the projected pole.

To find the projected diameters of the successive circles of latitude, proceed as in the preceding example as far as the parallel of 20° south latitude, up to which their centres will all be found to lie upon the same side of the centre C of the primitive circle (and, of course, at continually increasing distances from it). The parallel next succeeding—that of 30°—passes through the point of projection, W, and will be represented by a straight line. The centres of the two remaining parallels (those of 40° and 50°) will be found to lie in the prolongation of the line N S, but in the *opposite* direction to that in which the centres of the parallels comprehended between 30° south and the pole were found—i.e. they are to the *south* of the central point C of the primitive circle. The diameters of these two circles (and, of course, by bisection, their respective centres) are obtained by a process similar to that previously employed, but directed towards the opposite prolongation of the line N S, or by drawing lines from W through the points corresponding to 40° and 50° on the primitive circle until they meet that line.[1]

The meridians will be obtained in a similar manner to that shown in the previous example.

(88) The most interesting property of this projection is its enabling us, by means of a scale graduated according to

[1] Neither this nor any other example that may be selected will offer any difficulty to the student who examines with care the principles involved in the stereographic projection. In this particular case of 30° latitude as the centre of the plane of projection, the parallels comprehended between the pole and the latitude of 40° N. lie wholly upon one side of the *pole of projection* E, and their projected diameters (Art. 72, pr. 3), will be the differences of the semi-tangents of their greatest and least distances from that pole. Thus, the projected diameter 80, 80, is the difference between the semi-tangent of 50° (the *least* distance of the parallel of 80° from the pole of projection E) and the semi-tangent of 70° (the greatest distance of the same parallel from E). Similarly, the diameter 40, 40, is the difference between the semi-tangents of 10° and 110°, respectively the least and greatest distances of the parallel of 40° from the pole of projection. The six parallels next ensuing (those of 30° N., 20° N., 10° N, 0°, 10° S., and 20° S.), are also inclined to the plane of projection, and partly upon one side of the pole of projection. The distances of the projected extremities of their diameters from the centre C (Art. 72, pr. 5) are the semi-tangents of their least and greatest distances from the pole of projection. Thus the distance from C to the point 10° (S. latitude, is the semi-tangent of 40°, the least distance of the parallel of 10° S. from the pole of projection E, on the primitive circle; and the distance from C to 10′, the opposite extremity of the diameter, is the semi-tangent of 160° (i.e. the tangent of 80°) the greatest distance of the same circle from E.

That the parallel of 30° is represented by a straight line is evident from pr. 1, Art. 72; since the farthest distance of that parallel from the point E is 180°, and a portion of it hence passes through the eye, or point of projection. The remaining circles, 40° and 50° S., lie oblique to the plane of projection, but wholly on the opposite side of its pole P, and their projected diameters are hence entirely to the southward of C.

the central meridian of the map, to measure the direct distance from its centre to any place contained in the hemisphere represented. By marking the thirty-two points of the compass round the outer circumference of the map, as in fig. 6, Pl. I., we may also see on what point of the compass any place is situated with regard to that which occupies the centre. Thus, by making London the centre, and describing round it circles, at any assumed distance (as 500 miles) apart, and graduated according to the ratio of increase from the centre outwards, we may at once ascertain the direct distance and bearing of any part of the world from that city. So that, whatever place be taken as the centre, the stereographic projection on the plane of its horizon exhibits all parts of the surrounding hemisphere in the relations which they really bear to that place.

(89) *Equidistant, or Globular Projection of the Sphere.* It has been observed (Art. 75) that in this projection the diameters of the primitive circle which represent great circles of the sphere become divided into nearly equal parts, and that all other circles, excepting those parallel to the plane of projection, are represented by ellipses. These properties are, however, very rarely preserved by those who are in the habit of constructing maps, and as the increased trouble occasioned by the latter of them is not compensated by any advantage which the globular projection is capable of affording, we shall content ourselves with a brief description of the modifications of it which are commonly employed.

The following is the method used in forming a globular projection when the map is to be drawn *on the plane of a Meridian.* Describe a circle N E S Q to represent a meridian (fig. 7, Pl. I.), and draw two diameters N C S, E C Q, perpendicular to each other: N and S will then represent the north and south poles, N C S a meridian 90° distant from the plane of projection, and E C Q the equator. Divide each quadrant of the circle N E Q S into nine equal parts, numbering them 10, 20, &c. from the equator towards either pole, and each of the radii C E, C N, C Q, C S, also into the same number of equal parts, as *a*, *b*, *c*, &c. on the equator, and *x*, *y*, *z*, &c. on the central meridian. Then, *to represent the Parallels of Latitude*, draw circles through the points *x*, *y*, *z*, &c. from correspondent divisions on each side of the central meridian, as 80 *x* 80, 70 *y* 70, which will represent the parallels of 80° and 70°, and so on for the others: their centres will all be in the prolongation of the line N S. The tropics and polar circles may be drawn by setting off arcs at 23½° from the equator and the poles, and marking off a correspondent distance on the central meridian. *To draw the Meridians*: describe circles passing through the three points N *a* S, N *b* S, N *c* S, &c., the centres of which will all be found in the line E Q or its prolongation; these circles will represent the meridians at 10° apart, and should be numbered on the equator from each side of that chosen as a first meridian.

(90) To draw a similar map *on the plane of the Equator*,—describe a circle A B E D (fig. 8, Pl. I.) to represent the equator, and draw the diameters A C E, B C D, perpendicular to each other: divide each of the quadrants, and one of the radii, as A C, into nine equal parts. To *represent the parallels*, about C as a centre describe circles passing through each division of the radius A C. Straight lines drawn between the opposite divisions of the quadrants, and passing through the centre C, will represent the *meridians*. The parallels should be numbered 10, 20, &c., from the equator, towards the pole, and the meridians 10, 20, &c.

to 180° on each side of that assumed as a first meridian.

(91) The two methods last described (particularly the former) are those commonly employed in the construction of Maps of the World, although it would be difficult to find any other reason for the preference shown to them than the facility with which they may be executed by the numerous class of map-makers who never take the trouble to inquire into the *principles* on which the projection of maps depends. In that on the plane of a meridian, there is thoughout an inequality in the diagonals measured across the space intercepted between any two meridians and parallels, owing to their deviation from right angles at their intersection. This inequality becomes very considerable towards the borders of the map, so that the distortion in the figures of objects delineated on it, which prevails to some extent throughout, is there very great, as is at once apparent by comparing a map thus constructed either with the globe, or with one drawn on the stereographic projection. Thus, if (as is usually the case) the plane of projection be assumed as 20° west of the meridian of Greenwich, the British Isles and the western parts of Europe will become considerably *elongated* beyond their true proportions in the direction of N. E. and S. W., and as greatly *contracted* in the opposite direction. Nor is the evil remedied by using a similar construction on the plane of the equator, for in this the degrees of *longitude*, for more than 15° distance on each side of the equator, are made greater than the degrees of *latitude*, so that the breadth of South America becomes nearly half as much more in it than in the projection formed on the plane of a meridian. Nor is any scale capable of being applied to either of these constructions, excepting on the diameters, or from the centre towards the

circumference, properties which may also be attained by a properly graduated scale on the stereographic projection, which thus appears to possess a decided superiority over all the others described.[1]

(92) The globular projection may be applied to the construction of a map on the horizon of any place, in which case the parallels and meridians become ellipses, those representing the former being considerably elongated in an east and west direction. It does not, however, possess any features which render it desirable to describe its construction in detail.

(93) An ingenious and novel application of the laws of geometrical projection, as applied to planispheres, has recently been made by Col. Sir Henry James, superintendent of the Ordnance Survey of Great Britain. In Sir Henry James's projection, above two-thirds of the surface of the sphere are brought within the circumference of the circle limiting the plane of projection. The eye, or point of projection, is assumed to be in the axis of a great circle of the sphere, and at a distance above its surface (upon the side opposite to that which is to be represented) equal to half the radius. The plane of projection is made to coincide with a circle removed 23° 30′ from the assumed great circle, *towards* the point of projection. Lines are then supposed to be drawn from the point of projection to every point on the opposite hemisphere, and *also to every point*

[1] It may, nevertheless, be admitted that the great facility with which the globular projection on the plane of a meridian is formed renders its construction a not undesirable exercise for beginners in *map-drawing*, and the use of maps drawn on this projection may be advantageously employed in the more elementary stages of the subject. But the stereographic projection will always be preferred by those who are sufficiently advanced to understand principles, and to inquire into comparative merits.

falling within the additional space of 23° 30′ (included between the assumed primary great circle and the plane of projection); the intersection of such lines with the plane of projection giving, of course, the representation of the spherical surface *in plano*. The projection hence embraces 227° (i. e. 180° + 47°) of a great circle, and consequently $\frac{7}{10}$ths, or rather more than $\frac{2}{3}$rds, of the surface of the sphere.

The assumed point of projection, in this case, is somewhat nearer to the surface of the sphere than in the theoretical 'globular' or 'equidistant' projection, to which it bears most analogy in principle. In this latter, a distance equal to the sine of 45° is taken for the point of projection (see fig. 13, p. 77), which is reduced in Sir H. James's map to a distance equal to half the radius. The most important and novel feature of the projection lies in the inclusion of a belt of 23½°, in addition to the entire opposite hemisphere, within the space represented on the plane of projection. If, in fig. 13, p. 77, we suppose the plane of projection to be represented by a line drawn parallel to D F, and 23½° distant from it towards E, the principle upon which Sir H. James's map is projected will be made sufficiently clear (allowance being of course made for the greater proximity of the point E to the surface of the sphere).

The laws of the globular projection, as respects the representation of the circles of the sphere, apply equally to this map. In the application made of it by Sir H. James, the point of projection is supposed to lie in the axis of a great circle whose pole is in 23½° N. lat., and 15° E. long. (from Greenwich), by which means the great continents of the Old and New World are brought within the limits of the map. In this case, all the circles on the sphere (with the exception of the axis meridian) become represented by elliptic curves, and the construction of the map hence involves some technical difficulties. It may, however, be usefully employed for purposes which require the great land divisions of the earth to be shown under a single view (as in illustrating some of the conditions of physical geography, as the course of isotherms, lines of equal magnetic variation, &c.), and has also been used by its ingenious author for the construction of maps of the stars.[1]

(94) Sir John Herschel, in vol. 30 of the Journal of the Royal Geographical Society of London (1860), investigating

[1] An ingenious mode of representing the globe in four circular maps, each embracing one-third part of its surface, and therefore in its exterior parts overlapping the other sections, so as to show the connection between each, was proposed by J. W. Woolgar, Esq., of Lewes, in the 'Mechanics' Magazine' for December 7, 1833. Mr. Woolgar's original idea was 'to project the sphere in four equal portions, on the faces of an equilateral pyramid,' in order that, by representing an extent of surface less than half the globe, the great expansion of scale which occurs towards the exterior parts of hemispheres stereographically projected might be avoided. By extending the limits of each plane of projection, however, so that it might embrace a third of the spherical surface, the connection between the several parts would be preserved, and the evils attendant on hemispherical maps considerably diminished. He therefore proposed to make the North Pole correspond to the apex of a pyramid, and the South to touch the base of the solid at its centre. The middle latitude of three of the planes will be 19° 28′ 16″ north, the pole being at the upper point of the circumference, and the greatest south latitude nearly 51°: the centre longitudes will of course differ by 120°. Mr. Woolgar proposed to use the stereographic projection, justly observing that 'the principal objection to it, as applied to hemispheres, will here disappear, since the radius of each circle will be $70\frac{1}{2}°$ instead of 90°, and the variation of scale only from 1 to $1\frac{1}{2}$, instead of from 1 to 2.' A Table of the central distances and radii of curvature for the meridians and parallels of the proposed projection is given in the 'Mechanics' Magazine,' vol. xx. p. 169.

the 'conditions under which a spherical surface can be projected on a plane, so that the representation of any small portion of the surface shall be similar in form to the original,' suggests a new formation of the sphere, in which the whole surface of the globe, excepting that portion which is in immediate proximity to the southern pole, is brought within the limits respectively—1st, of a section of a circle comprising 240° of its circumference; 2nd, within a semicircle; or, 3rdly, within a section of 120°. It is assumed as a condition, in either case, that the projected representations of all circles about a fixed pole on the sphere shall be concentric circles about a fixed centre on the plane. A Table showing the proportionate value of the radii for the successive projected parallels, in each of the supposed cases, is given by the learned author, with examples of the developed map according to the 2nd and 3rd of them. The last of these (that in which the entire longitudinal circumference of the sphere is comprised within a sector of 120°) is considered by Sir John Herschel to be preferable to either of the others. The student may examine these projections with advantage. Though possessing undoubted value for special purposes, it is not likely that either they, or the projection proposed by Sir Henry James, and described immediately above, will ever supersede, for purposes of general use, the forms of projection described in the prior portions of this chapter.

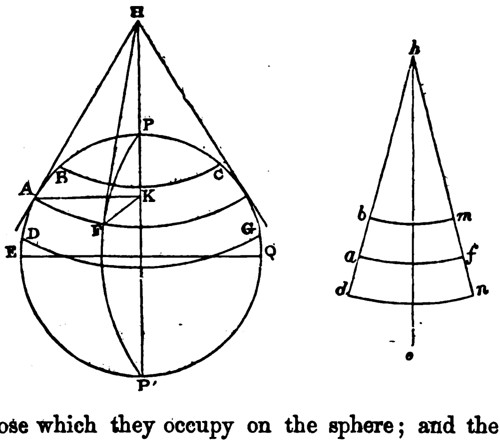
CHAPTER X.

MAPS (*continued*)—DEVELOPMENTS OF PORTIONS OF THE SPHERE—CONICAL PROJECTION.

(95) The projections which have been described in the last chapter show the impossibility of representing a spherical upon a plane surface without altering the dimensions, or distorting the forms, of the different portions of it. Although they are employed for the representation of hemispheres, and sometimes for portions of the globe comprising less than half its surface, it is desirable, in the representation of less considerable portions, to adopt some mode of projection which will preserve the dimensions of the parts delineated with greater equality throughout.

It is well known that the curved surface of a cone is capable of being spread out, or represented upon a plane, without any alteration in the figure or dimensions of its parts. Now a part of the surface of a sphere which does not possess much breadth, or which is contained between two parallels of latitude not very distant from one another, will not differ much in dimensions from part of the surface of a cone supposed to circumscribe it: and if the latter surface be developed on a plane, the countries and objects contained within the correspondent globular surface may be delineated with more exact proportions than by any other mode of projection. Thus, in fig. 15, let B C, D G, represent two parallels of latitude, and the space comprised between them part of the surface of a spherical zone; if a cone be then supposed to circumscribe the latter in such manner that its sides touch the sphere at a point equally distant from each parallel, then the parallels of latitude contained within the spherical surface will be represented on the surface of the cone by circles described from its apex or summit as a centre, and passing through points on it which are at distances from the point of contact equal

FIG. 15.



to those which they occupy on the sphere; and the meridians will be straight lines drawn from the summit of the cone to the points at which they intersect the middle parallel of latitude. Since the conical and spherical surfaces correspond at this middle parallel, distances measured along its development will, of course, be exactly equal to those taken on the sphere itself, while those on the parallels above and below it will exceed by a little their true dimensions, as the surface of the cone there recedes from the spherical surface, and therefore occupies a wider space.

(96) To illustrate the mode of developing a conical surface, suppose it is desired to represent that part of the spherical zone (fig. 15) which is contained between B C and D G, respectively the parallels of 10° and 50°, and between the meridians P A P′ and P F P′, assumed to comprise 60° of longitude.

The side of the cone, H A, is obviously the tangent of the angle contained between the middle parallel, or that of 30° (where it touches the surface of the sphere) and the pole, P; or the *co-tangent* of the latitude of the middle of the zone. Its length in degrees and minutes of latitude may be thus found: since the circumference of a circle is to its diameter as 3·1416 is to 1, the number of degrees which the latter contains is shown by the proportion— 3·1416 : 1 : : 360° : 114·591°, the half of which, 57·295°, will be the number of degrees contained in the radius. Hence the length of H A in degrees is 1·73206 (the co-tangent of 30°) × 57·295 = 99·23837°, or 99° 14′ 18″. If then on any line *h o* (fig. 15), we assume the point *c* as the middle latitude (30°) of the zone to be represented, and from this point set off a distance equal to 99° 14′ 18″ of any unit assumed for a single degree, the extremity of the line so set off will be the centre of the parallel of 30°, and will also be the common centre of the parallels comprehended within the required map. The points through which these latter require to be drawn should, in strictness, be determined by lines drawn from the centre of the sphere to the equal divisions of its quadrant, and prolonged until they meet the side H A of the circumscribing cone. The points so obtained would of course exhibit unequal divisions for the measure of degrees on the meridian, the intervals between successive parallels showing a progressive increase from the point A in either direction. In the modification of the purely conical development which is adopted, it is usual to set off equal spaces on the line of the central meridian, at 10° (or any other required interval) apart, to represent the equal divisions of the quadrant upon the surface of the sphere.

The angle corresponding on a plane surface to 60° of longitude in the parallel of 30° will be found by considering that the angle A K F is to the angle A H F as H A (the co-tangent of 30°) is to A K (its co-sine); or, since radius : sine : : co-tangent : co-sine, the radius 1 : ·50000 (nat. sine of 30°) : : 60° : 30°, the required angle. If, therefore, half this angle be set off on each side of *h o*, and the space between the extreme points be divided into six equal parts, lines drawn from each of these divisions to the centre will represent the meridian at 10° apart.[1] The space enclosed between the outer parallels and meridians will then be very nearly equal to the part of the spherical zone which it represents, but the degrees of longitude measured on the parallels above and below the middle parallel will be a little in excess of their due proportions. It is obvious that this excess will be *greater* in proportion as the part of the sphere to be represented embraces a greater extent of latitude, so that it is applied most correctly to maps which extend farthest in the direction of the meridians, and do not comprise a great number of degrees of latitude. But it

[1] It will be sufficient in practice to find by the Table (No. III.) the number of miles contained in a degree of longitude in the required parallel, and, taking the equivalent extent of 10° by means of a scale formed from the space assumed as 10° of latitude, to set it off on the line representing the parallel of 30° on each side of the central meridian *h o*.

possesses in any case the great advantage of preserving rectangular intersections of the parallels and meridians, similar to those on the globe, so that the opposite diagonals measured across any of the spaces comprised between them are in all cases equal to one another.

(97) Various modes of modifying this projection have been proposed by geographers, with the view of obviating the increase in the distances measured along the parallels above or below that which represents the middle latitude of the map. One of these consists in substituting *curves* for the straight lines which represent the *meridians*; preserving the laws of the conical projection in so far as regards the *parallels*—they being all described from a common centre, at a distance from the middle parallel of the map equal to the co-tangent of the latitude which that parallel represents. The degrees of longitude (at 5° or 10° apart, as may be required by the scale of the map) are then marked upon each parallel according to the law of their decrease, that is, as the co-sine of the latitude is to the radius (Art. 65), the degrees of latitude being employed as a scale from which they are measured: curved lines drawn through these points will represent the meridians. But if a map thus projected embraces much extent of longitude, the spaces included between the parallels and meridians towards its upper and lower extremities become extremely irregular figures, two of the angles of which are *greater*, and the opposite two *less*, than right angles, so that diagonals measured across them are far from equal, as they should be in order to afford a correct representation of similar spaces on the globe.[1]

[1] This defect, which greatly distorts the form of the objects represented, is very apparent in the maps of Asia (and, to a less extent, in those of Europe,) in common use; in which, however, the centre of

(98) Another modification of the conical projection consists in regarding the cone not as a tangent to the sphere, but as being partly inscribed *within* it, or as entering it at two points between the middle and extreme parallels of the zone to be represented. It is possible to make the cone enter the sphere in such a manner as to produce in the development a surface exactly equal to that of the part of the sphere which it is desired to represent, and a rule for this purpose is given by Mr. Murdoch, by whom this method was proposed.[1] But the most useful application of this principle is that which was employed by De Lisle in the construction of a general map of the Russian Empire, in which he supposed the cone to enter the sphere in such a manner as to intersect it at two parallels equally distant from the middle parallel, and from one of the extremes. In this projection, the parallels are represented by concentric circles described from the point at which the axis or central meridian of the map meets the apex of the cone, and the meridians by straight lines drawn from this point to the degrees of longitude, which are set off, according to the law of their decrease, upon either of the two parallels in which the

the parallels is not placed at a distance from the middle latitude equal to its co-tangent, but made the point of concourse of straight lines drawn through the degrees of longitude corresponding to any two parallels which may be arbitrarily assumed as preferable, and set off on each side of the central meridian of the map. In the map of Europe this point is usually taken at 8°, and in that of Asia at 30° or 32½°, beyond the North Pole: but by the assumption of these centres the evil complained of is increased beyond what it would be if taken according to the strict laws of the conical projection, so that in a map of Asia thus drawn the distortion becomes very great towards the upper corners of the projection.

[1] Philosophical Transactions for 1758, vol. L. part ii. p. 553 *et seq.*

cone intersects the sphere. Distances measured on those two parallels are exactly equal to the correspondent parts of the globe, while in the space between them they are deficient, and in the parts beyond in excess, of their true proportions, so that the errors balance one another, and are distributed more equally throughout the map.

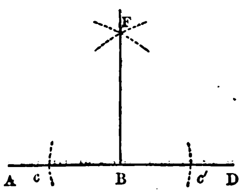
For maps which are not required to embrace more than 20° or 30° of latitude, this modification of the true conical projection presents an extremely near approximation to exactness in the representation of a spherical surface; and even in those which embrace a considerable extent in latitude, as in maps of Europe, Asia, or North America, it possesses the decisive advantage of preserving the rectangular intersections of the parallels and meridians, and therefore of representing the objects delineated by figures *similar* to those which they bear upon the globe. We have accordingly employed it, in reference to them, in the following directions for projecting maps of the large divisions of the earth.

(99) *To project a map of Europe.* Draw a base line A B (fig. 1, Plate II.) of any length, bisect it in E, and at that point erect the perpendicular E D of an indefinite length,[1] to constitute the central meridian of the map,

[1] To raise a perpendicular, at any required point, on a given base line:—

1st. If the point be near the middle of the given base, as in fig. 16. From the given point B, set off, with any radius, equidistant arcs, crossing the base in the points *c c'*: then from each of those points as a centre, and with any radius *greater* than B *c*, set off arcs of circles in the direction of the required perpendicular; the point F in

FIG. 16.



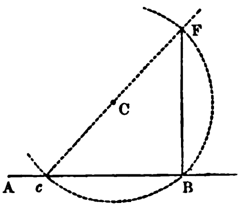
which it will be convenient to take as 20° east from the meridian of Greenwich.

To draw the parallels. Assume any space as equal to 5° degrees of latitude, and since the whole of Europe will be comprised within the 35th and 75th parallels, set off upon the central meridian eight of these spaces from E towards D, in order to mark the points through which the parallels must pass. The centre from which to describe the parallels will be a point in the central meridian corresponding to that in which the apex of a cone intersecting the globe at the 45th and 65th parallels (or equidistant from the mean parallel of 55° and the extremes of 35° and 75°) would meet the axis of the sphere. This point will be found to be 4° 30′ 25″ beyond the north pole, which will be situated at P:[1] measure off therefore along

which these arcs intersect one another will be that through which a line perpendicular to A D, at the point B, will pass.

2nd. If the given point B be near one of the extremities of the base line, as in fig. 17. From any assumed point C, and with the radius C B, set off an arc of a circle, *c* B F, cutting the base line in the point *c*; draw a straight line through the points *c* C, prolonging it until it intersects the opposite side of the circular arc: the point of intersection F will be that through which the required perpendicular must pass.

FIG. 17.



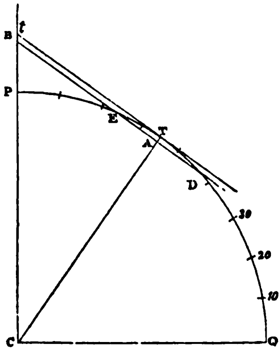
[1] The distance of the centre may be found in the following manner. Let P Q (fig. 18) represent a quarter of the sphere, of which C is the centre, P the pole, and C Q the radius of the equator: divide P Q into nine equal parts, each containing 10° of latitude, numbered 10°, 20°, &c., from Q towards P. The middle latitude between 35° and 75° (the extreme parallels requisite for our map) is 55°, and if we suppose a cone circumscribing the globe to *touch it* at this parallel, the length of its side T *t* would be, as has been shown in Art. 96, the *co-tangent* of 55°, and *t* would be the centre from which

the central meridian a distance P C equivalent to this amount, and the point C will be the centre through which to describe circles, passing through every fifth degree of latitude, to represent the parallels.

To draw the meridians. Since on the parallels of 45° and 65°, in which the cone intersects the globe, the degrees of longitude will be exactly equal to those on the globular surface (Art. 98), if on *either* of those parallels we set off from each side of the central meridian distances equivalent to 5° of longitude in the *due proportion which they bear in those parallels* to the length of the degrees of latitude (that is, as the cosine of the latitude to the radius),

to describe the parallels. If, however, the cone intersect the globe at the 45th and 65th parallels (each equidistant from the middle parallel), then its side, B D, will intersect C T, the radius of the sphere, in the point A. Now, because the triangles C A B, C T *t*, are equiangular and similar, C T : T *t* :: C A : A B; but C A is equal to the cosine of the angle T E = 10°, and T *t* is the co-tangent of 55°, or the tangent of its complement, 35°; therefore, radius : tangent of 35° :: cosine of 10° : A B. Now, as the radius of the sphere contains 57·295° (Art. 96), the length of A B in degrees may easily be found; for

FIG. 18.



57·295° (radius) : 40·118° (tang. 35°) :: 56·424° (cosine 10°) : 39·507° (= 39° 30′ 25″). The length of A B is thus found to be equal to 39° 30′ 25″, and consequently the point B, the centre of the parallels, to be at that distance from the middle parallel, that of 55°; or 4° 30′ 25″ (= 39° 30′ 25″ − 35°, the distance of the middle parallel from the pole,) beyond the pole. In projections of a small size, it will not occasion any material error, if, for greater convenience, the centre for the parallels be taken at 5° beyond the pole.

and through the points thus found draw straight lines from C, the centre of the parallels, these lines will represent the meridians at 5° apart. To find the proportionate length of the degrees of longitude, it will be necessary to construct a *diagonal scale*, which may be done in the following manner. On the line A B (fig. 2, Plate II.), equal to the space assumed for 5° of latitude, erect the perpendiculars A C, B D, each equal to A B, and join C D: divide the sides A C, B D, each into six equal parts, numbering them 10, 20, 30, &c., and join these points by diagonal lines from 0 to 10, 10 to 20, and so on; then divide the base A B into 10 equal parts, 1, 2, 3, 4, &c., and through these points draw lines parallel to A C, B D; these latter lines will then constitute decimal divisions of the diagonals, and enable us to take any portion not less than a 60th of the line A B. Now, by referring to the Table (No. III.), we find that a degree of longitude in the parallel of 45° contains 42·495 geographical miles or minutes of the equator: this number of parts of the line A B (=5° of latitude), measured off from the diagonal scale, will therefore correspond to 5° of longitude in the parallel of 45°, and will be accordingly the distance to set off upon that parallel on each side of C E.[1] As many of these divisions must be set off as will comprise the extent of country which the map is intended to embrace, for which purpose eleven will in the present case be requisite upon each side. Straight lines drawn

[1] This length should in strictness be diminished by the excess of an *arc* of 5° in the parallel of 45° above its *chord*, for the spaces measured upon a curved line will be chords of arcs, and not the arcs themselves. As the curvature of an arc of 5° is, however, very slight, the difference will occasion no appreciable error, unless the projection be upon a very large scale, in which case it might be obviated by setting off spaces equal to one or two degrees only, instead of 5°.

from C through these divisions will represent the meridians.

Finally, the lines A a, B b, a b, must be drawn to form the boundary lines of the map, and those parts of the parallels and meridians which extend beyond them must be erased. The lines of latitude and longitude should then be numbered on the outside of the map, and the spaces between them graduated, by dividing them into single degrees, as on the Plate, and the projection will be complete. When the countries, &c., are inserted upon it, a scale of miles should be made, in order to measure distances by, and inserted in one corner of the map. This will be done by taking one degree of latitude as equal to 60 geographical, or 69·12 English, miles, and measuring on a straight line a sufficient number of these spaces to form a scale of any required length.

(100) The above forms an exceedingly good projection for a map of Europe: the total extent of the conical surface developed is very nearly equal to that of the globular surface which it represents;—the degrees of latitude are of the same length throughout;—the degrees of longitude have exactly their true proportions upon the 45th and 65th parallels, while their deficiency upon the intermediate, and their excess in the direction of the extreme, parallels, are so trifling as to occasion no appreciable error in a measure even of 200 or 300 miles in extent, and, as it occurs in opposite parts of the map, the disproportion is distributed throughout, instead of being all thrown into one part;—the intersections of the parallels and meridians being all *rectangular*, their diagonals are equal, and figures on the globe are therefore represented by figures exactly *similar* upon the map;—and, finally, since the shortest distance between any two points on a conical surface

corresponds with the straight line which joins them when that surface is extended into a plane, and the conical surface in the present case does not differ materially from the spherical surface, measurements taken in a straight line in any direction across the map will differ very little in length from the arc of a great circle joining the extreme points, or the shortest distance between them upon the sphere.[1]

(101) *To project a map of Asia.* Draw, as before, a base line A B (fig. 3, Plate II.), and a perpendicular E D as a central meridian, 85° east from that of Greenwich.

To draw the parallels. Assume a space for 10° of lati-

[1] Amongst various other methods occasionally employed in the case of maps representing the large divisions of the globe (Europe, Asia, &c.), perhaps that described by Sir H. James in vol. 30 of the Geographical Society's Journal, and in use at the War Office, is one of the most ingenious. In Sir H. James's development, the parallels are arcs of circles, not concentric, but with radii which exhibit a progressive decrease in the ratio of the altered co-tangents to each successive parallel, their centres all lying in the prolonged line of the middle meridian of the required map. The meridians are represented by curved lines, drawn through the parallels at points determined constructively, in accordance with the ratio borne by the sine of the co-latitude (=co-sine of latitude) to the radius, in the case of each. The meridians and parallels intersect one another at right angles, and the true proportion between degrees of latitude and longitude on each successive parallel is preserved. Sir H. James gives a table showing the lengths (a degree of the equator being assumed as a unit) of the radii for the successive parallels, and also the lengths of a degree of longitude in different latitudes. The prime defect of this projection lies in the inequality of the meridional spaces between the successive parallels (owing to the latter being non-concentric), and in the resultant increase in the length of degrees of the meridian, from the middle line of the map towards either border. An obvious error is hence involved in the application of a scale of miles, for purposes of measurement. In this important point, as well as in simplicity of construction, it seems to the present writer inferior to the projection described in the text.

tude, and set off 7½ such from E towards D, commencing at the 5th parallel; the points thus marked will be those through which to draw the parallels at 10° apart. Since Asia extends between the 5th and 80th degrees of latitude, it will be convenient to suppose the cone to enter the globe at the 25th and 60th parallels, which are about equidistant from its central and extreme points. The centre from which to describe the parallels (or the point in which such a cone would meet the axis of the globe) will be situated at 12° 7′ 58″, or 12° 8′, beyond the pole.[1] Measure off, therefore, a space equivalent to this upon the central meridian, and from the point C thus found describe circles to represent the parallels.

To draw the meridians. Since at the 25th and 60th parallels the conical and globular surfaces correspond, the degrees of longitude will there possess their correct proportions. It will be seen by the Table (No. III.) that in the 25th parallel a degree of longitude contains 54·410 minutes of the equator: measure with a pair of compasses a space equivalent to this, by means of a diagonal scale, (constructed, in the present case, upon the space assumed for 10° of latitude,) and set it off upon that parallel as many times as are requisite upon each side of the line E D; or the length of 10° of longitude on the 60th parallel may be similarly ascertained and set off upon it. Straight

[1] This point is found in a manner similar to that in the previous case, by ascertaining the proportion between the distance, from the middle parallel, of the apex of a cone which is a tangent to the sphere at that point, and of one entering the sphere at the required parallels; thus, radius of sphere : tangent of 47° 30′ (or the co-tangent of 42° 30′) :: cosine of 17° 30′ (the distance between the middle parallel 42° 30′ and the 60th parallel) : 59° 37′ 58″, the distance of the vertex of the cone from the middle parallel, which is therefore (59° 37′ 58″ − 47° 30′ =) 12° 7′ 58″ beyond the pole.

lines drawn from the centre C through the points thus found will then represent the meridians, and the outer lines A *a*, B *b*, *a b*, being drawn, and the degrees numbered and divided, as in the previous case, the projection will be complete.

A scale to the above map will be formed by regarding *one* degree of latitude as equivalent to 69·12 English miles, or to the proper number of any other measure which may be required. If the projection be on a large scale, it will be better to draw the parallels and meridians at 5° apart, as in the map of Europe. The advantages of this projection are, of course, similar to those of the preceding, but in rather a less degree, inasmuch as the greater extent of the map in the direction of latitude causes the deficiency of the degrees of longitude on the intermediate, and their excess on the extreme, parallels, to be more apparent, although even here its results do not importantly affect the correctness of the map.

(102) *Another method of projection for a map of Asia.* Since the great extent of Asia in latitude as well as longitude renders the application of the conical projection less strictly suitable to it, the following modified projection may in some cases be advantageously employed. The cone is here regarded as intersecting the sphere at the 20th and 50th parallels, in which case the centre from which to describe the parallels (or the apex of the cone) will be at the distance of 24° beyond the pole.[1]

[1] The middle latitude will, in the case assumed, be 35°, and the distance between the middle latitude and the points of intersection will be 15°. Then, radius : tangent of 55° (co-tangent of 35°) :: cosine of 15° : the required distance of the apex of the cone from the middle parallel;—or, 57·595 : 81·825 :: 55·343 : 79·035 = 79° 2′ 6″. Whence 79° 2′ 6″ − 55° = 24° 2′ 6″, distance of apex of cone beyond pole.

To draw the parallels. Assume any space for 10° of latitude (fig. 1, Plate III.), and measure off upon the central meridian of the map a distance equivalent to 24° beyond the pole. The point C thus found will be the centre from which to describe circles to represent the parallels.

To draw the meridians. Ascertain, by means of the Table (No. III.) and a diagonal scale, the measure of 10° of longitude upon *each* of the successive parallels, and set off this measure upon either side of the middle meridian of the map, carrying forward the measure *upon each parallel* for a sufficient distance to embrace the requisite extent of longitude for a map of Asia. Then join the points thus marked upon the different parallels, and a succession of curves will be obtained which will represent the required meridians. This method of obtaining the meridians is similar to that employed in the maps of Africa and South America, hereafter described, and requires the exercise of great care in obtaining the requisite curvature of the lines. If on a scale of any magnitude, it will be necessary to draw the lines (both parallels and meridians) at 5° instead of 10° apart, and to set off the true proportional measure of the degrees of longitude upon each parallel accordingly.

The method of projection last described, or one analogous to it, is that most frequently employed for maps of Asia, and specimens of its application may be found in the greater number of the collections of maps in popular use. But it has great and obvious defects, especially in the measurements towards the outer extremities of the map, and is altogether wanting in the simplicity and truthfulness of the conical projection.[1]

[1] A technical reason for the employment of the projection here described may be found in the fact that the conical projection produces a greater *squareness of shape* than is generally found desirable;

(103) *To project a map of Africa.* The mainland of Africa extends to a nearly equal distance upon each side of the equator, which line therefore occupies a middle position between the parallels of latitude which cross the map. It is obvious that lines drawn as tangents to the equator, or entering the globe at an equal distance on each side of it, could never meet the prolonged axis of the sphere, to which they would be *parallel*, and would therefore not form part of the surface of a cone of which the apex lay in that axis, but of a *cylinder* circumscribed in or about the globe. The mode of projection adopted in the two preceding instances is therefore inapplicable to a general map of Africa, and the development of a *cylindrical* surface, although extremely useful for nautical maps (as will subsequently be shown), possesses defects which render its employment inconvenient in such a case as the present. It is observed, however, by Lagrange, that 'it is sufficient for the mathematical exactness of a map, that the parallels and meridians be traced after any *constant geometrical law* whatever.' The mode of projection usually employed for maps of Africa, which is founded on this condition, seems best suited for the purpose required: it consists in representing all the parallels as straight lines, and afterwards tracing the meridians upon them in curved lines, drawn according to the law of the successive decrease in the length of the degrees of longitude, that is, bearing the same proportion to the degrees of latitude as the cosine of their latitude to the radius of the equator (Art. 65).

To draw the parallels. Draw a line E Q (as in fig. 2, Plate III.) of any required length, to represent the equa-

while the modified method referred to above involves less deviation from the oblong form which is usually preferred, and which suits best with the proportions of the majority of maps.

tor, and at right angles to it the line C D, and let the latter represent the meridian of 20° east from Greenwich. Assume a space for 10° of latitude, and, since it will be convenient to make the map extend 40° on each side of the equator, set off four of these divisions from the equator E Q, on each side towards C and D. Through the points which mark these divisions draw lines parallel to E Q, to form the parallels to every tenth degree.

To draw the meridians. Since at the equator the degrees of longitude are equal to those of latitude (Art. 59), with the same measure of 10° set off four spaces upon it, on each side of the middle meridian, towards E and Q; these points of division will be those through which the meridians must pass at the equator. To find the points through which they should be drawn on the tenth parallel, refer to the Table (No. III.), by which it will be seen that a degree of longitude on that parallel contains 59·094 geographical miles, or minutes of latitude; this amount must therefore be measured from a diagonal scale, constructed as in the preceding cases (Art. 99), and set off along the tenth parallel upon each side of the central meridian, both to the north and south of the equator. The extent of 10° of longitude must, in like manner, be found for each of the other parallels, 20°, 30°, &c., in succession, and similarly set off upon those lines. The points thus found will be those through which to trace lines to represent the meridians: if of large extent, it may perhaps be found convenient to draw them by means of a *shipwright's bow*, so placed that its edge touches each point; but if the projection be small, it will be sufficient to form them by a succession of straight lines drawn from point to point.

The outer lines, A *a*, B *b*, being then drawn, the parallels and meridians numbered, and the spaces between them divided, the projection will be complete. If the map is to be of large size, it will be necessary to draw the lines to every *fifth* instead of every *tenth* degree only. The chief defect of this projection is the inequality of the angles at the intersection of the parallels and meridians, whereby the quadrilateral spaces between those lines become irregular figures, one of the diagonals of which is considerably longer than the other. This defect, which becomes greater as we recede from the middle meridian, and is very apparent towards the corners of the map, distorts the figures of the objects represented, and prevents the correct application of a scale of measurement in those parts in any other direction than along the parallels.

(104) *To project a map of North America.* The northern half of the American continent extends between the 5th and 80th parallels, like Asia in the old world, and the projection for a map to represent it might consequently be made in a similar manner, and from precisely the same data as those given for Asia (Art. 101). But as the part of the continent which lies south of the 30th parallel occupies comparatively little breadth, it will be desirable to regard the surface of the cone which is to be developed as entering the sphere at the 30th and 60th parallels, instead of the 25th and 60th; because, as a smaller number of degrees of latitude will be comprised between these parallels, the deficiency in the length of the degrees of longitude contained within them will be proportionably diminished, and the general correctness of the map thereby increased; since the central parts of the map are those in which the deficiency of measurements from east to west will be most appreciable, as they comprise the greatest breadth of country, whilst in the more southern parts the error of excess

cannot amount to much, on account of the contracted width of the land there.

In this case, therefore, the centre from which *to describe the parallels* will be placed in the middle meridian, at a distance of 55° 20′ 34″ beyond the middle parallel (that of 45°), or 10° 20′ 34″ beyond the pole.[1] The points through which *to draw the meridians* will be found by setting off, on the 30th parallel, spaces equivalent to five or ten degrees, the proportionate length of these in that latitude being ascertained, as in the previous instances, from the Table (No. III.), and a diagonal scale. This projection resembles in every other respect those already given of Europe and Asia, and is represented in fig. 3, Plate III. It will be convenient to take the 100th meridian west from Greenwich as constituting the central meridian or axis of the map, and spaces will require to be set off on each side of it, extending on the one hand to the 30th and on the other to the 170th degrees of west longitude; but the outer lines of the map, forming the border, will cut off a considerable portion of the meridian lines which are distant from that occupying the centre.

(105) *To project a map of South America.* A projection similar to that already described for a map of Africa will also serve for South America, excepting that, as this portion of the New World lies between the 13th parallel of north, and the 56th of south, latitude, it will be requisite to set off to the north of the line which represents the equator

[1] The distance of the centre is ascertained, as in the previous cases, by the following proportion; radius : tang. of 45° (the middle parallel) :: cosine of 15° (the angle contained between 45° and 60°) : the distance of the apex of the cone from the middle parallel. No perceptible error will be occasioned by taking the centre at 10½ degrees beyond the pole.

only two of the spaces taken as equal to 10°, and six of them to the south of the same line; finding on each parallel the points through which the meridians must pass by ascertaining, as before, from a diagonal scale, the proportionate length of the degrees of longitude upon each. It will be convenient to regard the meridian of 60° west from Greenwich as constituting the central meridian of the map. The projection will, of course, possess similar defects to that of Africa, but as the southern part of the land comprised in it will be not far removed from the middle meridian, the inequality in measurements across the spaces included between the parallels and meridians will not very materially influence the correctness of the map. This projection is shown in fig. 4, Plate III.

(106) *To project a map of any considerable portion of the Globe.* The principles on which the projections above described are constructed are equally applicable to the construction of maps of any part of the globe, and, if the countries which it is desired to represent occupy a considerable extent of surface (exceeding ten or twelve degrees of latitude), it will be desirable to employ a mode of projection similar to the one or the other of them. In the selection of either, reference must be made to the circumstances of the case, such as the position of the parts which are to be represented, and the particular object for which the map is required. If it be a part of the globe which extends on both sides of the equator, it will generally be preferable to employ the mode adopted in the maps of Africa and South America; but in almost all other cases the conical projection, as employed in those of Europe, Asia, and North America, possesses a decided superiority over all other methods of projection for *geographical* maps. Its advantages will be most manifest when the parts to be

represented do not occupy a large extent of latitude, not exceeding 20° or 30°, in which case measurements may be made in *any direction* with a very great degree of accuracy.

It will in every case be necessary for the student to decide upon the two parallels at which the cone is supposed to enter the sphere, and to determine accordingly the centre from which they are to be described. Thus, suppose it be desired to make a projection for a map which is to comprehend Australia and the adjacent island of Tasmania: since these countries lie between 10° and 44° of south latitude, it will be desirable to regard the surface of a cone as coinciding with the sphere at the 20th and 35th parallels. In this case the middle parallel will be that of 27° 30′, and the centre from which to describe circles to represent the parallels will be 109° 7′ 12″ beyond it, or 46° 37′ 12″ beyond the south pole. Straight lines drawn from this point to the divisions of the degrees of longitude upon the 35th parallel (measured off from a diagonal scale according to their correct proportion) will then form the meridians. In a similar manner a projection may be made for a map of any part of the globe.

(107) *To project a map of England and Wales.* If the country which it is intended to represent occupy but a small extent of surface, not exceeding 8° or 10° of latitude, the scale on which the map is to be drawn will necessarily be larger than in one which is to comprise a more extensive portion of the globe. The centre from which the parallels should be described, according to the conical projection, would therefore be found in most cases to lie so far distant from the required extent of the map, as to render it extremely inconvenient to describe curves constituting parts of circles with so great a radius. It is hence desirable to adopt some mode of tracing these circular arcs by which

this difficulty will be obviated; and since in such a map their curvature will be very slight, the desired object may be accomplished in the following manner.

Suppose it be desired to construct a map of England and Wales, for which purpose it will be requisite to include the space comprised between the 50th and 56th degrees of north latitude. In the middle point of a base line A B (Plate IV. fig. 1) erect the perpendicular C D, which should represent the meridian of 2° west longitude from Greenwich, and, assuming a space as the length of one degree of latitude, measure off six of these degrees from C towards D, leaving between the base line and the first division a space equivalent to 10′ of latitude for a small part of England which extends to the south of the 50th parallel. Number the divisions 50, 51, 52, &c., and through the 51st and 55th draw lines of an indefinite length at right angles to C D, and therefore parallel to the base A B: then construct a diagonal scale (fig. 2) upon the space assumed for the length of a degree of latitude, and by the aid of the Table (No. III.) ascertain the proportionate length of a degree of longitude on the parallels of 51° and 55°, which will be found to be represented by the lines *x x*, *y y*. On the line drawn parallel to A B, from the point *c*, through which the 51st parallel is to pass, set off on each side of the central meridian, C D, the spaces *c a*, *c a′*, each equal to the half of *x x*, or half a degree of longitude in that parallel; and similarly at the 55th degree of latitude set off the spaces *d b*, *d b′*, each equal to half the line *y y*: then draw the lines *a b*, *a′ b′*, and the quadrilateral figure thus formed will constitute the projection of half a degree of longitude upon each side of the central meridian. In order to carry this onward to a whole degree on either side, extend a pair of compasses between the points *a b′* or *a′ b*, which will thus measure the *diagonal* of an entire degree, and, fixing one leg at the point *c*, describe with the radius *a b′* the arc *e e′*, and from the point *d* with the same radius the arc *f f′*; then from the point *c* with the radius *a a′* (=*x x*), and from the point *d*, with *b b′* (=*y y*) as a radius, describe arcs intersecting the others in the points *f*, *f′*, *e*, *e′*; join the points *c f*, *c f′*, *d e*, *d e′*, by straight lines, and draw lines passing through *e f*, *e′ f′* (which will represent meridians), and the projection will then be formed for 1° on each side of C D.

This process must be carried on upon each side of C D as far as the map may require: thus from the points *f* and *e*, with the same diagonal *a b′* as a radius, the arcs *g*, *h*, must be described, and intersected by other arcs measuring the lines *x x*, *y y*; and similarly from the correspondent points *e′*, *f′*. It will be necessary, in the present case, to carry this operation on to a distance of 4° of longitude on each side of C D, and the lines *c f*, *f h*, *h k*, *k n*; *d e*, *e g*, *g i*, *i m*, joining the points thus found, will give the proper degree of curvature to the parallels which they represent. As these parallels include 4° of latitude, the lines *e f*, *g h*, &c., must be divided into four equal parts, and a space equal to one of these parts, or 1°, set off upon each of the meridians above and below the parallels already drawn. These divisions being then joined by straight lines, the intermediate and extreme parallels will also be obtained; the lines forming the border of the map, and the division and numbering of the degrees, will then complete the projection.

It is scarcely necessary to say that the lines *a b*, *a′ b′*, and the various arcs, should only be drawn in pencil, so that they may be afterwards erased. If the projection be made on a large scale, it will be desirable to set off on the central meridian spaces equivalent only to half a degree of latitude, in which case it will be better to measure off the degrees of longitude upon the parallels of 51° 30′ and 54° 30′, forming the projection by the diagonals between the quadrilateral figures thus obtained, in a manner similar to that already done.

(108) *To project a map of Palestine.* Suppose it be desired to draw the parallels and meridians for a map of the Holy Land, which should embrace, in the direction of latitude, from the 31st about as far as the 34th degree, and in the direction of longitude, from the meridian of 34° to about that of 37°. The middle meridian of such a map will coincide with 35° 30′ east longitude.

Draw a base line A B (fig. 3, Plate IV.), and erect in its middle point the perpendicular C D. Assume any space to represent one degree of latitude, and measure off three such spaces from C towards D. Number these divisions respectively 31°, 32°, 33°, and 34°, for the degrees of latitude which they represent.

Construct a diagonal scale (fig. 4) upon the space assumed for the length of one degree of latitude, and ascertain the proportionate length of degrees of longitude upon the parallels of 31° and 34° respectively. These will be found (Table III.) to be equivalent to the lines $x\ x$, $y\ y$. From the point C, upon either side of the central meridian C D, set off on the line A B a space equal to the half of $x\ x$. Through the point which marks the parallel of 34° draw a line at right angles to C D, and set off on either side of it a space equal to the half of $y\ y$. Connect the points marked A a, B b, by straight lines, which will then represent the meridians at half a degree distant on either side of the middle meridian—that is, those of 35° and 36°.

The next step is to carry forward the projection to the further distance of a degree upon either side, in a similar manner to that employed in the projection last described. Thus, by extending a pair of compasses between the points A *b*, or *a* B, we obtain the diagonal measure of an entire degree: then from the point A we describe (with this measure as a radius) the arc *e e'*, and from the point B the similar arc *h h'*: also, from the points *a*, *b*, respectively, the arcs *g g'*, and *k k'*. Next, from the points A, B, with a radius equal to the line *x x*; and from the points *a*, *b*, with a radius equal to the line *y y* (that is, with the respective measures of a degree of longitude upon the parallels of 31° and 34°); describe arcs intersecting the others in the points *m*, *n*, for the lower parallel, and *o*, *p*, for the upper. Straight lines drawn between the points thus found—that is, through *o*, *m*, and *p*, *n*,—will then represent the meridians of 34° and 37°, which is as far as the projection requires to be carried. If the points A and B be connected with *m* and *n*, and the points *a*, *b* with *o* and *p* respectively, the parallels of 31° and 34° will be obtained, with the slight requisite degree of curvature for each.

Since the space comprised between the extreme parallels represents in the present case three degrees of latitude, each of the meridians must be divided into three equal parts, and the respective divisions connected by straight lines drawn from meridian to meridian, which lines will constitute the intermediate parallels, or those of 32° and 33°. Lines being drawn to form the border of the map, and the degrees being numbered and divided all round, the projection will then be complete.[1]

[1] After forming the projection in the manner above described, it may be desirable, in drawing the border lines round the map, to include a narrow space (equivalent to about 5' of latitude) to the south of the 31st parallel, and to take off a similar (or rather greater) space from the upper part of the projection, so as to make the map embrace

(109) The principle on which the two last-described projections are formed is perfectly similar to that of the preceding conical projections, the intersection of the lines being in all cases rectangular, and all the diagonals across similar spaces being equal to each other. Its only deviation from the conical projection consists, in fact, in the formation of the curved parallels by the junction of a number of short straight lines, instead of describing them from a centre which would be placed so far off as to occasion considerable trouble in ascertaining its exact position, and great inconvenience in its application. It constitutes a simple and convenient mode of drawing the projection for a map of any part of the globe which is not of great extent. As in the other conical projections, the degrees of longitude will be a very little in deficiency on the parallels which fall between, and in excess on those beyond, the two which are selected as those upon which the remainder are to be formed; and it will therefore be desirable, for reasons similar to those previously stated (Art 98), to select for this purpose two parallels which are as nearly as possible equidistant from the central and extreme latitudes to be comprised in the map.[1]

from about the latitude of 30° 55′ to 33° 50′. It will be seen, on examination, that this is the plan commonly pursued in maps of the Holy Land. Or the map may be extended northward to a short distance beyond the 34th parallel, as may be thought desirable.

[1] In the case of so small a country as Palestine, which embraces less than 3° of latitude, it is sufficiently exact for all practical purposes to take the extreme parallels north and south as those upon which to construct the projection; the deficiency of measure on the intermediate parallels being so trifling that it may be disregarded, unless the map be drawn upon a very large scale, in which case the parallels of 31° 30′ and 33° 30′ might be advantageously substituted for those of 31° and 34° in obtaining the requisite data for the parallels and meridians.

(110) Where this projection is made for an extent equivalent to 8° or 10° of latitude, it may perhaps in some cases be advantageously modified, after the *parallels* have been drawn, by setting off upon *each of them* the proportionate length of a degree, or half a degree, of longitude, ascertaining this from the Table of Degrees of Longitude and the diagonal scale, and then forming the meridians by lines joining the divisions thus marked upon each parallel, in a manner similar to that described in Arts. 102 & 103. The meridians will in this case become lines curved slightly from each side of that occupying the middle of the map. The degrees of longitude will thereby be made of their proper length upon each parallel, but the simplicity of the conical projection will be lost, and the usual evils complained of in such maps (Art. 97) will be in some measure incurred. But it is needless to dwell longer upon these kinds of projections, which we believe the student who has examined the preceding examples will experience no difficulty in applying to any of the purposes he may require.

CHAPTER XI.

MAPS (*continued*)—DEVELOPMENT OF A CYLINDRICAL SURFACE —MERCATOR'S PROJECTION.

(111) Were we only to consider maps in reference to their application to *geographical* purposes, the preceding chapter might terminate our enquiry into the modes of projecting them: but there is another and most important purpose for which they are required—that of navigation—the wants of which are not satisfied by any of the projections that have yet been described.

The navigator guides his vessel between any two places by sailing along a line which corresponds in direction with one of the points of the compass. We have seen (Art. 17) that the *cardinal points* are determined, in reference to the whole earth, by the points in which a meridian, and a great circle which is perpendicular to the meridian and passes through the zenith, meet the rational horizon. Since all the meridians are great circles of the sphere, and all pass through the poles, the north and south points *at any place* on the globe always correspond to the north and south points *of the earth*; but not so the east and west points. The east and west points *at any place* are always indicated by a line which crosses the meridian at right angles—that to the right hand of a spectator facing the north being the east, and that to his left the west point. Since the equator is a great circle which intersects all the meridians at right angles, the east and west points at any place situated under it correspond to those of the earth in general: but at all other places, the absolute direction of those points, and therefore of all the others comprised between them and the north and south points, is different; for as the east and west points are always determined by a line at right angles to the meridian, and the distance between the meridians is constantly diminishing as they approach the poles, a line continued from any place in the direction of those two points must always preserve the same distance from the pole, and will therefore not be a great circle of the sphere, for the equator is the only great circle which is at an equal distance from the poles (Art. 13).

These differences produce results which are of great importance to navigation: if a vessel under the equator sails continually in an east or west direction, her course will describe part of a great circle. In like manner, a vessel which sails constantly in a north or south direction will describe an arc of the meridian, also part of a great circle of the globe. If she be sailing in either an east or west direction, without being under the equator, her course being necessarily always at right angles to the meridians which it crosses, she will describe part of a parallel of latitude, but not an arc of a great circle. But if she be sailing for a length of time in any other direction than that of one of the cardinal points, her course on the globe will not form an arc of a circle of any kind, but will constitute a spiral curve, of which the essential property is that it intersects all the meridians *at the same angle.* Such a line is called a *rhumb* or *loxodromic line*: that it does not form part of a circle is rendered evident by considering that a *circle,* whether great or small, which was drawn *obliquely* to any one meridian, would intersect all the other meridians at unequal angles, and therefore would not represent the same point of the compass on each.

Now in all the projections which have yet been described, the direction either of the north and south, or of the east and west, points (that is, of the meridians, or the lines at right angles to the meridians), and in many cases that of all the cardinal points, is represented by curved lines; and it is therefore obvious that on such maps the course of a vessel would in almost all cases be represented by a curved line also. In all cases similar to the latter of the instances we have supposed, (that is to say, in which a ship's *course* did not lie either in a due north and south, or east and west, direction,) the line which she described could only be traced by continually laying off from the meridians under which she passed a line at an angle equal to that made with the meridian by the point of the compass on which she was sailing. It would in many cases be exceedingly difficult to draw such a line, and as the navigator constantly requires to lay down on a map the track which he has been pursuing, and also to see the *bearing* of other places from that which he occupies (or the point of the compass on which they are situated), in order that he may be enabled thereby to direct his course, the main purpose which *he* requires a map to serve is that of enabling him to represent correctly by a *straight line* any rhumb or point of the compass. Since this line must cut all the meridians at the same angle, it is obvious that the required object can only be attained by representing the meridians as straight lines parallel to each other, in which case any line drawn across them will cut them all *at the same angle.*

Such, accordingly, is the method pursued in Mercator's projection, in which the meridians are all drawn as straight lines perpendicular to the equator, and at equal distances from each other. The parallels are represented by straight lines parallel to the equator, and also, like it, at right angles to the meridians. Now we have seen that on the globe the degrees of latitude are equal to each other (excepting as regards the slight difference arising from the earth's figure not being exactly spherical), and that the degrees of longitude diminish as they recede from the equator in the proportion which the cosine of the latitude bears to the radius of the equator, or as the radius is to the secant of the latitude (Art. 65); and since, in the present projection, the meridians are drawn at equal distances through their whole length, and the degrees of longitude therefore made throughout *equal* to their dimensions upon the equator, it becomes necessary, in order to preserve a due proportion between them and the degrees of latitude, to *increase the length* of the latter in a corresponding ratio.

(112) The theory of Mercator's projection consists, in fact, in regarding the globe as circumscribed by a *cylinder*, which touches the sphere at the equator: if we then suppose the hollow interior of the sphere to be inflated, and its surface made to expand uniformly in every direction until it touched the *interior* of the cylinder, the parallels of latitude would become circles inscribed within the cylinder, and the meridians would be lengthened out into straight lines parallel to each other, and in the direction of its length. If the cylinder were then cut open along one of these meridians, and spread out or developed into a flat surface, the inside of it would represent the parallels and meridians for a map of the world on Mercator's projection.

(113) In order to form this projection, it is necessary to ascertain the increased length of a degree of latitude, or that measured upon the meridian, which is proper to each

parallel. We have seen that this is in the same proportion as that in which the degrees of longitude diminish upon the globe, or as the radius of the equator is to the secant of the latitude. If, therefore, we assume 1′ of the equator (or 1′ of longitude) as the radius of a circle, we have this proportion; radius : the secant of the latitude : : the length of 1′ of longitude : the length of 1′ of latitude at the given parallel. Since the first and third terms in this proportion are equal, the second and fourth will of course be so likewise, and therefore the length of a *minute of latitude at any parallel* will be expressed by the number which is given as the natural secant of that latitude in the Trigonometrical Tables; the Tables of Natural Sines, &c. being calculated to a radius taken as 1. By adding together the secants of 60′, we shall have the whole length of one degree of latitude, and thus by the continual addition of the secants of each minute we may obtain the whole number of minutes of the equator corresponding to any number of degrees measured upon a meridian. A table thus constructed is called a *Table of meridional parts*, or a table of increasing latitudes; and by means of a table thus formed, Edward Wright, an English mathematician, explained, in the year 1599, the principles on which the chart bearing Mercator's name might be constructed,—Mercator himself, who first published his chart in 1566, having never made public the mode by which he had constructed it.

A table thus formed, although sufficiently correct for all practical purposes, does not, however, give *exactly* the true length of the increased meridian, for the cosines of latitudes which differ only by 1′ are not exactly equal, and the secants of such do not increase in any regular proportion; and it was subsequently shown that the increased meridian is analogous to a scale of logarithmic tangents of half the complements of the latitudes.[1] Tables of meridional parts for every successive minute of latitude have been long since calculated by the latter proportion, and from such is derived the Table (No. IV.) given at the end of this volume, which shows the number of minutes of longitude comprised between the equator and every degree of latitude up to 89°.[2] A slight difference in the length of the increased meridian is also occasioned by the deviation of the earth from a true spherical figure; we have accordingly added to the Table a column showing the length of the increased meridian on the supposition of the spheroidal figure of the earth. The use to be made of this Table will be seen in the construction of a map on the principles which have been explained.

(114) *To draw the Parallels and Meridians for a Map of the World on Mercator's Projection.* Draw a line, A B, (Plate V. fig. 1) of any length to represent the equator, and, assuming a space for 10° upon that circle, set off thirty-six such spaces upon the line drawn: the whole extent comprised within these divisions will then be 360°, or the circumference of a great circle. At the extreme divisions raise the perpendiculars $a\ a'$, $b\ b'$, which will represent the outer meridians of the map.

Now, by the properties of the projection, the parallels

[1] This was first ascertained by Henry Bond, about the year 1645.

[2] Since an arc of 90° has no secant, it is obvious that these tables cannot be carried up as far as 90°, or to the position of the pole, which is in fact at an infinite distance; so that a whole hemisphere cannot be comprised within the limits of Mercator's chart. It is, however, never requisite in practice to go beyond the 83rd parallel, since that latitude constitutes the limit of our knowledge of the lands on the surface of our globe.

are to be represented by straight lines parallel to the equator, and placed at distances from it which increase in proportion as the spaces comprised between the meridians diminish upon the sphere (Art. 111). To find the distance of the parallel of 10°, therefore, refer to the table (No. IV.), by which it appears that 603 meridional parts (or *minutes of the equator*) are comprised between the equator and that parallel. Now, since each of the divisions measured off upon the equator represents 10°, it of course contains 600′; if, therefore, we increase one of these spaces by 3′, we shall have the correct distance of the parallel of 10° from the equator. It will facilitate the measure of these small quantities if we construct a *diagonal scale*, C D F E (fig. 2), upon the space assumed as 10°, in a similar manner to that formed in a previous instance (Art. 99); the diagonal divisions of the lines C E, D F, will each represent 100 parts, and the divisions of the line C D will divide them into tens; and by careful measurement there will be no difficulty in setting off from it even smaller quantities. When the length of 603′ of the equator has thus been ascertained, it must be set off from the point A on each side of the equator towards a and a', and from the point B towards b and b': straight lines drawn between the points thus found, as from 10 to 10 (both north and south of the equator), will then represent the tenth parallel of north and south latitude.

In a similar manner, the parallel of 20° will be found by the Table to be 1,225 meridional parts from the equator: this distance, consisting of two of the equal divisions of 10° on the equator, with the addition of 25 parts $(600 \times 2 + 25 = 1{,}225)$, must also be ascertained, by adding the 25 parts (taken from the diagonal scale) to two of the divisions of the equator, and then set off from the points

A and B towards *a a′* and *b b′*. Lines drawn through the points thus determined, as 20, 20, will then be the parallels of 20° north and south latitude. The distance of the parallel of 30° will similarly be found to be 1,888 parts ($=600 \times 3 + 88$), the length of which must be in like manner set off from A and B, and lines drawn between the points 30, 30 to represent that parallel: and so on for the rest of the parallels.

The points through which to draw lines to represent the Tropics and Polar Circles will be found in a similar manner, by setting off from the equator the number of meridional parts given in the Table for the latitudes of 23½° and 66½°. If the parallels be drawn to the 65th degree of south and the 80th of north, latitude, as in the Plate, the map will comprise nearly all the known *land* on the surface of the globe, although it may be extended further on each side of the equator at the pleasure of the student.

Straight lines drawn perpendicular to the equator, through each of the divisions of that line, and extending to the extreme parallels north and south, will constitute the meridians at 10° apart. Any one of these may be chosen as a first meridian, and it is usual to make the meridian of Greenwich, which serves for this purpose, correspond with that in the middle of the map; in which case the extreme meridians will each be 180° distant from that meridian, measuring on the one side east, and on the other west, longitude.[1] The meridians should be numbered on the out-

[1] The selection of the particular line to be used as representing the meridian of Greenwich may be advantageously varied according to the special purpose which the map is required to serve. For the ordinary purposes of a Map of the World, no better arrangement can be made than that above suggested; but if it be desired to exhibit more fully the aqueous portion of the globe, and to show the con-

side of the map, 10, 20, &c., on each side of the first meridian, and the parallels on each side of the equator: the spaces between the parallels and meridians being then divided round the border into single degrees (or, if the scale be very small, into spaces representing two or more degrees), the projection will be complete. In thus dividing the spaces between the parallels, it should, however, be particularly observed that *each degree* must be accurately measured off from the equator, according to its distance as given in the Table of meridional parts: thus, to divide the space between 60° and 70° will not give the position of the 65th parallel, for the ratio of increase is continually greater as the distance from the equator increases. Finally, it may be observed that if the projection be not made of a large size, it will be sufficient to draw the meridians and parallels at 20° instead of 10° apart; still, however, taking care to ascertain from the Table the true distance of each degree of the latter from the equator.

(115) Mercator's projection, although chiefly valuable from its application to the purposes of nautical maps, or *charts*, is nevertheless frequently used for geographical representations either of the whole or a part of the earth. The same principles and mode of construction are of course

tinuity and vast extent of its waters, it will be desirable to make the extreme meridian on either side represent that of 20° west of Greenwich, in which case the middle meridian would be that of 160° east. It is frequently found desirable, in a Map of the world on Mercator's projection, to extend its limits in the direction of east and west *beyond* the measure of 360°,—that is, to repeat at one extremity of the map a portion of the countries (comprised within ten or more degrees of longitude) which have been shown at the other extremity, thus making one end of the map overlap the other, for the sake of exhibiting the continuity and relative bearings of all the different portions of land and water.

applicable to it, whether it be made to comprehend a large or a small portion of the globe; and in making use of maps thus projected, the student should be especially careful to observe the defects which of necessity belong to them. From the true proportions being preserved throughout between the meridians and parallels, the figures of the objects delineated on it are in every part correct; but as the lengths of the degrees (both of latitude and longitude) at a distance from the equator are enormously exaggerated beyond their true magnitude, the *sizes* of the objects in those parts of the map are increased accordingly,—so that the whole map gives a most inaccurate notion of the relative magnitude of different parts of the globe. Thus, in a Map of the World drawn on Mercator's projection, the size of Greenland (between the 60th and 80th parallels) appears to be nearly as great as that of South America, which extends between the 12th parallel of north and the 56th of south latitude. From the inequality of the spaces which represent degrees upon the meridians, and the exaggerated size of those upon the parallels, no one scale of measurement can be applied throughout the map; and the distance between any two places upon it can therefore be only ascertained by the aid of numerical calculations.

None of these defects, however, at all detract from the great utility of Mercator's projection as the basis of nautical charts, this utility consisting in the fact of *a straight line drawn through any part of it intersecting all the meridians at the same angle*, thereby showing correctly all the relative bearings, and enabling a ship's course to be readily laid down, on whatever point of the compass she may be sailing. This property, which had hitherto been a desideratum in navigation, rendered its invention one of the most remarkable and useful events of the sixteenth century, and has deservedly consigned to immortality the names of those who were engaged in its first construction and subsequent improvement.

(116) Although not rendered (strictly speaking) requisite by the immediate purposes of the present work, it may be desirable, while describing the construction of Mercator's Chart, and its important uses in navigation, to add a few remarks on the subject of Great-Circle Sailing, to which attention has been extensively directed of late.

It is well known, as remarked in a preceding page, that the shortest distance between any two points on the sphere is measured by the arc of a great circle passing through them. If a vessel, therefore, in passing from the one point to the other, could sail continually on the line of a great circle joining the respective points, she would pursue the shortest possible course, and would accomplish the voyage (other circumstances being equal) in the smallest amount of time. And should it (as may often happen) be impossible to follow absolutely and undeviatingly the direction of a great circle, still, the more nearly she can keep to such a course between any two given points, by so much will she approximate towards the directest line, and shorten the distance accordingly. The truth of these propositions is obvious; but their application in the practice of navigation involves an apparent difficulty,—though one that may be readily overcome,—from the fact that on a Mercator's Chart (which alone shows correctly the relative bearings of places, and is therefore the only one suited to the purposes of the navigator), the equator and the various meridians are the only great circles which coincide with rhumbs, and which are represented by straight lines. *All other great circles* on the sphere become represented by curvilinear lines on the chart, and the direction (or bearing) which a ship must pursue in following their courses can only be found by continually ascertaining the angle of their intersection with the successive meridians under which they pass. The bearing of a great circle's course (excepting only in the cases of the equator, or of a meridian) is, in fact, continually varying; while it is the essential property of a rhumb line that it intersects all the meridians at the same angle, and is always represented by a straight line upon the chart (Art. 111).

In all cases, then, excepting the rare ones where the two points between which a ship's course lies are either directly north and south, or else are *both* of them exactly under the line of the equator, a straight line drawn between them on the chart does not represent an arc of the great circle by which they are connected, and therefore fails to show the successive bearings which it is necessary for the ship to pursue in order to follow such a course. But in order to facilitate the practice of Great-Circle Sailing, Tables have been constructed which show, with the aid of a trifling mechanical measurement, the requisite bearings, and enable the desired course to be readily followed.[1] By means of these Tables, the track of a Great Circle between any given points may also be traced on the chart with comparative facility, and the length of distance which it passes over be easily computed.

The saving in the amount of distance passed over which is accomplished by Great-Circle Sailing, as compared with the ordinary practice of Mercator's (or Rhumb) Sailing, is in many cases very considerable, and is equally great when the ship has to contend against adverse winds, and is consequently obliged continually to change her tack, as when

[1] Tables to facilitate the practice of Great-Circle Sailing, &c., by J. T. Towson. London, 1852.

she is enabled to pursue more nearly a direct course. Thus, in the case of a voyage from the mouth of the English Channel to New York, supposing a due west or adverse wind to last during the entire voyage, and presuming the ship to advance at the rate of 150 miles a day, the length of time occupied by her following throughout the tack nearest to the rhumb course (or that which would be pursued in the ordinary practice of navigation) would be forty-nine days, while by pursuing the tack *nearest* to the great-circle course the time would be diminished to forty-three days eight hours;—the distance passed over being in the former case 7361 miles, and in the latter 6488 miles, a difference of 873 miles in favour of the great-circle course.

The saving of distance (and consequently of time) is still greater in cases where the difference in latitude, as well as the meridional difference, between the two points is more considerable than in the instance here referred to. But in many such cases to follow rigidly the great-circle track would carry the vessel into latitudes so high as to be unfavourable for navigation, and hence it is often found desirable to follow a partially intermediate course, or to act on the principle of "composite great-circle sailing," as it is termed;—that is, to fix a maximum latitude, upon reaching which the ship's course may be conducted for a time by the rules of parallel sailing, the other portions of her voyage being made on, or as nearly as possible on, the track of a great circle. But for fuller details on these points the student must consult works treating directly on navigation, such as have been already referred to.[1]

[1] Notes to pages 43 and 139.

CHAPTER XII.

PRACTICAL SUGGESTIONS ON MAP-DRAWING.

(117) The inquiries hitherto pursued in this work have related chiefly to the *principles* involved in the subject of map-drawing, and to the mathematical laws by which all representations of the earth's surface upon a plane must be regulated. After having formed the projection of his map by one or other of the methods which have been described, the next business of the geographer is to draw upon it the details of land and water, &c., embraced within the portion of the globe which it is intended to represent. The *student* of geography (who uses maps chiefly as an exercise, and as a means by which to acquire a knowledge of his subject,) will probably use for this purpose some map of similar character to that which he is desirous of drawing, making the one serve—more or less directly—as a copy for the other. In doing this, he should be aware that it is by no means requisite for the map which he proposes to follow to be of the same scale of dimensions as that which he is about to draw, or that it be even constructed on a projection of a similar kind. The *parallels and meridians*, the only true test of comparison, must serve as the land-marks (so to speak) by which to transfer from one map to another the coasts, rivers, mountains, towns, or other features, which may be delineated upon either.

Whatever features of land or water may fall within the space comprised within any two consecutive parallels and meridians of the map used as a copy, should be represented upon the *similar space* contained in the map which is in process of being drawn; and the smaller the correspondent spaces upon each, the more accurately can the delineation be made, as the consequent greater proximity of the parallels and meridians will afford to the eye a more constant means of comparison. Hence, in drawing from one map on to another, it is usual to divide the spaces *on each* into single degrees (or even half or quarter degrees, or yet smaller subdivisions, as the case may require), by means of pencil-lines lightly drawn, so that they may be erased without injury to the drawing when they have served their temporary purpose.

(118) Proceeding on the principle above referred to, the student may either enlarge, or reduce, the scale of any map which he is desirous of following as a copy—always taking care that whatever comes within the space comprised between certain parallels and meridians on the one must be shown in the similar space on the other, though the correspondent spaces may be of widely different dimensions. But it is always desirable to avoid *enlarging* maps, because any errors of delineation which may be contained in the original will of necessity be transferred thence to the copied drawing, and will run the risk of being greatly exaggerated in the process. In *reducing* maps, on the other hand—that is, in using a map on a large scale as a copy for one to be drawn of smaller proportions—any errors in the former become diminished in the process, and a much more truthful result is obtained, even though the diminution of scale may make it requisite to omit some of the minuter details of the work. It will, indeed, be found easier to *reduce* a map, or to draw from a large scale

on to a smaller one, than to follow as a copy one on a scale similar to the drawing about to be made, because in the former case the eye more readily catches the salient points of the coast, the bends of the rivers, and other prominent features, owing to their enlarged size, and is enabled to transfer them with the greater fidelity to the reduced drawing.

Again, in drawing any map, as *Europe*, for example, the student may find it desirable to make use of several different maps as data from which to copy its various portions. Thus, he may use separate maps of England, France, Italy, or other countries, as materials from which to fill up the respective parts of his drawing—it being for this purpose immaterial on what kind of projection they have been constructed, so long as the parallels and meridians are always used as the true data of comparison.[1]

(119) Turning from the consideration of maps as mere geographical exercises for the learner, to the subject of their higher qualities and value, we find them associated with scientific inquiries of the greatest interest; and we may express regret that the kind of labour which the production of *really good maps* involves, and the critical discrimination which selects and combines the various data upon which they are based, are so little appreciated by the majority even of those to whom the casual use of maps is most

[1] In map-drawing, the outline of the countries, rivers, and other features, should first be sketched in with the pencil only, and whatever colouring it may be intended to apply to it should be done while in this state, as to attempt to colour it after having been drawn in ink would involve the risk of *washing-up* the ink (especially in the case of Indian ink, which it is always preferable to use), and so defacing the drawing. The hills should be shaded either with *sepia*, or with a light tint of *Indian ink*, the shape and direction of the ranges having been first drawn in with the pencil.

familiar. A good map is a geographical document of the highest value, and represents an amount of labour of more various description—some of it of a kind which involves scientific acquirements of the first order—than is, probably, to be found combined in any other document whatever. The labours of the astronomer and the mathematician, of the land-surveyor and the hydrographer, the observant traveller and the statistician—to make but a passing reference to the too often more merely mechanical labour of the *map-maker*—are represented in the conventional signs and marks by which it is covered, and the information which it professes to convey.

The most precise and complete elements for a geographical map are found in topographical surveys, the details of which may be abridged, condensed, and reduced into such form as the geographer may specially require. Thus, he may be desirous of drawing a map to illustrate more especially the *physical features* of a particular tract of country—to show the form and connection of its mountain-ranges—or to illustrate its hydrography. Or he may wish to delineate more particularly its artificial divisions—its counties, townships, or parishes—its towns, villages, and hamlets. For all of these purposes a really good topographical survey affords the best and completest materials. If every portion of the globe had been actually surveyed in such a manner, the making of maps would be a task much simplified, and would, indeed, become to some extent merely mechanical—although even then the labour of selection would require the exercise of critical judgment and discrimination.

Few countries, however, present us with sources of information such as those above referred to, and, in regard to most parts of the globe, the best maps which we possess have been compiled from a variety of materials, amongst which the *itineraries* of observant travellers, combined with the ascertained latitudes and longitudes of a few leading points, hold a prominent place. By carefully estimating his *rate* of travel, and observing with a compass the *direction* of his route, and the bearing of conspicuous land-marks on either side, the explorer of any little-known region accumulates information, which, in the hands of the practised map-maker, often supplies the means for a first delineation of its surface; a delineation which becomes the more complete as the number of such routes, starting from different localities, and intersecting one another at various known points, is greater.

Again, the maritime surveys carried on in different parts of the world, both by our own and foreign governments, supply accurate delineations of the coasts of many regions, the interior of which is only known by vague and indistinct native reports, or by the occasional visits of adventurous travellers. And the positive knowledge of any one or more points (as a mountain-peak, or a prominent headland) as *fixed* sites—that is, the knowledge of their true latitudes and longitudes—enables numerous other positions to be deduced, with greater or less accuracy, according to the kind of observations which have been made from them.

(120) It is the business of the geographer, in preparing a map of any country, to consider carefully the materials at his command, to ascertain their relative value and trustworthiness, to compare and combine them in such manner as he may find requisite, and, in fine, to *compile* from them the best delineation for which—as a whole—they afford the means; always bearing in mind the particular nature of the object which his work is designed to accomplish, and which may (as already remarked) make it

requisite to give especial prominence to a certain class of features. The use of maps in illustration of different subjects is almost infinitely varied in its application; and the frequency with which they are employed in the present day for *special* (instead of merely general) purposes is favourable evidence of a more extended appreciation of their true utility and their real value—both as an adjunct to geography, and for various purposes more or less connected with that science. Thus, by the aid of colouring, combined with particular styles of engraving or lithographic drawing, we have special maps to illustrate particular subjects of physical geography, as currents, tides, winds, rains, and other atmospheric phenomena—as well as maps to exhibit the localities of particular industrial pursuits, the comparative densities of population, the ratios of crime, and, in fact, the *localised* details of almost every phenomenon of social life.

(121) In estimating the comparative merits of different maps, the student who has perused, and maturely considered, the above remarks, will, we trust, see the necessity of exercising a criterion of judgment very different from that which is too commonly employed. It is no evidence of the value of a map that it is full of names, and may thus appear, at first sight, to possess a laborious completeness. On the contrary, the presumption lies in most cases the other way, and the mere numerical abundance of the names will very often be found in an inverse ratio to their critical value.

The really *best* maps (and especially the maps most adapted for educational purposes) are those in which the names,—whether few or many in number—have been *selected* with care, and so arranged as to combine with the other features of the work in presenting clear and definite information concerning the geography of the countries which they profess to represent. It is the common fault of maps that they attempt to teach *too much*; and an almost equally common fault, that they are put together in almost entire disregard of sound geographical criticism, and in defiance of the simplest standards of comparison. It is an absurdity to see, in a Map of Asia, the barren and frozen plains of Siberia covered over with names in a similar manner to the populous plains of China and India; as, in a Map of the World, it is equally absurd to observe but little (if any) difference between the comparative abundance of the names written around the shores of the Mediterranean, and those spread over the deserts of Northern Africa and Arabia.

The truth is, that *no name whatever* should be written upon a map *unless there be a positive reason* for its being thus written; so that it may have a real purpose to serve, and *that* a purpose connected with the general or special objects of the map in question. It is the amount of information brought to his task, and the skill exhibited in the judicious selection and arrangement of his matter, that mark the difference between the *geographer* and the *map-maker*—a difference often of wide extent.

(122) In drawing any number of maps—especially in a case where they are designed to form parts of a general series—it is always desirable to preserve as great an *equality of scale* as possible; for maps of different countries drawn to various scales of measurement are sure to give erroneous notions of their relative magnitudes, especially to learners. Thus, in a series of maps of the continental divisions of the globe, of the principal countries of Europe, or of the counties of England, great and obvious advantages would in either case result from the facility of

comparison between different members of the series, if a positive uniformity of scale in the objects delineated were preserved throughout—advantages so great as to more than counterbalance the inconvenience felt from some of them occupying a larger sheet of paper than others. Desirable as this may be, and however feasible in theory, the inequalities in magnitude which so often obtain in provincial as well as in other divisions (and of which our own counties offer a sufficiently striking example) forbid its complete realisation. But where perfect uniformity of scale is unattainable, the same advantages may be in some degree realised by delineating the smaller countries (in such cases as Greece, and other instances in which their importance renders it desirable) on a scale which bears a fixed ratio to that of other members of the series —that is to say, on a scale which is exactly double, or five times, or which bears some definite proportion to, that of the maps representing countries of larger superficial extent. This consideration is deserving of especial regard in relation to maps used in school tuition, for, in some of the most popular collections of maps, scarcely any two of the series are drawn on the same scale, their dimensions in this respect having been, in fact, treated as a mere matter of accident, and made entirely subsidiary to the map-maker's convenience.[1]

(123) In terminating our inquiry into the mathematical principles involved in those relations of geography which

[1] The justice of the remark on this subject made in a former edition of the present work (1843) may be assumed as admitted, from the fact of the appearance, during the interim, of more than one collection of maps in which the defect complained of is in a great degree remedied. But in the majority of instances the evil still exists.

we have been engaged in considering, it may be finally observed that they constitute a portion of the subject which cannot be too carefully studied—too fully investigated—or too extensively applied in practice. The foundation of all Geography is furnished by the exact representation of *localities*; and if some of the details given in the present volume may seem in themselves to be deficient in that combination of *interest* with utility which we would claim for every part of our subject, the student must regard the former of these qualities as attaching to them from the consideration that they constitute the only safe basis of the elevation from which he can view the physical diversities of our planet, and the political, moral, and social features of its inhabitants.[1]

[1] Of the following Tables, Nos. II. and IV. are from Mendoza's Tables for Navigation and Nautical Astronomy (London, 1809), and Table III. is calculated from one given in Dr. Pearson's Introduction to Practical Astronomy, computed from a formula given by Lieut.-Colonel Lambton. To these has been added another, No. V., which shows the superficies of each zone of the globe which occupies a breadth of 1° of latitude: this has been calculated by the Author upon the geometrical principle that the surface of a spherical zone is to the area of the sphere as the distance of the parallels which bound it (or the difference between the sines of the latitude of each parallel) is to the diameter of the sphere. This Table will be found extremely useful in calculating the dimensions of any part of the earth; for it is obvious that the part of a zone which is comprised between any two meridians will bear the same relation to the entire zone which the difference of longitude does to the entire circumference, and thus by observing the number of degrees of latitude and longitude which any country occupies, and ascertaining from the Table their value in square miles, the whole extent of its surface may be readily and accurately found. In a similar manner, the relative proportion of land and water contained in any zone of the earth's surface, or in its whole extent, may be ascertained.

TABLE I.

PRINCIPAL ELEMENTS OF THE SOLAR SYSTEM.

1. SUN AND LARGER PRIMARY PLANETS.

Names	Equatorial diameters in English miles	Mean distances from the sun, in English Miles	Periods of revolution round the sun, in mean solar days
THE SUN	882,000		
Planets.			
Mercury	3,140	36,784,000	87·969
Venus	7,800	68,734,000	224·701
Earth	7,926	95,025,000	365·256
Mars	4,100	144,789,000	686·979
Jupiter	87,000	494,394,000	4332·585
Saturn	79,160	906,423,000	10759·219
Uranus	34,500	1,822,807,000	30686·821
Neptune	41,500	2,854,247,000	60126·710

2. SATELLITES.

Names	Diameters in English miles	Mean distance from Primary, in English miles	Periods of revolution round their Primaries, in mean solar days
THE MOON	2,153	237,000	27·321
Satellites of Jupiter.			
1st.	2,508	263,000	1·769
2nd.	2,068	418,000	3·551
3rd.	3,377	667,000	7·154
4th.	2,890	1,170,000	16·688
Satellites of Saturn.			
1st.	..	133,000	0·942
2nd.	..	170,000	1·370
3rd.	..	210,000	1·887
4th.	..	270,000	2·739
5th.	..	378,000	4·517
6th.	..	876,000	15·945
7th.	..	? 1,108,000	? 22·500
8th.	..	2,547,000	79·329
Satellites of Uranus.			
1st.	..	..	? 4·000
2nd.	..	293,000	8·705
3rd.	..	? 341,000	? 10·958
4th.	..	393,000	13·463
5th.	..	? 767,000	? 38·083
6th.	..	? 1,569,000	? 107·500
Satellite of Neptune.			
1st.	..	? 249,000	5·868

TABLE I.—*continued.*

3. MINOR PLANETS, OR ASTEROIDS, WITH THE DATES OF THEIR DISCOVERY.

	Names.	Date.		Names.	Date.
1	Ceres	1801	40	Harmonia	1856
2	Pallas	1802	41	Daphne	1856
3	Juno	1804	42	Isis	1856
4	Vesta	1807	43	Ariadne	1857
5	Astræa	1845	44	Nysa	1857
6	Hebe	1847	45	Eugenia	1857
7	Iris	1847	46	Hestia	1857
8	Flora	1847	47	Aglaia	1857
9	Metis	1848	48	Doris	1857
10	Hygeia	1849	49	Pales	1857
11	Parthenope	1850	50	Virginia	1857
12	Victoria	1850	51	Nemausa	1858
13	Egeria	1850	52	Europa	1858
14	Irene	1851	53	Calypso	1858
15	Eunomia	1851	54	Alexandra	1858
16	Psyche	1852	55	Pandora	1858
17	Thetis	1852	56	Melete	1858
18	Melpomene	1852	57	Mnemosyne	1859
19	Fortuna	1852	58	Concordia	1860
20	Massilia	1852	59	Olympia	1860
21	Lutetia	1852	60	Echo	1860
22	Calliope	1852	61	Danae	1860
23	Thalia	1852	62	Erato	1860
24	Themis	1853	63	Ausonia	1861
25	Procea	1853	64	Angelina	1861
26	Proserpine	1853	65	Maximiliana	1861
27	Euterpe	1853	66	Maia	1861
28	Bellona	1854	67	Asia	1861
29	Amphitrite	1854	68	Leto	1861
30	Urania	1854	69	Hesperia	1861
31	Euphrosyne	1854	70	Panopea	1861
32	Pomona	1854	71	Niobe	1861
33	Polyhymnia	1854	72	Feronia	1861
34	Circe	1855	73	Clytie	1862
35	Leucothea	1855	74	Galatea	1862
36	Atalanta	1855	75	Eurydice	1862
37	Fides	1855	76	Freia	1862
38	Leda	1856	77	Frigga	1862
39	Lætitia	1856	78	Diana	1863

TABLE II.

The Number of Geographical Miles, or Minutes of the Equator, contained in a Degree of Longitude under every Parallel of Latitude, on the supposition of the Earth being a Sphere.

Parallel of Latitude	Length of Degree	Parallel of Latitude	Length of Degree	Parallel of Latitude	Length of Degree
°	′	°	′	°	′
0	60·000	30	51·962	60	30·000
1	59·991	31	51·430	61	29·089
2	59·963	32	50·883	62	28·168
3	59·918	33	50·320	63	27·239
4	59·854	34	49·742	64	26·302
5	59·772	35	49·149	65	25·357
6	59·671	36	48·541	66	24·404
7	59·553	37	47·918	67	23·444
8	59·416	38	47·281	68	22·476
9	59·261	39	46·629	69	21·502
10	59·088	40	45·963	70	20·521
11	58·898	41	45·283	71	19·534
12	58·689	42	44·589	72	18·541
13	58·462	43	43·881	73	17·542
14	58·218	44	43·160	74	16·538
15	57·956	45	42·426	75	15·529
16	57·676	46	41·680	76	14·515
17	57·378	47	40·920	77	13·497
18	57·063	48	40·148	78	12·475
19	56·731	49	39·364	79	11·449
20	56·382	50	38·567	80	10·419
21	56·015	51	37·759	81	9·386
22	55·631	52	36·940	82	8·350
23	55·230	53	36·109	83	7·312
24	54·813	54	35·267	84	6·272
25	54·378	55	34·415	85	5·229
26	53·928	56	33·552	86	4·185
27	53·460	57	32·678	87	3·140
28	52·977	58	31·795	88	2·094
29	52·477	59	30·902	89	1·047
30	51·962	60	30·000	90	0·000

TABLE III.

The Number of Geographical Miles, or Minutes of the Equator, contained in a Degree of Longitude under each Parallel of Latitude, on the supposition of the Earth's spheroidal shape; with a compression of $\frac{1}{304}$.

Parallel of Latitude	Length of Degree	Parallel of Latitude	Length of Degree	Parallel of Latitude	Length of Degree
°	′	°	′	°	′
0	60·000	30	52·004	60	30·074
1	59·991	31	51·475	61	29·161
2	59·964	32	50·930	62	28·240
3	59·918	33	50·370	63	27·310
4	59·854	34	49·793	64	26·372
5	59·773	35	49·202	65	25·426
6	59·673	36	48·596	66	24·471
7	59·556	37	47·975	67	23·509
8	59·419	38	47·339	68	22·540
9	59·266	39	46·688	69	21·564
10	59·094	40	46·021	70	20·581
11	58·905	41	45·346	71	19·592
12	58·697	42	44·654	72	18·596
13	58·472	43	43·948	73	17·595
14	58·229	44	43·229	74	16·588
15	57·968	45	42·495	75	15·577
16	57·690	46	41·750	76	14·560
17	57·394	47	40·992	77	13·539
18	57·081	48	40·220	78	12·514
19	56·751	49	39·437	79	11·485
20	56·403	50	38·642	80	10·452
21	56·038	51	37·834	81	9·416
22	55·657	52	37·015	82	8·377
23	55·258	53	36·185	83	7·336
24	54·842	54	35·343	84	6·292
25	54·410	55	34·400	85	5·246
26	53·962	56	33·627	86	4·199
27	53·496	57	32·754	87	3·150
28	53·015	58	31·870	88	2·101
29	52·518	59	30·977	89	1·050
30	52·004	60	30·074	90	0·000

TABLE IV.

Showing the Number of Meridional Parts contained between the Equator and every Degree of Latitude from 0° to 89°, both on the Sphere and on the Spheroid; the Earth's compression being assumed as $\frac{1}{321}$.

Degrees	Meridional Parts		Degrees	Meridional Parts	
	Sphere	Spheroid		Sphere	Spheroid
1	60·00	59·63	31	1958·01	1946·98
2	120·02	119·27	32	2028·38	2017·03
3	180·08	179·04	33	2099·53	2087·87
4	240·19	238·70	34	2171·48	2159·51
5	300·38	298·52	35	2244·29	2231·99
6	360·66	358·43	36	2317·99	2305·39
7	421·05	418·44	37	2392·63	2379·74
8	481·57	479·04	38	2468·26	2455·08
9	542·23	538·89	39	2544·93	2531·46
10	603·07	599·36	40	2622·69	2608·93
11	664·09	660·02	41	2701·60	2687·76
12	725·32	720·87	42	2781·71	2767·38
13	786·78	781·97	43	2863·10	2848·48
14	848·49	843·31	44	2945·81	2930·94
15	910·46	904·92	45	3029·94	3014·78
16	972·73	966·82	46	3115·55	3100·14
17	1035·30	1029·04	47	3202·71	3187·05
18	1098·22	1091·61	48	3291·53	3275·62
19	1161·49	1154·53	49	3382·08	3365·91
20	1225·14	1217·81	50	3474·47	3458·06
21	1289·20	1281·52	51	3568·81	3552·15
22	1353·69	1345·67	52	3665·19	3648·30
23	1418·63	1410·27	53	3763·76	3746·65
23° 28′	1449·10	1440·74	54	3864·64	3847·29
24	1484·06	1475·35	55	3967·97	3950·42
25	1549·99	1540·95	56	4073·90	4056·15
26	1616·47	1607·09	57	4182·62	4164·63
27	1683·52	1673·79	58	4294·30	4276·12
28	1751·16	1741·11	59	4409·14	4390·76
29	1819·44	1809·05	60	4527·37	4508·81
30	1888·38	1877·68	61	4649·23	4630·47

TABLE IV.—*continued.*

Degrees	Meridional Parts		Degrees	Meridional Parts	
	Sphere	Spheroid		Sphere	Spheroid
62	4774·98	4756·07	76	7210·07	7189·16
63	4904·94	4885·82	77	7467·21	7446·30
64	5039·42	5020·15	78	7744·57	7723·62
65	5178·81	5159·38	79	8045·71	8024·63
66	5323·51	5303·94	80	8375·20	8354·05
66° 32′	5403·03	5383·32	81	8739·06	8717·93
67	5474·01	5454·27	82	9145·46	9124·21
68	5630·82	5610·94	83	9605·82	9584·55
69	5794·56	5774·52	84	10136·89	10115·59
70	5965·92	5945·75	85	10764·62	10743·27
71	6145·70	6125·43	86	11532·52	11511·09
72	6334·84	6314·46	87	12522·11	12500·84
73	6534·42	6513·90	88	13916·43	13895·03
74	6745·74	6725·12	89	16299·56	16277·78
75	6970·34	6949·60	90	Infinite.	Infinite.

TABLE V.

Showing the Number of Square English Miles of Surface contained in each Zone of the Globe extending over One Degree of Latitude, from the Equator to the Poles; the whole surface of the Globe being taken as 196,861,755 Square Miles.

Degrees	Number of square miles contained between each two consecutive parallels.	Degrees	Number of square miles contained between each two consecutive parallels.	Degrees	Number of square miles contained between each two consecutive parallels.
0	1,717,855·050	30	1,480,301·967	61	819,712·662
1	1,717,343·206	31	1,464,769·574	62	793,234·756
2	1,716,280·152	32	1,449,863·144	63	766,520·615
3	1,714,705·258	33	1,432,543·305	64	739,589·927
4	1,712,618·522	34	1,415,770·683	65	712,206·457
5	1,710,019·949	35	1,398,584·652	66	368,771·439
6	1,707,870·160	36	1,380,945·839	66° 32′	316,258·409
7	1,703,228·218	37	1,362,913·302	67	657,419·831
8	1,699,054·749	38	1,344,447·670	68	629,603·265
9	1,694,349·753	39	1,325,588·313	69	601,609·523
10	1,689,251·033	40	1,306,315·548	70	573,458·292
11	1,683,423·926	41	1,286,649·058	71	545,090·313
12	1,677,203·094	42	1,266,588·845	72	516,584·931
13	1,670,450·736	43	1,246,134·909	73	487,902·174
14	1,663,186·537	44	1,226,133·755	74	459,081·612
15	1,655,449·870	45	1,204,105·124	75	430,123·248
16	1,647,161·990	46	1,182,528·876	76	401,046·767
17	1,638,401·642	47	1,160,598·477	77	371,812·797
18	1,629,149·140	48	1,138,333·412	78	342,500·081
19	1,619,365·110	49	1,115,694·310	79	313,069·249
20	1,609,128·298	50	1,092,740·230	80	283,520·299
21	1,598,379·647	51	1,069,431·798	81	253,931·978
22	1,587,138·841	52	1,045,788·701	82	224,225·539
23	736,696·059	53	1,021,850·312	83	194,460·042
23° 28′	838,729·507	54	997,596·943	84	164,655·172
24	1,563,239·824	55	973,048·283	85	134,791·243
25	1,550,561·927	56	948,184·643	86	104,868·257
26	1,537,431·248	57	923,025·711	87	74,925·584
27	1,523,808·415	58	897,610·858	88	44,963·225
28	1,509,732·799	59	871,900·713	89	14,981·180
29	1,495,204·402	60	845,934·647	90	
30		61			

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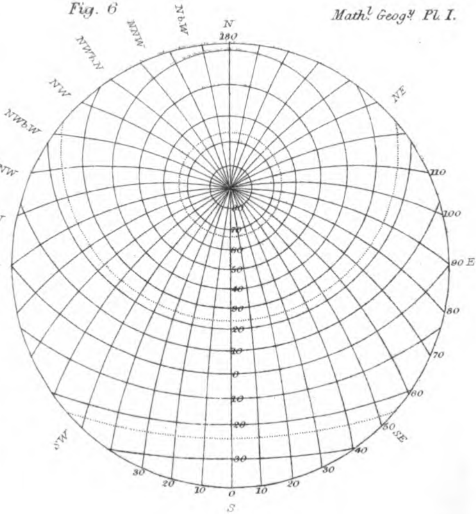
Fig. 6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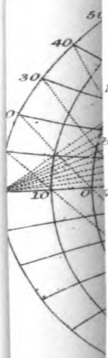
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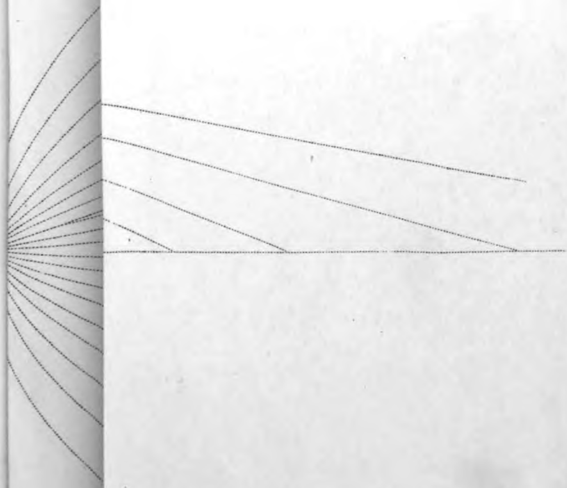

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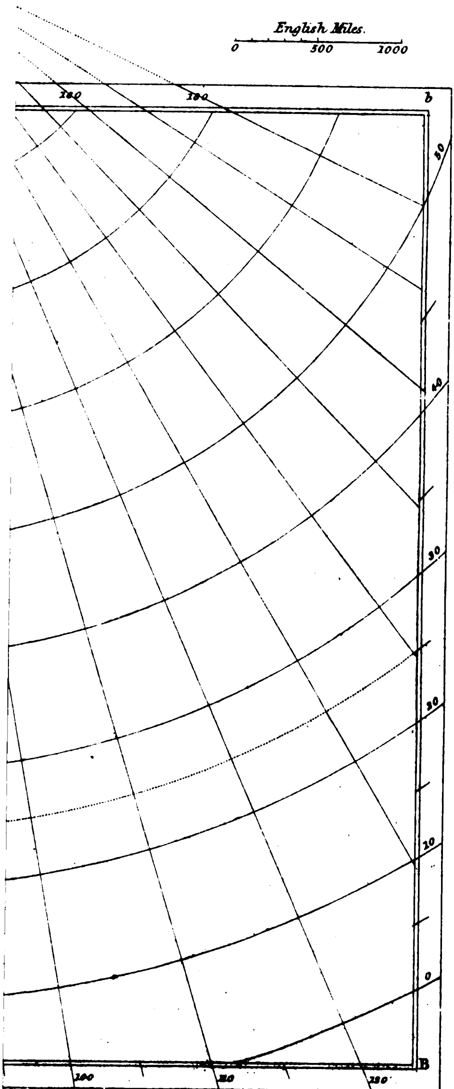

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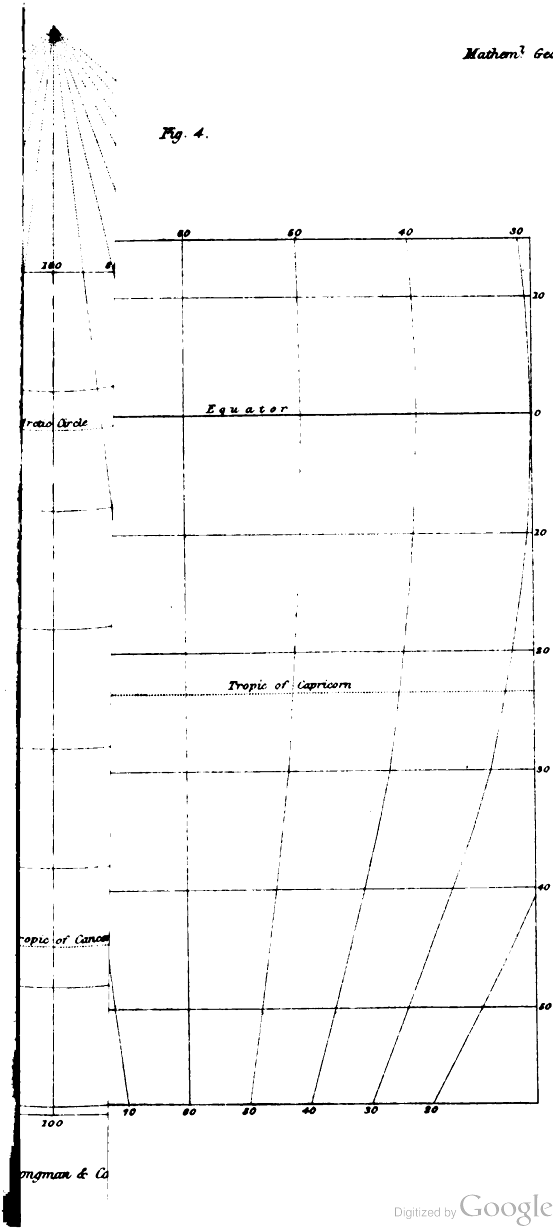

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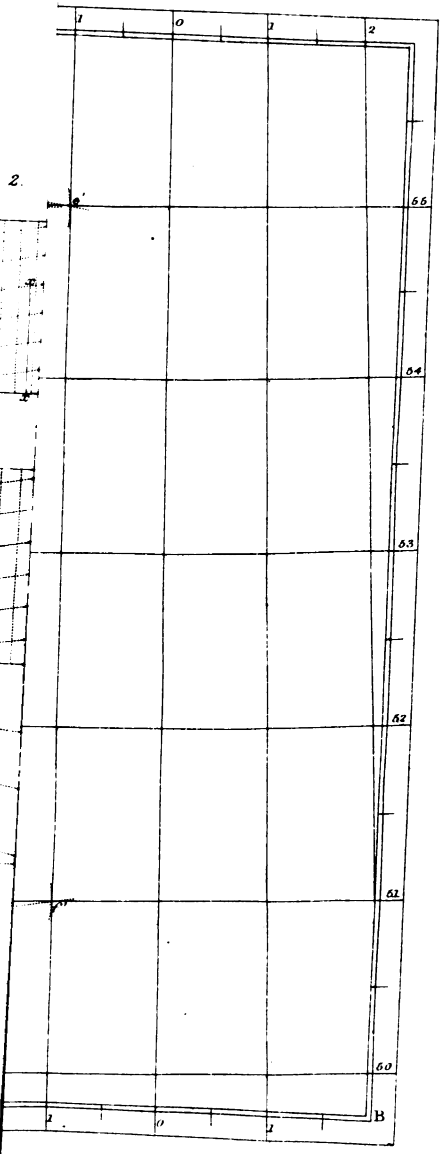
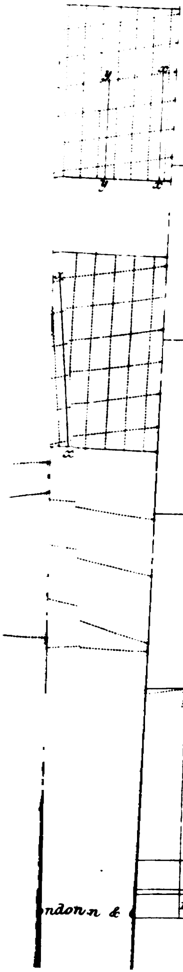


Fig. 2.



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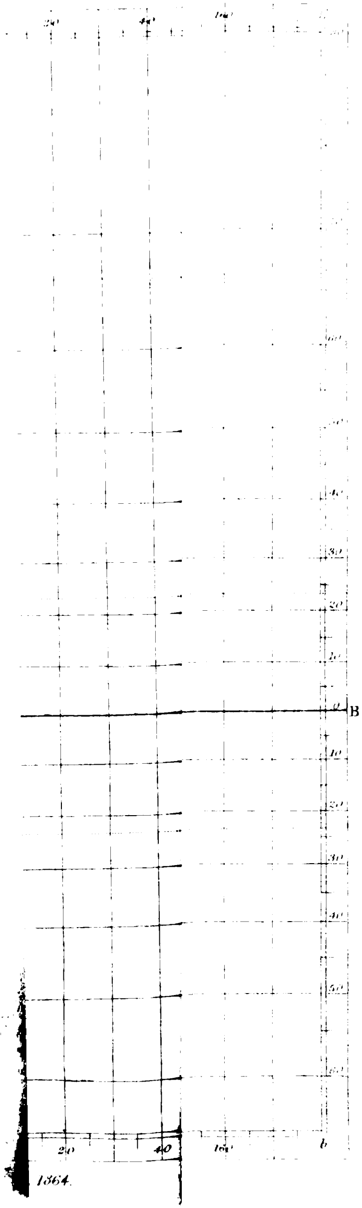
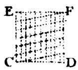


Fig. 2



book and the diffuseness of a treatise. Fuller details of individual events or places are often given in a smaller type, so as to leave unbroken the continuity of the main text; and frequent foot-notes contain valuable supplementary items of curious information. A copious index completes this very excellent and hitherto unique volume.' ECONOMIST.

'With his usual ability, Mr. Hughes has produced a manual, the early part of which will be read with special interest by students of English history. That history and geography should be read side by side ought not to be an open question; no one indeed will doubt the advantage of such a course, except those whose opinion on this matter is worthless. To have a clear acquaintance with the geography of history, is to double the chances of histories becoming a permanent acquirement. And for this reason we recommend Mr. HUGHES's "Geography of British History," as an almost indispensable manual for students of that particular subject. Of its construction we need say nothing, as the Author is so thoroughly trustworthy and so extensively known as a geographical writer.' PAPERS FOR THE SCHOOLMASTER.

'This work, which owes its origin to a series of lectures which the Author was called upon to deliver at King's College, London, on English History and Geography, fills a void which has long existed in our educational literature. On the Geography of the British Empire, Physical, Political, and Commercial, we have had treatises numberless; but few or none worthy of the name, on what may be called the "Geography of its History." The interweaving of History and Geography, in the way Mr. HUGHES recommends, is undoubtedly calculated to be of material assistance in the study of both these important subjects. Districts and particular places become associated in the mind with the great events of which they have been the theatre, and not unfrequently, as is well shown in the rise and progress of commercial and manufacturing towns, their history is intimately connected with the geographical peculiarities of the localities in which they are situated, and by which their fortunes have been mainly influenced. Keeping this important relation constantly before the reader, Mr. HUGHES, in the present work, begins by giving a general view of the situation, extent, and superficial aspect of the British Isles; their climate, animal and vegetable productions, &c. The history of Great Britain from the earliest times is next traced through the Roman, Saxon, Norman, and succeeding periods; and short notices are given of the chief battle-fields, the divisions of the country at various periods, the growth of its great towns, and the rise and extension of its commerce and manufactures. In this way the Geography and History of England, Scotland, and Ireland, are successively passed under review; each illustrating, and being illustrated by, the other. The value of the work is greatly enhanced by some carefully-executed maps, showing the extent and divisions of the British dominions at various periods of our history, and by a very complete and copious index.' EDUCATIONAL TIMES.

'Mr. W. HUGHES, the well-known geographer, who has been engaged for several winter sessions in conducting evening classes at King's College, having felt the want of a comprehensive work on geography, treated historically and politically, has now produced *The Geography of British History*. We have often regretted that authors of geographical publications should so insufficiently recognise the close connexion which ought to subsist between history and geography, and that in maps so many places of historical importance should be omitted simply because of their present insignificance in point of size, population, and productions. Mr. HUGHES is quite right in thinking that English students ought to feel no less interest in the topography of such places as Naseby, Clarendon, and Runnymead, than in that of Marathon and Salamis. In his account of the various battle-fields of England, he supplies an abundance of desirable information. We do not know where else to refer for so accurate and complete a description of the physical, historical, political, and industrial condition of our country and its dependencies as his present work contains.'

ATHENÆUM.

'A book of home geography—*The Geography of British History*, by WILLIAM HUGHES—just published, is new in its plan, thoroughly well done, and in the highest degree valuable and interesting. Divested of all dryness, while it is made unusually exact and complete, the geography of England, Scotland, and Ireland, illustrated by maps showing their political aspect at successive periods, is taught in direct connexion with their history. The British people live and move in the page as no insignificant part of the cities they fill with their industry, the ports from which they trade. No town is here a mere abstraction, but the land is explored for the signs and memories of that life upon it which alone has created its political geography. Mr. HUGHES treats not only of the industrial growth of the three kingdoms and the geographical evidences of it, of the battle-fields, and all other famous historical sites, but he also follows England abroad to her colonies, in connexion with a sketch of the history of colonisation.'

EXAMINER.

'Every student of history has frequently felt the want which it is the object of the volume before us to meet. He finds constant allusions and references which are almost unintelligible to him from lack of geographical knowledge; he encounters events which naturally lead him to consult the map, and his consultation is never more than partially satisfactory, because the map requires a commentary. Such a commentary Mr. HUGHES has furnished. We cannot recommend this volume too strongly; it will be found of more service than many historical works of infinitely loftier pretensions.' PARTHENON.

'Die vergleichende Erdkunde hat im letzten Menschenalter bei den europäischen Cultervölkern einen solchen Aufschwung genommen und einen solchen Einfluss auf den internationalen Verkehr gewonnen, dass eine Anpreisung ihres Werthes als überflüssige Wortvergeudung erscheinen könnte. Und doch fehlt es nicht an Klagen, dass die geographische Durchschnittsbildung noch immer eine sehr oberflächliche und namentlich die Bekanntschaft mit den früheren topographischen, physikalischen und ethnographischen Zuständen der grösseren Nationen des Morgen- und Abendlandes noch im Ganzen eine sehr lückenhafte ist. Der Unterricht in der Geographie, wie er selbst in den höheren und höchsten Lehranstalten ertheilt zu werden pflegt, trägt einen grossen Theil der Schuld, einen nicht geringen aber auch der Mangel an ansprechenden, geniessbaren Lehr- und Lesebüchern zur häuslichen Fortbildung. Ueber diesen Mangel, der sich mit jedem Jahre fühlbarer macht, je lebhafter und verwickelter die Beziehungen der modernen Völker unter einander geworden sind, wird in Frankreich und England fast noch mehr geklagt, als in Deutschland. Der gelehrte Vice-Präsident der geographischen Gesellschaft in Paris, Vivier de Saint-Martin, erhob in Bezug auf Frankreich in seinem geographischen Jahrbuche seine Stimme fast gleichzeitig mit William Hughes, der in seiner englischen Geschichts-Geographie (" *Geography of British History* ") meint, wie allgemein der Werth der Geographie für eine gesunde Erziehung in der Theorie auch anerkannt sei, so werde derselbe in der Praxis doch bei Weitem noch nicht hoch genug geschätzt, und in vielen Schulen sei es damit noch geradezu kläglich bestellt; im Volksunterrichte, wie in den höheren Lehranstalten, sei der alte Schlendrian noch allmächtig, und selbst auf den englischen Universitäten sei dieses Studium als besondere Zweig noch frommer Wunsch........ Hughes wurde zur Ausarbeitung seiner geographischen Beschreibung der britischen Inseln, nach den auf einander folgenden Perioden von der ältesten Zeiten bis auf die Gegenwart, veranlasst durch die Vorträge, die er in den Abendclassen von King's College in London übernommen hatte. Er ging von dem richtigen Gesichtspuncte aus, dass eine klare Einsicht in die historische Entwicklung der englischen Nation nur erlangt werden könne, wenn der geographische Bestand des englischen Staates, wie er begonnen, sich fort und fort entwickelt und zu seiner jetzigen Grösse aufgebaut habe, den Schülern in seinen Hauptmomenten vorgeführt werde. Und diesen Plan hat der Verfasser so verständig durchgeführt, dass sein Buch nicht bloss ein sehr lohnendes Studium, sondern zugleich in ihrem historisch-geographischen Theile eine fesselnde Lecture bietet. Man fühlt es überall durch, dass Macaulay's geistreiche Behandlung von englischen Geschichte auch belebend auf die Geographie von England zu wirken begonnen hat.'

KÖLNISCHE ZEITUNG.

'Mr. HUGHES's *Geography of British History* is one of the very best school-books that have appeared for a long time. It is simply and clearly written, and, so far as we have ascertained, is a model of conscientious accuracy. It brings together a great body of facts which every one ought to know, yet which, before its appearance, could only be found scattered over many volumes, some of them costly.

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