ASTRO-THEOLOGY.

BY

THE REV. HENRY MOSELEY, M.A., F.R.S.

ONE OF HER MAJESTY'S INSPECTORS OF SCHOOLS, LATE PROFESSOR OF NATURAL PHILOSOPHY AND ASTRONOMY, KING'S COLLEGE, LONDON.

"For the invisible things of Him, from the creation of the world, are clearly seen, being understood by the things that are made, even his eternal power and Godhead."—*Romans* i. 20.

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ADVERTISEMENT.

It is the object of the following papers to treat of some of the more obvious phenomena of the visible universe in a devotional spirit. I have republished them in a cheap form, from the 'Church of England Magazine,' in which they were first printed, in the year 1838, with the hope that they may promote the cause of popular instruction, and with an especial reference to the education of elementary schoolmasters, with which I am officially connected.

O LORD God, whose name only is excellent, and thy name above heaven and earth; we adore and bless thy mercy and thy power for creating us after thine own image. Thou spakest the word and we were made; thou commandedst and we were created. And as thou hast established thy creation with a law for ever, that all should minister to thy praises in their several proportions; so give us grace that the laws of sanctity, of faith and obedience, which thou hast given to us, may never be broken; that we, serving thee, not only in the order of thy creatures, but in the capacity of thy children, may sing thy praises amongst the angels and the numerous host of saints reigning in thy kingdom, for ever and ever. Amen.

BISHOP JEREMY TAYLOR.

ASTRO-THEOLOGY.

THE ISOLATION OF THE EARTH IN SPACE.

"He stretched out the north over the empty space, and hangeth the earth upon nothing."—*Job*, xxvi 7.

It is not easy to conceive the entire isolation of the earth in space. That it does not spread out its dimensions into the abysses of the universe, until at length it attains some immovable basis upon which it may repose—that it rests on no pedestal, *hangs* upon *nothing*—floats in space, not being buoyed up—and not being supported does not fall,—are ideas which lie at the foundation of all our knowledge of the wisdom and power of God in the universe; but to *realize* which it is necessary that we approach them if not by the steps of a rigid demonstration, at least by those of a gradual progression. They are indeed but elementary deductions of science; but not to be arrived at, until many false perceptions have been purged away from the eye of the mind, and the evidence of much experience presented to the understanding.

When we look forth upon the earth, it appears to us a surface broken into hill and dale but everywhere *terminated* by the margin of that vast concavity of the heavens which is stretched out above us; and when we are at sea, we seem to be upon a circular plain of water, whose limit is no where far distant from us.* That error which assigns to the earth and to the heavens the boundary of the visible horizon, *corrects* itself indeed immediately that we travel from place to place; but how are we to free ourselves from the other error? Go where we will, we seem to be moving on a flat if not an even surface—we appear no where to be descending the sides of the earth, or climbing on its acclivity; and an impression of our senses irresistibly grows upon us that it is an extended plain. Astronomy tells us of a huge sphere self-supported in the space of the heavens, and of that space stretching forth interminably and immeasurably. How shall we realise this idea, and reconcile it with what we see?

Let us suppose a traveller, impressed with the belief that the earth is a plain, to set out and travel continually in the same direction in search of its boundaries. Travelling on until he meets the sea; let him embark upon it and traverse it until he again encounters the land; thus continuing his forward course unimpeded by any of the natural obstacles on the earth's surface. Never will he find any termination to it. Go where he will, still sea or land will lie open before him. There is no limit, no boundary, no interruption of its continuity; no chasm in it, no elevation extending itself into infinite and unknown regions of space—no

* If the eye be placed at a height of about ten feet from the surface of the water, the horizon is distant from it, in every direction, between four and five miles.

greater obstacle than a mountain—no more impassable space than a valley, a lake, a river, or a sea.

His first conclusion would be, that he was travelling on a surface of infinite extent. After a time, however, this conclusion would correct itself, and he would perceive, to his amazement, that, although he had travelled on, continually away, as it seemed to him, *from* the region where his journey began, this onward journey had nevertheless brought him back to that region again. Has he then unconsciously turned round and retraced his steps? On this point he may assure himself, and he will find that, without ever turning backwards, or deviating from his course otherwise than perhaps to the right or the left of it, he has yet returned to the place whence he set out.

But a very slight exercise of his judgment will be sufficient to shew him, from this fact alone, that the earth's surface is not one extending *infinitely*, at least in the direction in which he has travelled, nor bounded by any edge or limit; but, like the surface which encloses a solid body, continuous, and returning into itself.* If this were not the case, the farther he travelled in the same direction, or towards the same direction, the farther he would of necessity have receded from the point at which he set out; and he could never, travelling as he did, have reached that point. Thus, if I see a fly making a journey across my table with his head always in the same direction, or deviating only to

* Not, for instance, a surface like that of the page on which this is printed, lying flat, and terminated by an edge; but like that which it would have if it were rolled up so that its opposite edges met and were perfectly joined.

the right or left of that direction, it is manifest to me that he continually recedes from his starting-place, at least as long as he remains upon the upper surface of the table. To reach it again, thus continually advancing, he must crawl over the opposite edge of the table and along its under surface.*

Since, then, our traveller, journeying continually in the same direction over the earth's surface, or deviating from that direction only to the right or left, has returned to the same regions of the earth again, he must have gone round it; and it must be a surface returning into itself, at least in the direction in which he travelled. And if from his starting-place he has travelled in every possible direction, and always thus arrived at the same place again, then must it, not in one or two directions only, but in every direction, be a surface returning into itself—such a surface as would not only partly but *completely* contain a solid. Moreover, if in the course of these numerous journeys he met with no obstacle which he could not overpass, then would he be assured that there was no solid mass on which it rested, no pedestal by which it was supported, nothing from which it was suspended.

But it will be asserted that these journeys are all hypothetical, and that no traveller has thus, setting out from one place, made journeys in all directions round the earth. True; but if all the journeys and voyages which have been made were collated and compared, it would be found that these supposed journeys

* This illustration will be complete, if we compare the case of a fly crawling over the surface of an orange with that of the fly crawling on the table.

have been made, if not by one, at any rate by a number of different persons; and we have the results of their experience, which is to us as certain evidence, and indeed more certain than that of a single traveller would have been.*

There is indeed scarcely a week in which this great fact is not put to the test of experiment. Never perhaps does a week pass in which there does not arrive, in some port of Europe or America, some vessel which, having sailed from that port continually on the same course, or deviating only to the right and left of that course, has, nevertheless, returned to that port again; which it could never have done if the earth's surface were other than that of a continuous solid; if it were a flat, or infinitely extended, or a terminated surface, not returning into itself; † or a small portion of the surface of an infinitely extended plane; or an island, floating in the abysses of space; or the

* It is not strictly to all the points of the earth that our experience extends, for there are some which no human being has perhaps ever crossed, and many which have never been visited by any one whose authority we have for the fact asserted in the text; yet so few are these cases, when compared to those of which we have experience, that, although they leave the matter under the *form* of a probability, it is one which is *practically* a certainty.

† A year or two ago it was announced that vessels set out every six weeks from the port of Liverpool, to make the voyage round the world. Their course is south-west until they reach Cape Horn; then still westerly until they make New Holland; then perhaps north-west, to some port of India; again south-west, to the Cape of Good Hope; and then north-west, home. Thus sailing continually to the west, they have returned to their port Had the world not been round, they must continually have receded from it.

summit of a mountain, whose base reposes in some fathomless region unknown to us. This earth of ours is a huge mass, self-poised, supported upon nothing, hung upon nothing—enveloped by the air which we breathe, and surrounded by the space of the heavens.

How many thoughts does the mind embrace in this idea! The surface of the earth being that of a solid mass, there must be some point on the opposite side of it now immediately beneath my feet. Yet have I reason to believe, indeed I know, that every thing goes on there as it does here; all heavy bodies tend to fall to the surface of the earth there as they do here, and yet falling there and here they must fall in opposite directions. Men move about there as freely as they do here; although their position is inverted in respect to mine, they have no tendency to fall off; on the contrary, they are pressed by their weight to the earth's surface there as I am here; so that, in fact, we are pressed by our weight in the direction of our feet towards one another; and were we to fall, each would fall towards the other. Since, then, weight is something which on opposite sides of the earth presses bodies towards its surface, it is evidently a power in the earth itself, of which I see the analogy in the attraction of a magnet, which all round, and on its opposite sides, in opposite directions, fixes small particles of iron upon its surface.

THE FORM AND DIMENSIONS OF THE EARTH.

"And in his hand
He took the golden compasses, prepar'd
In God's eternal store, to circumscribe
This universe, and all created things;
One foot he center'd and the other turned
Round through the vast profundity obscure,
And said, 'Thus far extend, thus far thy bounds,
This be thy just circumference, O world.'"
Paradise Lost, vii. 225.

But what is the form of the earth, and what are its dimensions? As yet we know only that it is a solid mass; but not being able to comprehend any considerable portion of it at once in our sight, we know not but that its form may be irregular, with many angles, or a cone, or a cylinder. Astronomy assigns to it the form of a sphere. How is this determined? It affixes to it certain enormous dimensions. How are these measured?

Since the earth is not a *transparent* mass, it is evident that, however great might be our power of vision we could not see the whole of its surface at once—a portion of it must of necessity be hidden from us by the intervention of the earth itself; moreover, that by the same intervention of the earth itself, a large portion of the space of the heavens must be hidden from our view. In fact, if in any direction I suppose a line to be drawn from my eye to a point where it meets, but only just touches, the earth's surface, it is evident that I cannot possibly see any part of the earth's surface in that direction beyond that point, or any portion of the heavens in that direction beneath that line; and if I suppose lines thus to be drawn in every possible direction from my eye, touching as many points in the earth's surface, then, though I used the most powerful glass yet could I see nothing of the earth's surface not lying within the boundary of those points, nothing of the heavens not above those lines. It is evident that the distance at which this boundary of points will be situated from my eye depends upon its height; the higher my eye is raised from the earth, the more distant will be the points where the lines drawn from it will touch the earth's surface. And it is for this reason that from an elevated spot we see farther than when we stand on a level plain. The line of points which bounds our vision extends itself as we ascend—lines drawn from the eye touching the earth at more and more remote points as it is more and more elevated.

Now, go where we will over the sea, this line of points, which includes within it all of the surface that we can see at once, is, when the water is calm, a perfect circle; and this fact is in itself sufficient to prove that the surface of the ocean is part of the surface of a sphere, for it proves that a circle would every where fit accurately on the surface of the ocean. If, for instance, a huge circle were constructed, which should coincide with the circular margin of the horizon, and were pushed about from place to place on the surface of the calm sea, it would every where accurately *coincide* with it, no where rising above, and no where being depressed beneath it.* Now that surface which has this property that a circle of any size (less than a certain greatest size) being any where applied to it will lie throughout its whole length upon it, or accurately fit it, is *the surface of a sphere.* This is a fact well known and commonly applied in the arts. Did we wish to work a stone accurately into the form of a sphere, the stonemason would get a circular ring of any size not greater than the girth or *great* circle of the sphere, and applying it to different parts of its surface, he would observe where the edge of the circle did or did not coincide with it or fit it, and by this he would judge whether it was or was not a true spherical surface; and when he had so worked it that the circle every where coincided with the surface he would know that it was a true sphere.†

Since, then, wherever we go upon the ocean, the boundary of that which we can at once see of it, is a circle, its surface is that of a sphere;‡ and since the surface of the *sea*, which is seven-tenths of the whole

* This ring is supposed without weight.

† It is thus that the surfaces of the earthenware marbles used by boys are made true spheres. The circle used by the potter is the edge of a thimble; this he rubs upon the surface of a lump of unbaked clay until he has made its surface every where to fit it it is then a sphere

‡ It may, perhaps, be imagined that the boundary of the horizon is circular because it is the boundary of our power of direct vision which is in every direction the same; but this is not the case we could see, were the earth's surface in reality a plane, much farther than the horizon; our power of direct vision extends much more than four or five miles. This is proved by the fact that we see a mountain thirty or forty miles distant.

surface of the earth, is that of a sphere, it is evident that the general character of the surface of the *land* must be spherical, for it no where greatly recedes from the surface of the sea. This method, however, whilst it *indicates* the *general* form of the earth's surface to be spherical, leaves it possible that there may be deviations from that form; for we cannot very *accurately* determine that the margin of the horizon *is* a circle, although it *appears* to be so; and a slight error on this point is sufficient to introduce a considerable one in our result.

To arrive at a more certain conclusion, we must have recourse to observations upon the heavens.

THE DIMENSIONS OF THE EARTH.

> " For the whole world before thee is as a little grain of the balance, yea, as a drop of the morning dew that falleth down upon the earth."—*Eccl.* ii. 22.

THAT portion of the heavens which we can see has been stated to be divided from that which we cannot by lines drawn from the eye in every direction, so as just to touch the earth, and supposed to be produced or lengthened until they reach the heavens. That portion of the space in which the earth is situated which lies beneath these lines, we could only see if we could look through the earth; which we cannot. Now so small, comparatively, is our height, that when we stand upright the portion of the *heavens* * we can see is, without any sensible error, the same as it would be if our eye were where our feet are, or actually in the earth's surface. If this were the case, the lines spoken of above as drawn from the eye, and dividing the visible from the invisible portion of the heavens, would all lie in one plane touching the earth's surface. If, then, we imagine such a plane actually touching the earth's surface under our feet, and stretching out infinitely until it reaches the heavens, it will form the actual division of them which we experience. All

* The portions of the *earth* we could see would be very different.

above this plane is visible to us, all beneath it invisible; and objects appear to us higher or lower upon the vault of the sky, as they are more or less distant from it.

Now, as we move about from place to place, this plane will evidently alter its position, in the same way as though it rolled upon the earth's surface under our feet; and thus rolling so as to be inclined in one place to what its position is in another, it will roll nearer to the stars in one direction, and farther from them in another; and thus the stars will appear nearer to the horizon in one place than another.

Being unconscious of the true cause of this phenomenon in an alteration of the position of the plane of the horizon we attribute it to a motion of the stars themselves; and, as we move southward, the northern stars seem to sink continually upon the sky behind us, and the southern stars to rise; it being in reality the dividing plane of the visible and invisible heavens, or our horizon, which has rolled nearer to the northern stars, and farther from the southern, the angle through which it has revolved being exactly equal to the angle through which the star has, by our motion, been made apparently to rise or sink.

Now it may be shewn certainly by geometry, that if to revolve through the same angle, this plane of the horizon must be made to revolve over the same distance every where on the earth's surface; or, in other words, that if to make a star by my motion apparently to ascend or descend by the same angle upon the sky, I must, wherever I am on the earth, alter my position by the same number of miles,—then certainly the earth's surface must every where be accurately the surface of a sphere. This will be sufficiently understood, if we imagine a flat card to be applied to the surface of an egg and made to roll upon it—it is plain that at the thick end of the egg, to alter its inclination by a certain quantity it will have to roll over a greater distance than it will have to roll over to alter its inclination by the same quantity at the thinner end; but if the same card be applied to a sphere, and made to roll upon it, it will every where have rolled through the same angle when it has rolled over the same distance.

Now, observations like these have been made with extraordinary care at different places on the earth's surface; and the result of them has been this, that to cause a star by the motion of the observer to appear to ascend or descend by the same angle on the heavens, he must every where move over very nearly the same space. *The earth is therefore very nearly a sphere. Very nearly*, for it is not accurately thus; towards the poles of the earth the space moved over must, it is found, be somewhat greater than towards the equator. The earth is therefore flatter towards the poles than towards the equator; as on the egg, where, to revolve through the same angle, the card had to roll the greater distance, the surface was flatter than where it had to roll over the less distance.

It is evident, that completely to turn round upon itself, or to cause that side of it which was before towards one direction now to be towards the opposite direction, a plane thus rolling upon a solid must roll completely round it. Thus, a card which I make to roll on a sphere will not have turned completely round upon itself, or turned that side which was before *towards* me now *from* me, until it has rolled completely round the sphere: and since, as it turns upon itself through the same angle, it always rolls on the sphere through the same distance, it is also clear that when it has turned upon itself through half a revolution, it will have rolled upon the sphere through half its complete girth or circumference; that when it has rolled through a quarter of a revolution upon itself, it will have rolled on the sphere through a quarter of its circumference; and generally, that whatever part it has made of a complete revolution upon itself the same part of a complete circumference will it have rolled over the sphere.

The complete revolution of a body's position is usually supposed to be divided into 360 equal parts of a revolution, called degrees; for each degree, or 360th part of a complete revolution, through which the card revolves upon itself, it will roll over the 360th part of the circumference of the sphere. Now for the sphere substitute the earth, and for the card the rolling plane of the horizon. The angle through which this plane revolves upon itself is measured by the apparent ascent or descent of a star; the space, then, through which an observer must move to make by his motion a star appear to ascend or descend one degree, is the 360th part of the circumference of the earth. Now there are instruments by which observations like these can be made, and they have been made with great care and with every possible precaution;* and

* This is called measuring a degree.

the result has been this, that the distance through which the observer must move to cause the apparent ascent or descent of a star through one degree, is every where very nearly $69\frac{8}{100}$ miles. The whole circumference of the earth is therefore 360 times this number of miles, or it is 24869 miles; and knowing its circumference, we find by certain rules of geometry that its radius, or the distance from its surface to its centre, must be 3958 miles. These are nearly its dimensions, but not exactly; for it has been stated that, to cause the ascent or descent of a star through one degree, we must move through a greater distance when we are near the poles than when near the equator; thus in Lapland this distance has been ascertained to be $69\frac{26}{100}$ miles, whilst in Peru it is found to be only $68\frac{72}{100}$ miles. Thus, if the earth were a sphere, every where of the same curvature of surface as in Lapland, it would have a circumference of $24933\frac{6}{10}$ miles; and if it were every where of the same curvature as in Peru, of $24739\frac{2}{10}$ miles.

In reality, it is not a sphere, but of that geometrical form to which has been given the name of a spheroid, or somewhat of the flattened form of an orange, its polar diameter being less by about $26\frac{1}{2}$ miles than its diameter at the equator. This difference, however, which is scarcely 1-300th part of the greater diameter, is in the great bulk of the earth, scarcely an appreciable thing; so that were an exact model made of the earth flattened exactly in the same proportion in which it is, a foot in diameter, no sight or touch would be able to discover it not to be a sphere. Knowing the circumference of the earth, we easily find its surface to be 196,862,256 square miles, and its solidity to equal 259,726,936,416 cubical miles; its weight, if it could be weighed, would be about five times that of as much water. But 3-10ths of its whole surface, or 59,058,676·8 square miles, is land, the remaining 7-10ths being water. Of this land, if that in the northern hemisphere be divided into 16 equal parts, that in the southern will be found only to equal 5 of those parts. The highest mountain upon its surface* is about $5\frac{1}{3}$ miles in height; and if we suppose that mountain to be a cone, the diameter of whose base is the same at its height, it would contain about 38 cubical miles; its mass would therefore bear scarcely a conceivable proportion to that of the whole earth. The height of the highest mountain, added to the depth of the deepest sea, would not probably exceed 10 miles, or be more than 1-800th part of the earth's diameter; so that if a globe were made one foot in diameter, on which all the inequalities of the earth's surface were represented in the same proportion to the size of the sphere which they actually bear to the earth, they would with difficulty be visible on it, the greatest depression not exceeding the thickness of this paper. It is but as the inequalities of the rust on a ball of iron. And to upheave the bottom of a sea, or to bury a continent in the waters, supposes but a change in the form of the earth's surface such as the mere daily variation of temperature might produce in that sphere of metal.

For the most part, the level of the surface of the land is above that of the surface of the sea. This is not, however, every where the case. There is in Asia a region

* Dwalagiri, one of the Himalaya range.

occupied partly by the Caspian Sea, extending over 162,000 square miles, and containing many large cities and an abundant population, which is every where between 300 and 400 feet beneath the level of the Black Sea and the ocean.* However, it is certain that the relative levels of land and water have not always been the same as they are now. There is probably no place on the earth's surface, where, if they were sought for, there would not be found traces that the sea had once been there; and could we examine the bottom of the ocean, we might find equally certain evidence that it had once every where been dry land.

These changes, which appear to us at first sight so vast that they overpower the imagination, shrink within the limits of our conception when we have once realised the idea of the isolation of the earth in space, and its *magnitude*, and of the comparative insignificance of the greatest elevations or depressions of its surface, included but as it were within the thickness of a film, or but as the finest dust scattered upon it, or as the most imperceptible abrasion of it. The wonder is, not that changes such as these have taken place, and do continually take place, but that, considering the infinite variety of heterogeneous materials out of which, for the great purposes of God in creation, the earth's mass is

* Halley conceived the wild idea, that this depression was produced by the impact of a comet. All the knowledge, however, which we can acquire of comets brings us to the conclusion that they are of a substance so aerial, that this indentation of the Caspian is an effect greater than could be produced were one of them to impinge upon us. The explanation of Halley is, therefore, universally rejected.

wrought,—these remain from day to day without rushing into that state of chemical combination to which each element tends, and which supposes the entire annihilation of every existing form of organised being, a melting of the elements with fervent heat, and the burning up of the earth also, and the works that are therein (2 Peter, iii. 10). Philosophy, after all, can but resolve itself into the continued providence of God, and re-echo here too, as throughout all its boundaries, that declaration of universal nature, "The Lord God omnipotent *reigneth*" (Rev. xix. 6).

To Him, in whose sight the huge bulk of this earth is as entirely comprehended as in ours is the far-distant planet which we look at through a glass, and by whom it is so minutely seen that no individual of the thousands of forms of living things ever escapes his watchful care; "who hath measured the waters in the hollow of his hand, and meted out the heaven with a span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales and the hills in a balance" (Is. xl. 10),—those things which we call mighty catastrophes, cataclysms, and dire phenomena of nature, are but as to us the changes on that modelled sphere of metal that has been spoken of. God holds in an equal view, and in the circle of an equal power embraces, these, and the most ordinary interpositions of his providence.

THE HEAVENS.

"When I consider the heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou art mindful of him? and the son of man, that thou visitest him?"—*Ps.* viii. 3, 4.

It is with the heavens that men have ever associated their ideas of the power and majesty of the Most High. The countless host that peoples them; their depths unfathomable to the sight; their majestic silence; their slow progression through an endless cycle of change, unshaken by the tumult of these lower elements—unchecked by the far-spread contest of human passion, the wide vicissitude of human affairs; their benignant and mysterious *power*—night, bringing with her an insensibility as of death; day, a new creation of life; the seasons, year after year returning; the sun waking, with his breath, the bud and the blossom from their slumber, calling forth the beauty of the tree and the flower, covering the earth with greenness, and making it "plenteous with all manner of store;" the rains, that fall as marrow and fatness; the winds, which are loosed through heaven; the lightnings by which it is cleft asunder; the thunder, which is its voice:—these are all manifestations of the power of God, which the mind so associates with its conception of him, that they become to it as symbols.

To the eye of Faith, the heavens are, moreover, sanctified by the *actual presence* of God; for "God dwelleth in the heavens from the beginning." Joining hand in hand with knowledge, she wings her way rejoicing through the measureless paths of the universe; and in worlds *innumerable*—stars and systems *countless*—finds a field of investigation but equal to the fruition of the disembodied spirit, and the "strength and beauty of a sanctuary" (Ps. ix. 6) not more than sufficient for an infinite God; in the silent adoration of the unnumbered hosts of heaven she beholds a worship but worthy of an omnipotent God; and in the gratitude of myriads of myriads of intelligent creatures but the tribute due to a redeeming God.

When we look above and around us, whether in the daylight or at night, we see a vast hemisphere, the centre of which appears to be precisely in the place where we stand. In the day-time its surface is of a pure unsullied blue, except that sometimes huge masses of cloud float over it, which, although they do not partake in its pure azure colour, yet agree in its general form, and, however varied their outline, appear to mould their surfaces into its spherical shape.

Journeying in a zone across this fair canopy, and "rejoicing like a giant to run his course," appears the Sun—a circle of brightness—occupying but a very small portion* of the sky, but sending forth a flood of light by which the whole space beneath him is pervaded, which is returned in an infinite variety of tints by the clouds, and of which the colour and brightness of all the things around us are but so many varied modifications; for in the evening, when he disap-

* About the hundred and fourteen thousandth part.

pears, sinking under the western margin of the horizon, and the stream of his light is diverted to a region beneath our feet, night succeeds, and darkness. The moon now comes forth, and pursues with a tranquil but ever-varying aspect her silent course through the sky; or the heavens are black "as sackcloth of hair," except that innumerable stars, so minute as to be visible only by their excess of brightness, are scattered upon it like gems.

Without acquired knowledge and instruction, the first belief of every man would be, that he is really in the centre of the hemisphere of the heavens, as he seems to be; and that the sky above him is in reality a vast dome, within whose cavity he might conceive himself to be imprisoned—to the surface of which he might ascend, could he lift himself up in the air—up to the crown of which he might, with the requisite labour, build a column or a tower—or to the margin of which he might, by persevering in a straightforward course, eventually travel.

To destroy this false notion, but little observation, however, would be required: so that the folly, as well as the presumption, of the descendants of Noah, who would have built in the plain of Shinar a tower "whose top might reach to heaven" (Gen. xi. 4); and the simplicity of the youth who sought to overtake the rainbow,—have passed into proverbs.

Whoever set to work to travel to the margin of the horizon, would find that journey as far as he might, he would never even get nearer to it. He was in the centre of the dome of the heavens at first; and wherever may have been his journey, he will find himself in its centre still; nay, even when he has reached one of the very points of the earth's surface on which, when he first set out, its margin seemed to rest.

Again; when he considers, that every body else, all over the world, when he looks above him seems to be in the centre of a similar dome, and that if the one on which he himself looks be really one somewhere existing, because it seems to be so, then, for a like reason, that on which every other person looks must be one; and that there must thus be as many skies as there are people to look at them, so that, in point of fact, out of these millions of different skies he must—stand where he will—be actually standing upon the margin of one of them, without perceiving it;—these things will convince him that in believing in the actual existence of a dome of the sky any where, except indeed, at an infinite distance, he has been labouring under a deception of the senses.

There is no such hemisphere of the heavens. What he sees above him is a mighty unfathomable space, being part of that in which the huge mass of the earth exists; the other portion of which space he would see, if he were on the side of the earth opposite to that on which he stands. This space appears to him limited and bounded, simply because his sight enables him to judge of the distances of objects only within a certain limit; and it appears to him every where at the *same* distance from him, because this limit is, in all directions in which he looks, the same. Thus the stars, the sun, the moon, the planets, which appear all alike on the surface of the dome of the sky, and equally near to him, *may* be scattered at distances immeasurably different, and through regions of space infinitely remote—as the clouds are some very much nearer to him than others, although they appear to him in the day-time to be all at the same distance as the sun, and at night on the same concave surface with the moon and stars.

PARALLAX.

LET us now assign to this observer a mind more than ordinarily sagacious and inquiring, and let us suppose him to have been struck by the fact, that the different stars thus scattered through space do not *appear*, as he moves about, to occupy different positions in respect to one another; or to be at different angular distances from one another when he is in different positions. This fact, when he has well considered it, will greatly astonish him. All the objects around him on the earth appear thus to alter their *relative* positions as he moves about among them. Distant trees as he looks at them nearly in the same line or in front, appear to be separated by a less or a greater interval; the hills seem farther and farther apart as he travels past them;* nay, even sitting in his room, if he look through his window on any two objects *without*—two chimneys or two trees, for instance—he will find that by moving about in the room the apparent distance of these from one another, estimated by the distance of lines drawn from the eye to them, or, as it is called, the *angle* between these

* It has been observed by Sir John Herschel, that this fact is particularly remarkable in Alpine regions.

lines, will be continually changed. This effect will be the more remarkable the nearer they are to him. If, indeed, their distance be very considerable, he will scarcely be able to perceive it at all, however large the space may be over which he moves; whilst if one of them be very near to him, even the slight motion which he can give to his head, without moving from his chair, will be sufficient to produce it.*

But to take an illustration applying itself more directly to the case in question; let us suppose him to be sailing at no great distance from the sea-coast at night, and to observe two lights upon projections at the shore. At one instant, when he is situated not far out of the prolongation of a line joining the lights, they will appear to him to *coincide*, blending momentarily into one light; as he sails on parallel to the shore they will seem gradually to separate from one another, appearing to be divided by a wider and a wider space, until they have acquired a greatest or maximum separation; after which, as, still advancing on the same course, he leaves them behind him, they will approach one another again, going through all the same circumstances now of approximation as before of separation. All these changes of the apparent distance of the lights from one another will be

* This appearance will most strike him, if he compare the relative positions of one of the upright portions of the frame of his window and some external object—a tree, for instance, at the distance of 100 yards. Were he, however, to use an instrument, such as are every day constructed for measuring angles, there are scarcely any two objects within the reach of his vision which would not appear under different angles when viewed from different parts of his room.

less as the distance of the ship is greater. If it be very great, they will scarcely be perceptible, and only to be traced by the assistance of accurate instruments. If it be not very great, they will be plainly visible, and evident to the naked eye. Moreover, all these changes in the apparent distance of the lights from one another will be referred to, and apparently take place upon, the circular margin of the horizon; or, if the lights be raised high enough above the shore, they will seem to take place on the face of the sky. The appearance will be that of beads of light, moving towards one another on the circle of the horizon, or on the surface of the heavens; coinciding, then receding, and again approaching to one another. These *apparent* motions of distant objects in respect to one another, which result from a change in the position, not of the objects themselves, but of the eye of the observer, are called *parallactic*.

THE REGION OF THE FIXED STARS.

"He made the stars also."—*Gen.* i. 16.

Why are there not changes of apparent relative position—parallactic changes—among the stars?

THIS is a question which might suggest itself among the first and simplest to an intelligent inquirer. Go where he will on the earth's surface, even to the farthest point from that on which he now stands, he will still find no difference in the apparent distances of the stars from one another. *Measure* them with ever so delicate an instrument and the result will still be the same; no trace of this parallactic change will be perceptible. *Why is this? Why do not these stars go through the same series of changes in their relative distances as do the objects within our reach?*—Simply because they are *not* within our reach,—because they are immensely removed from us, as compared with any distance through which we can move on the earth's surface. We know by *experience*, and we can *prove* demonstratively from the rules of geometry, that any change in the apparent distances of two objects produced by a change in the place from which they are seen, is necessarily less as their distance from that place is greater; and that, when that distance is *infinitely* great in the comparison, and then only, is this apparent change of position insensible.

What, then, is the conclusion? Evidently this: that since, when we pass from one such point on the earth's surface to that which is even most remote from it, we can perceive (even by the aid of the most delicate instruments) no such apparent changes of relative position among the stars, these stars are *immensely* distant from us, even when compared, not with any ordinary unit of measurement—a mile, for instance, or a league, or a degree—but with the diameter of the earth itself.

Some notion may be formed of the magnitude of this disproportion from the following illustration:—Let a circle be measured, twenty or thirty yards in diameter, and let an observer walk round it, measuring, with an instrument contrived for that purpose, the angular distances of two distant objects—two trees, for instance. He will obtain in every different position a different admeasurement; and instruments have been made, of such delicacy, that different positions on such a circle would cause perceptible differences in the angles observed, even when the objects were distant, as much as 100,000 times the diameter of the circle.* Now, instruments of this kind, and of the most perfect workmanship, have been employed to observe the angular distances of the stars from points differently situated on an imaginary circle girding the earth,—and no variation in them, no parallax, has ever been traced. It follows, therefore, *demonstratively*, that the distance of the region of the fixed stars is more than 100,000 times the diameter of the earth. Now, the earth's

* See Herschel's Astronomy, p. 51

greatest diameter is 7925 miles: let, then, these 7925 miles be imagined to be taken 100,000 times, and a great sphere to be described having this distance for the length of its radius, and the earth for its centre. *The region of the fixed stars lies without that sphere: this much is certain.* But the measurement is yet far short of its limit. This sphere, 792 millions of miles in radius, is *lost* in the space which really intervenes between us and the region of the fixed stars. Our earth travels every year round the sun (as will be shewn in a subsequent paper), in a mighty circle of 190 millions of miles in diameter. The stars may therefore be observed, with instruments such as those spoken of above from different points of that huge circle at different seasons; and if they were not distant from us more than 100,000 times its diameter, parallax would be observable among them. Such observations have been continually repeated, and no parallax has ever been traced. It is therefore *certain* that the region of the fixed stars is distant from us more than 19 millions of millions of miles.* Although the *fixed stars* are thus observed to have no parallactic motions,

* This is a rude calculation, used only as an illustration. There are instruments which, in the hands of good observers, cannot, we are assured, err more than two seconds. That they shew, by repeated observations, no annual parallax, is therefore a proof that the annual parallax of no fixed star is greater than this number of seconds.

It may here be mentioned, that some disputed observations of MM. Arago and Matthieu, made in 1812, assign to the sixty-first star of the constellation of the Swan a parallax of $1''\cdot 2$; and that some observations by Dr. Brinkley, at Dublin, appear in like manner to shew an almost inappreciable parallax.

yet the sun and moon, and those other wandering stars called planets, *have*.

These, then, we conclude, with equal certainty, to be *within* that sphere which does *not* contain the fixed stars. They are even within the first and infinitely smaller sphere spoken of; for they shew a parallax even when seen from different points of that comparatively small circle which girds the earth. Thus, then, the sun, moon, and planets, lie all *within* a sphere no part of which is distant more than 792 millions of miles,* whilst the region of the fixed stars is *without* the limits of a sphere having a radius of 19 millions of millions of miles.

* Saturn and Uranus must be omitted from this computation.

THE SINGLENESS OF THE SCHEME OF CREATION.

"The Lord our God is *one* Lord."—*Deut.* vi. 4.

NOT only, however, has science applied her *scale*, and measured her way thus far through the abysses of space—her *eye*, too, has pierced the interval;—she has seen something of the economy of the region separated from us by that interminable void, and she has found in it but another manifestation of the power and wisdom of God;—she has linked the state of passive being *there* with the conditions under which it exists *here* by a common law, and by that law bound creation, through its remotest limits, to the throne of one great Intelligence. *There*, as *here*, all matter tends to approximate by a mutual attraction of its elements; and *there* that attraction is governed by the same physical laws as here. There are stars called multiple stars, more than 3000 in number, which, appearing to the naked eye single, are seen, when looked at through powerful telescopes, to be double, triple, or even quadruple. The stars of each group are commonly of very different intensities of brightness, and of different colours, and they are not independent of one another, deriving their apparent approximation from an accident of their position, but *dependent* systems having motions of revolution about one another, as have the bodies of our *solar* system. This marvellous fact is the discovery of Sir John Herschel. But this is not all. There are certain remarkable laws, which were discovered, by the observations of Kepler, to govern the actual motions of the planets of our system and their satellites; and proved by Newton to establish the attraction of all these planets to the sun, and of its satellites to each planet, according to a certain remarkable law, and by a force the same with that by which bodies are attracted to the earth, and which we call gravity. Now, it is ascertained, by the observations of Sir John Herschel, that these laws of Kepler obtain in respect to the revolutions of each binary system of stars.* The

* The revolution of one of these round the other in its oval orbit varies continually, being at one period more rapid than at another; but this variation is subjected to this remarkable law, that the area swept over by an imaginary line drawn from one star to the other is in the same period, say a month, always the same; the revolving star when more remote moving slower, and when nearer moving faster, so as just to make up this equality. From this single fact it follows that the stars must *attract one another*. This is the fundamental proposition of the Principia of Newton. Again the oval orbit which one star describes about the other is found to be accurately an *ellipse*, in the focus of which is that of the two, which is fixed. From this fact, again, it follows that the attraction of the stars upon one another must be according to that remarkable law, called the law of "the inverse square of the distance," which governs the mutual attractions of the planets and sun. The following are the periods of the revolutions of those double stars whose orbits have been determined:

η in the constellation of the Crown .	43 years.
ξ in the constellation of the greater Bear	58

reasonings of Newton in respect to *our* system of the universe apply, then, to these. Each star of a system of double stars *gravitates* to that about which it revolves,—as do the planets of our solar system to the sun, as does the moon to the earth, and by the same law that a stone falls to the ground. Such is the *singleness* of the scheme of creation! such is the *unity* of the system of the universe! The *one* purpose of the *one* eternal God operating on worlds innumerable, and to the very verge of space. "The Lord our God is one Lord" (Deut. vi. 4). These multiple stars are commonly of different colours, the most common being combinations of red and greenish blue, and yellow and blue, and sometimes white and blue. It is ascertained that in many cases these are not *accidental* colours, or mere optical phenomena, but the coloured light with which each star really shines.

Shining with their own light, these and all others of the stars called fixed are *suns*; and, reasoning by every analogy of nature, we must believe that each group of suns is surrounded by a system of worlds. How shall the imagination conceive the glory of that region in whose sky different suns are thus variously and infinitely combined, and which is flooded by the ever-changing hues of a many-coloured light!

Now let us pause, and look back upon the progress we have made.

70 in the constellation of Ophiuchus .	88 years.
The star Castor	253
σ in the constellation of the Crown .	287
61 in the constellation of the Swan .	452
γ in the constellation of Virgo . .	629
γ in the constellation of Leo . .	1200

RETROSPECT.

"These are thy glorious works, Parent of good,
Almighty, thine this universal frame,
Thus wond'rous fair; thyself how wond'rous, then!
Unspeakable, who sitt'st above these Heav'ns,
To us invisible, or dimly seen
In these thy lowest works; yet these declare
Thy goodness beyond thought, and pow'r divine."

The earth is a solid mass, of great but finite dimensions, resting upon nothing, joined to nothing, "hanging upon nothing" (Job xxvi. 7), but self-poised, floating, self-supported in the infinity of space. Of this infinite space we know only this,—that within a portion of it, no part of which is distant from us more than 1800 millions of miles,* are found the sun, moon, and planets; that beyond this region there intervenes an immeasurable space, which, as far as we know or have reason to believe, is *void*; that this void being traversed for more than 19 millions of millions of miles, but *how much* more we know not, a region would at length be reached peopled by stars, which are *suns*, and whose number is countless as the sand on the seashore.†

* In *this* computation the orbits of Saturn and Uranus are included.

† There are bright spots in the heavens called *nebulæ*, which are, it is believed, clusters of stars, by reason of their number and closeness not to be distinguished from one another. There

"Another Heaven
From Heaven-gate not far, bounded in view
On the clear hyaline, the glassy sea;
Of amplitude almost immense, with stars
Numerous and every star perhaps a world
Of destin'd habitation."—*Paradise Lost*, vii. 617.

Throughout the whole of the vast surface of our own planet—more than 196 millions of square miles—where it is land, far into the bosom of the soil—where it is sea, to its very unfathomable depths—and to the unseen heights of the liquid air,—it is thronged with *living beings*. *Life*, under an infinite variety of forms, adapted to a variety as infinite in the qualities of the material things which surround it, *permeates* this mighty region. The naturalist who would count its individual forms, from the "cedar of Libanus to the minutest of the *algæ*" from the great leviathan of the waters to that unseen living thing, whose *shadow* only the most perfect appliance of artificial vision has yet reached,*—is as lost as the *astronomer*, who, taking for his scale the greatest distance which the mind can grasp, applies it to measure out the universe.

And if this be the universal association of *life* with every form of matter here, how shall we not, reasoning

are more than 2500 of these *nebulæ*, and they contain together many hundred millions of stars. Of the stars which form the milky way, Herschel saw 258,000 pass before the field of his telescope in forty minutes. Every improvement in the telescope shews more of them; and there appears to be no other limit to their number than the extent of the universe.

* The recent discoveries of Ehrenberg extend to certain shadows of animalcules, whose distinct parts he has never yet been able to see.

from every analogy, assign it, under some form or another, to matter wherever else it exists?

These things are, however, perhaps beyond the legitimate sphere of our speculations. "Great is the Lord; his understanding is infinite; his greatness is *unsearchable*" (Ps. cxlv. 3, and cxlvii. 5). In considering them, our most powerful impulse is one the tendency of which is to humble us to the confession, that man is in very deed as *nothing* among the created things of God. "When I consider thy heavens, O God, the work of thy fingers, the moon and the stars which thou hast ordained, what is man, that thou art mindful of him? and the son of man, that thou visitest him?" But let it be remembered, that of all the creatures of God, it was man alone who was created in his own image; and although he be morally fallen from the high estate in which he was first wrought, so that, on the beauty of that form of holiness under which he dwelt in paradise, and wherein was glassed the image of God himself, there has passed the ruin of sin, yet does the soul of man still, as to its intellectual lineaments, respond in some degree to the dignity of its origin, and vindicate the immortality to which it is reserved; "for there is a spirit in man, and the inspiration of the Almighty giveth him understanding" (Job, xxxii. 8). And thus the Psalmist says, in continuation of the passage last quoted: "For thou hast made him a little lower than the angels, and crownest him with glory and honour. Thou madest him to have dominion over the works of thy hands," &c. *The soul of man yet remains the greatest of the works of God in this lower world.* The philosopher who, first tracing the finger of God in the things around him, and marking their relations, both as to the component elements of each, and as to the system of created being which includes the whole,—then extends his thoughts to the dimensions of the earth on which he stands, and conceives the repetition, throughout these dimensions, of that which his own more immediate vision embraces; whose view then passes the limits of this single planet, to rest upon those others which with it form our system of the universe; and thence to wing its flight, through unmeasured paths of space, to that region of countless suns and worlds through which the eye of science alone expatiates

> "To God's eternal house ————
> A broad and ample road, whose dust is gold
> And pavement stars."—*Paradise Lost*, vii. 576.

will within these wide precincts of creation have beheld *nothing in dignity comparable to the human soul* nothing in which the creative power and wisdom of God are so manifested as in that gift of *understanding* with which it has pleased him to endow it. That *spirit of man*—which linked *here, but as for a moment*, to the few members and organs of a frail and decaying body—an *atom*, whose range is through an *evanescent space* in creation—proceeds thence to mete out the paths of the planets, to poise the forces which hold them in their courses, to trace the operations of God's hand among the stars of heaven, and to follow out the purposes of his wisdom in the mechanism of the universe;—that understanding of man, to feel the utter insignificancy, ignorance, and folly of which, in comparison with the wisdom of God, "wonderful in counsel and excellent

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in working," and its infinite dignity, value, and importance, in comparison with any other created thing, whilst it humbles us under the hand of God, will tend to establish our faith in the high destiny to which the soul is reserved, and the mighty price with which it has been bought.

THE ECONOMY OF CREATIVE POWER.

"The Lord of hosts, wonderful in counsel, and excellent in working."—*Is.* 28, 29.

It is a *thing observable* through every province of nature—a *principle* to which every science lends its authority, that the power of God, *infinite in its developement is infinitely economized in its operation*—a principle to be traced in every manifestation of force in inanimate matter, and under every form of independent motion. All that we call design in natural things has in some way a direction to it. The very weed under our feet shews it in the form of its stalk; and the tree of the forest shapes out its trunk, moulds its branches, and tapers the very stems and fibres of its leaves, in obedience to it. That economy of creative power which thus manifests itself in the works of God, infinitely *perfect* in its degree, has its remote but visible type in the *imperfect* husbandry of *our* efforts, which impels *us* to use the simplest possible means of effecting that which we have to do, and which is implied in what we call the best means of doing it. In us this economy has for its object the preservation of our living powers; and for its immediate origin, a sense of lassitude and fatigue, for that end specially implanted in every living thing. In Him by whom this sense was laid upon us as a law, but whose own arm is "not straitened," and who "fainteth not, neither is weary" (Ps. xl. 28), that which in us he has made a necessity of nature, is but a principle of wisdom in operation.

Let us now seek if there be any evidence by which it is given us to perceive the operation of this principle in the architecture of the heavens. Let us listen if, in the stillness of the universe, there be not a *voice* re-echoed from worlds which, "without speech or language," traverse its unfathomable regions, and stars which silently repose in its depths—the voice of revelation: "by His *wisdom* hath he made the heavens, and stretched them out by his *understanding*."

It is a high privilege thus to be able to commune with God in his works—to feel (as it were with a *sense* of the understanding) his wisdom guiding the hand of his power. It is to enjoy here a knowledge of which, little though it be, that of heaven, as far as it includes the mysteries of creation, cannot but be a continuation—to hold here a few links of a chain which proceeds from the throne of God. And although now it is to the silent monuments of nature that the researches of science are limited, and in respect to these although now we see but as "through a glass darkly," yet is there a spirit of devotion which, regarding these things as *beginnings*, with a faith almost invigorated into knowledge, anticipates, walking in this twilight,—the daylight of heaven—when we shall see "face to face," and "know even as we are known;"—a time when to the soul, now released from the corruptible body, in some degree (however slightly) schooled by the instruction of faith and knowledge, and no longer straitened by the imperfections of sense, the works of Grace, the works of Providence, and the works of Nature, shall present, under one vast but simple and united scheme, the equal evidence of God's mercy, his wisdom and his power.

THE APPARENT PATH OF THE SUN IN THE HEAVENS.

"In them hath he set up a tabernacle for the sun, which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run his race."—*Ps.* xix. 5.

Of the changes of the heavens, those which first fix our attention are the daily revolutions of the sun and stars. Every day the sun takes his course in a zone obliquely across the sky; and between sunset and sunrise the stars, each in a path like that of the sun, revolve from the eastern to the western margin of the horizon, there to disappear, but on the following night to present themselves again nearly in the same quarter of the heavens, having in the intervening period of light journeyed through some region unknown to us, but apparently beneath our feet.

In this motion of the stars the most remarkable fact is, that they preserve their relative positions, each star moving so that its distance from the adjacent stars, and its position in respect to them, remains always the same. It is as though the whole dome of the sky, carrying with it the host of heaven, swept with an equable motion round a mighty axis placed obliquely across the space beneath it. The point where this imaginary axis intersects the dome of the sky is, in our latitude, situated somewhat above half-way up its northern side, and is called its *pole*. The paths of the stars are circles, or, as it were, bands of the sky round this point. In their revolutions they preserve always the same distance from it, and seem to respect it. Being situated on the side, as it were, of the sky, some of them have not space to complete their circles beneath this point without sinking under the horizon; whilst the paths of others, did they leave a trace behind them, would be entire circles, completed on the face of the visible heavens. The first, when they sink beneath the horizon *set*, and *rise* when they come above it; the others, called circumpolar stars, neither rise nor set, never disappearing from the sky but in the daylight.

Of the stars which rise and set, the circular paths of some pass but little under the horizon, and the interval between their rising and setting is short; others, at greater distances, have larger segments of their paths cut off by the horizon, and are a longer time beneath it.

A star whose distance is equal to the quarter of a circle (or ninety degrees), measured from the pole over the crown or *zenith* of the sky, has *half* its path beneath the horizon, and half above it; and the interval between its rising and setting, and its setting and rising, are the same. If it were traced out upon the heavens, the path of this star would be a circle, called the equinoctial. All the stars beyond it, towards the southern margin of the horizon, have the greater portions of their paths beneath it, until at length but little of each path emerges, and the stars scarcely rise.

Imagining the sphere of the heavens, of which we see only one-half, to be *completed*, these appearances indicate to us an invisible point beneath the southern horizon, about which the stars revolve as about the *visible* pole, and which is situated at the opposite extremity of the great axis of the sky. About this invisible southern pole there revolve stars which never rise to us, as about the northern there revolve those which never set.

Were it not for the excess of brightness, the heavens would in the day time, when the sun shines, be seen covered with stars as at night. Amongst these stars the sun would not appear to keep his place, as they do in respect to one another; but, partaking at the same time in their daily motion, to travel amongst them, and, as it were, from star to star, with an *annual* motion, uniformly and in a circle.*

On a sphere an infinite number of circles can be described, but none greater than those which are said to *gird* the sphere. By geometricians those circles which gird a sphere are called *great* circles of it. Now, the path of the sun is not (like that of a circumpolar star, for instance) a small circle of the sphere of the heavens, but a great circle. Moreover it is not a circle parallel to the diurnal paths of the stars, but oblique to them, so as to intersect with those that lie near it. This circle is called the ecliptic, or sun's path. It intersects with the equinoctial, at points called the equinoctial points.

* There is an exact parallel to this motion of the sun amongst the stars in that of the moon, which, however, completing its course in the much shorter period of a month, may almost be *seen* to move amongst them.

THE PLANETS.

" The *worlds* were framed by the word of God."—*Heb.* 1, 2.

THE stars have been said all to retain, in their diurnal motions, the same places in respect to one another, and the same distances. This is not true in respect to six of them; these wander about among the rest, and are for that reason called (from a Greek word) *planets*. The paths of these planets on the heavens are not, like the path of the sun, circles; and their motion in them is not, like his, uniform, or always at the same rate. Their motions are exceedingly devious. Sometimes they are seen moving obliquely across the heavens, tending towards the north, but westward, or in the direction in which the revolution of the whole sky appears to take place; then the direction of their motion changes, and they travel among the stars southward and eastward. Thus irregular in the direction of their motion, they are yet more irregular in its velocity. At one time they move rapidly through the heavens; at another they are stationary. Their brightness, too, changes perpetually. Sometimes one of them will be seen fixed apparently from night to night, but rapidly augmenting its brightness, as though, from some distant region of space, it were approaching us in a direct line; or, in like manner, it may at other times be seen motionless, but shining night after night with a diminished lustre, as though in a direct line it were leaving us. The planet Venus varies, for instance, so greatly in brightness, as at one time scarcely to be distinguishable from a star of the second magnitude and at another to cast a shadow like the moon. It was by reason of their irregular motions, and their continually* varying brightness, that, in the early ages of the world, these planets were believed to move, not by any established and uniform law of nature, but each with an *independent will;* and that when, in God's anger, "men were given over to worship the host of heaven" (Acts, vii. 42), the imagination saw them surrounded as with the power and majesty of gods. The slowest, the dimmest, and the most distant, they called the god of time. He was represented as an old man, and appears to have been worshipped, with different attributes, under the different names of Saturn, Remphan, Phaënon.†

To another of them, in which, from its great size, its steady lustre, its wide range, and its less devious motion, it was easy for the imagination to see an ascendency, they gave the *throne* of the gods, and seem to

* The early period at which the planetary motions were made the subject of observation, and their intimate connexion with the most ancient mythology, is shewn in the division of the week, and the enumeration of its seven days according to the names and supposed distances of the sun, and moon, and five planets. This enumeration was common to the Egyptians and to all the nations of the East. It is of immemorial usage, and is called by La Place the most ancient monument of astronomical knowledge.

† "Ye took the star of your god Remphan" (Acts, vii. 43).

have called him, under different forms of worship, Jupiter, Osiris, Baal.*

A third is of the colour of blood. They made him, therefore, the god of battle, and named him Mars, Moloch, &c.†

That planet which, in its season, shed the fairest lustre, and gave the brightest light, but whose motion was most uncertain, and its path most devious, and which sooner than any other waxed faint, and was extinguished, they held to be the goddess of beauty, and, under what appear to have been but different forms, worshipped her as Venus, Astarte, Ashtaroth.‡

Lastly, there was the planet whose course was the most rapid, and which ever most closely attended upon the sun; this they took for the symbol of speed. As Saturn personified the slowness, so did this planet the quickness, of time, and they made him the messenger of the gods, under the names of Mercury, Stilbo, Nebo, (Is. xlvi. 1).

* They worshipped the host of heaven, and served Baal (2 Kings, xvii. 16). Them also that burned incense to Baal, to the sun, and to the moon, and to the planets, and to all the host of heaven (2 Kings, xxiii. 5).

† See Amos, v. 26, where the star of Moloch is spoken of.

‡ 1 Kings, ii 33.

THE THEORY OF EPICYCLES.

"With centric and concentric scribbled o'er
Cycle and epicycle, orb in orb."

Paradise Lost, viii. 80.

For centuries after the disappearance of the heathen mythology this belief in *planetary influences* remained, under the form of judicial astrology.* It had now, however, come to be known that the motions of the planets, uncertain and irregular as they seemed to be, were yet the subject of a certain law; a law of remarkable simplicity, if we consider the extreme complication of the phenomena embraced under it. As far back as the time of Aristotle, it had been suspected that there were certain geometrical curves, called epicycles, in which if the planets moved, their places in the heavens would be nearly those which they were observed to be. These curves they would describe if, each revolving round the sun as a central point,

* Even so late as the sixteenth century we find it maintained, by reasoning little different from that in which it probably had its origin, by Gerolamo Francostore, a distinguished writer, in his work called 'Homocentrica.' "The planets," says he, "are observed to move one while forwards, then backwards; now to the right, now to the left; quicker and slower by turns; which variety is consistent with a compound structure, such as that of an ANIMAL, which possesses in itself various springs and principles of action."

that central point were itself carried on in a circle round the earth.* The epicycle of each would have the appearance of a scroll passing round the circumference of that great circle which is the sun's path, and having a series of loops within it. And in describing each loop, to an eye too remote to estimate the change of distance, the planet would appear at one time to be stationary, and at another to move in a retrograde direction, varying its brightness, especially at its sta-

* As another illustration of the form of this curve—to the extremity of the hand of a clock let a watch be supposed to be fastened, carrying at the extremity of *its* hand a pencil so fixed as to trace a line on the face of the clock. The curve traced out by this pencil, as the hands of the clock and watch revolve, is an epicycle; and by setting the clock and watch to different times, its form may be varied in any way we think fit. To represent the true epicycles of the planets, or those in which, as it was afterwards discovered, they might, consistently with their appearances in the heavens, be considered actually to move, we must imagine the watch to have five hands, of lengths which bear the same proportions to the length of the hand of the clock that the distances of the planets from the sun do to the distance of the earth. These must, moreover, revolve in times which bear the same proportion to the time of the revolution of the hand of the clock that the periodic times of the planets do to the length of the year. The centre of the clock then representing the earth, and the centre of the watch the sun, the curves described by the different hands of the watch will truly represent paths in which if the different planets moved, their apparent motions in the heavens would be precisely what we see them to be. The ancient Egyptians are asserted, on the authority of Macrobius (Comment. in Somn. Scip., i. c. 19), to have given to Mercury and Venus orbits of this kind about the sun, as they accompanied him in his revolution about the earth. The same theory is obscurely hinted at by Cicero (Somn. Scip.), and distinctly by Vitruvius (lib. ix. c. 4).

tionary points, where its motion would be directly from the earth, or to it.

As in the progress of years, recorded observations increased in number, this theory of epicycles was gradually perfected;* and it was found that the places of all the planets, and their motions, might be with great accuracy predicted, by supposing them all to revolve in circular orbits round the sun in the same direction, but at different distances, and with different velocities—the sun himself being swept with all this train of attendant planets, in a circle round the earth. The distance of each planet from the sun, and its velocity, and the distance of the sun from the earth, were elements necessary to any calculation founded on this theory. These being at length, however, sufficiently well made out, the basis of an extensive knowledge of practical astronomy was laid upon them.

It is evident that this theory of epicycles supposes a continual change in the distances of the several planets from the earth. Since the discovery of the telescope by Galileo, it has become possible to measure the apparent diameters of the planets; and there have been found changes in them which accurately coincide with

* It is to the astrologers of the middle ages that this perfecting of the theory of epicycles is wholly due; they applied their knowledge of it to the purposes of their art. Fallacious as it was, science yet owes to it large obligations. It is not too much to assert, that without that knowledge of the law of the planetary motions which the theory of epicycles supposes, the system of Copernicus would have remained until now a bare speculation, as did that of Pythagoras for more than two thousand years. Whilst astronomy was thus being nurtured by astrology, chemistry was cradled by the sister delusion of alchemy.

those changes of distance which each would undergo moving in its epicycle. Similar observations on the sun shew that his diameter is nearly constant, as it would be moving in a circle. So that, on the whole, we may consider it to be a thing established by the most certain evidence of observation, that the positions of the planets are the same as they would be if, revolving all in different concentric orbits round the sun, and in different times, he swept them with himself every year in an orbit round the earth.

DO THE STARS REVOLVE ROUND THE EARTH?

> "Whether the sun predominant in heaven
> Rise on the earth, or earth rise on the sun,
> He from the east his flaming road begin,
> Or she from west her silent course advance."
>
> *Paradise Lost*, viii. 160.

Now, let us review the complicated and improbable conclusions to which the appearances of the heavens have hitherto led us. The first is, that the whole host of heaven, including the sun, planets, and stars, revolve round us with a common revolution every twenty-four hours. We have seen that the region of the fixed stars is distant from us by a space not less than 100,000 times the diameter of the earth's orbit, or by 19,200,000 millions of miles. Being thus distant, the magnitudes of the fixed stars must be enormous, or they could not be visible to us, however bright they might be.* Moreover, being thus distant, if they revolve round us every twenty-four hours, they must fly through space with inconceivable rapidity. A daily revolution of the heavens amounts, then, to this; that millions of huge spheres of matter, endued with the same principle

* Sir J. Herschel has calculated that the light emanated by the star Sirius cannot be less than twice that of the sun. It is probably far more.

of force, subject to the same laws, urged with the same primeval impulse, as that matter which composes our earth, each pouring forth a flood of native light through the abysses of space; that these stars innumerable, so thick in visible space that the eye cannot in some parts of it discover any interval or separation between star and star; so many, that whenever we succeed in fathoming more deeply the space in which they dwell, by powerful telescopes, we invariably find more of them;—that these stars innumerable each in its own mighty orbit of more than 19,200 billions of miles, revolve in the same direction, and in parallel circles, with a velocity greater than that of light round this earth of ours, which is but as an atom in comparison with the least of them:* moreover, that all the planets, describing each its particular orbit round the central sun, and the sun its orbit round the earth, besides their respective and proper motions, have one common daily motion of infinitely greater rapidity and extent around this earth, which is almost the least of them.

The fabric of nature more immediately around us manifests a simplicity in its design, a proportion and harmony in its parts, and an economy of creative power, with which every thing in this scheme of the universe is at variance. Now every element of disproportion vanishes from it; it changes into a system

* If anything could add to the force of this improbability, it would be the consideration that the stars are by no means disposed in space with any visible reference to the position of the earth; there is no uniformity, no correspondence of situation between them and it.

of marvellous simplicity and beauty, reconciling itself entirely to the analogy of nature, and worthy of Him who hath "established the world by his wisdom, and stretched forth the heavens by his understanding;" if, for the daily rotation of the heavens, the millions of stars, the sun and planets, round this little earth, we substitute a daily rotation of the earth about its axis; and for the annual revolution of the sun about the earth, accompanied by his train of attendant worlds, we substitute a revolution of the earth in common with the other planets round the sun at rest—thus giving to it two motions, one of rotation, and the other of translation, which two motions we shall shortly see to involve in themselves a probability.

A daily rotation of the earth upon its axis is sufficient to account for the apparent daily revolution of the heavens. An annual revolution of the earth about the sun similar to that of the other planets, and in the same direction, is sufficient to account for the apparent annual revolution of the sun about the earth in a circle, and for the apparent motions of the planets in epicycles, according to the theory of the astrologers. These facts first presented themselves to the mind of Nicolas Copernicus, a canon of the cathedral church of Warmia, and were published in 1543, after his death, in his work, 'De Revolutionibus Orbium Cœlestium.' They establish the system of the universe known by his name, and constitute the greatest discovery of the visible works of God ever yet vouchsafed to the human mind.

THE MOTION OF THE EARTH.

> "With inoffensive pace, that spinning sleeps
> On her soft axle, while she paces even,
> And bears thee soft with the smooth air along."
>
> *Paradise Lost*, viii. 165.

It has been explained, in a preceding paper, that the horizon of any observer on the earth's surface may be supposed to be a plane touching it under his feet, and hiding from his view that half of the heavens which is beneath it. Moreover, that as he moves about, this plane, rolling on the earth's spherical surface, and thus altering its position in space, varies continually the hemisphere of the heavens which he sees above him, approaching, as it were, and passing the stars in the quarter of the heavens *from* which, and receding from those *towards* which, he moves. This fact, unconscious of the motion of his horizon, he attributes to a motion of the stars themselves; and thus it is that those who sail from hence into southern regions of the world see, to their astonishment, the northern stars apparently sinking behind them into the sea, whilst before them stars unknown to our sky rise out of the south. Now, let us for an instant suppose the apparent daily motion of the heavens to cease, and let one of the persons just spoken of, instead of travelling southward, travel due east; his horizon will then, for the same reason as before, so alter its position as to cause the stars to appear to rise before him out of the east, and to set behind him in the west. Instead of the slow motion of a ship, suppose him to be carried round the earth with a velocity great enough to complete the circuit in twenty-four hours; the rising and the setting of the stars will then evidently be to him precisely as we see it: the only difference of the cases is, that he is conscious of his motion, and we are not. Make them, then, alike. Suppose that he floats upon a current which circulates round the earth and of whose flow he is unconscious; the deception will then be complete. Now, let the earth itself turn beneath this current with the same velocity with which the current circulates, and in the same direction; the whole, current and earth, will now turn round together and in one mass, and the phenomena of the daily motion of the heavens will present themselves precisely as we see them; the point of the heavens about which all the stars will appear to turn being that where the axis of the earth's revolution, being produced, meets them, and the position of the horizon in respect to that axis determining the apparent position of that point in the sky.

Thus is the apparent diurnal revolution of the heavens explained by an actual diurnal revolution of the earth.

Give to the earth, at the same time that it thus rotates continually round an axis within itself, an annual revolution round the sun, such as the other planets have, and in the same direction; the epicyclical orbits of these will then pass into circles described round the sun at rest and the earth will take her place amongst them—one of a system of worlds of which each has its particular orbit, and its own time of revolution; different elements, which are nevertheless related to one another by numerous analogies, and by various common laws of dependence upon the central sun.

What is required to prove this? It has been stated that all the apparent distances of the planets from the earth, and all their apparent positions in respect to the sun, have been found by observation to agree with the hypothesis of epicycles.

It is now, then, required to shew that these circumstances will all be the same on the hypothesis of the earth's revolution in common with the planets round the sun, as upon the opposite epicyclical hypothesis of the earth's quiescence, and the sun's revolution about it, carrying the planets with him.

The proof of this fact is very easy. It depends upon the general principle of relative motion, "that if any number of bodies be moving in any way in respect to one another, and you communicate to them all, other motions equal to one another, and in parallel directions, and towards the same parts, then whatever are the amounts of those motions, provided they are thus equal, and whatever are their directions, provided they are thus parallel and towards the same parts, the motions of the bodies in respect to one another, and their positions at all times in respect to one another, will remain *unaltered*"—that is, these bodies will all be in the same position in respect to one another, and at the same distances from one another, at any given time, as they would have been before.

To illustrate this principle, let the reader conceive to himself a number of people moving about with any regular motion on the deck of a ship at anchor—the sailors working the capstan, for instance; and to communicate to them equal motions in parallel directions, let the men be supposed to continue to work the capstan after the anchor is weighed and the ship under sail. The motion of these men in space will now be entirely different from what it was before; so that if each man as he moved could leave his footsteps marked on the surface of the sea, the trace would be a curve of a far more complicated nature than that circular path of which he would have left the trace, if the ship had remained at anchor; yet will the motion of every man, although in reality thus tortuous, be, *in respect to the rest*, and to the different parts of the ship, precisely what it was before.

Had, indeed, a portion of the ship admitted of separation from the rest, and had a different motion been communicated to that portion, it is manifest that the positions of the men in respect to one another on the two portions would have been *changed*—it is the fact of the whole receiving parallel and equal motions that constitutes the identity of their *relative* positions in the two cases.

To connect this illustration more immediately with the problem of the heavens, let us suppose that there are *two ships*, one of which is at anchor, and that the other sails round it in a circle. Let us further suppose that round the capstan of this last there are five men working, and not all moving round it in the same time as men usually do who work a capstan, but in different times, bearing the same proportion to one another, and to the time of the revolution of the one ship round the other, that the periodic times of the planets do to one another, and to the time of the apparent revolution of the sun. Let them, moreover, work at different distances from the capstan, having the same relation to one another, and to that of one ship from the other, that the distances of the planets and earth from the sun have ;* these men will then evidently come into precisely the same position in respect to the fixed ship, that the planets appear by observation to come into in respect to the earth.

Now, let us suppose the anchor of the fixed ship to be weighed, and forces to be applied to the two ships such as would be sufficient, if they were both at rest, to communicate to both of them motions precisely equal to that of the movable ship, but in an opposite direction ; the force thus applied to the movable ship acting against the force which moves it, and being equal to that force, will bring it to rest ; whilst that communicated to the fixed ship will give it a motion precisely equal to that which the movable ship had before, and therefore cause it to revolve round it in a circle concentric (if its capstan be in its centre) with those in which the men are working.

We have now, then, the case of the one ship, and the men on the deck of the other, all working round the same centre and in the same direction. Moreover, the relative positions into which they are thus brought are precisely the same as they were before ; for by communicating to the two ships equal and

* To preserve this proportion of distances, the deck of the movable ship must be extended by an imaginary plane, on which three of the men must be supposed to work in circles, including the fixed ship.

parallel motions, we have, in fact, communicated to the one ship, and to all the men on the other, equal motions in parallel directions, by communicating which we can in no way have altered their *relative* motions. Thus, then, the relative motions of the men and the second ship are the same, whether we suppose that ship to be at rest, and the first to carry the men working the capstan round it, or whether we suppose the first to be at rest, and the second to sail round it in the same direction in which the men are working round its capstan. Let the first ship represent the sun, the men working round its capstan the planets, and the second ship the earth, and the analogy to our system of the universe will be complete. The same conclusion, then, applies to it. The relative positions of the planets, and sun, and the earth, will be the same, whether we suppose them each to revolve in its proper orbit round the sun, and the sun to carry them all round the earth; or whether we suppose them to revolve round the sun at rest and the earth also to revolve round him in the same direction as they revolve, and in a similar orbit.

It only remains now to shew that the apparent motion of the sun amongst the stars in a circle round the earth would be produced by a revolution of the earth in space round the sun. For this purpose let an illustration again be borrowed from the motion of a ship. Let us suppose that it is night, and that a ship is sailing in a circle at a considerable distance (say a mile) round an isolated light-house. Let there be, moreover, another light visible at a much greater distance (say twenty miles; both these lights will be seen from the ship upon the circle of the horizon; and if the nearer one be a much dimmer light than the other, the difference of their distances will not be distinguishable. That round which the ship is sailing will, however, appear in succession at all the different points of the compass, whilst the other remains fixed at the same point. And if on board this ship there be an observer who is unconscious of its motion, he will believe that the one light actually revolves round him in the horizon, whilst the other remains fixed upon it. Now, instead of there being but one *distant* light, let there be supposed to be a number scattered all round the offing: these will all appear fixed; and the nearer light round which the ship sails will, to the observer who believes himself at rest, appear to move amongst them in a circle completely round him. Thus, the appearance is the same when the ship is carried round the light at rest, as it would be if the light were carried round the ship. If the central and nearer light be taken for the sun, the distant lights for the stars, which have been shewn to be immensely distant as compared with the sun, the ship for the earth, and the surface of the sea for the plane of the earth's orbit, this case will present an accurate illustration, and a complete analogy to the apparent motion of the sun among the stars. The same reasoning may be applied to both, and it follows that this motion would equally appear to take place whether the sun revolved round the earth, or the earth round the sun.

On the whole, then, we have, on the one hand, this complicated hypothesis, that the earth is at rest, and that the millions of stars and worlds which people that space, in the immensity of which the earth is but as an inconsiderable speck, revolve daily with a common motion round it; that, besides this daily motion, in which the sun and planets partake with the rest of the heavens, the planets revolve, each at a different distance, and in a different time, round the sun; and that the sun, of dimensions incomparably greater than the earth, and with this train of satellites, is himself a satellite of the earth, revolving round it once a-year; —on the other hand, we have this hypothesis, possessing, as we shall shortly shew, an *independent* probability, that the earth rotating about an axis within itself, at the same time revolves round the sun at rest in an orbit similar to that of the other planets of our system, and in the same direction.

> "When I behold this goodly frame, this world,
> Of heaven and earth consisting, and compute
> Their magnitudes; this earth a spot, a grain,
> An atom, with the firmament compared
> And all her numbered stars, that seem to roll
> Spaces incomprehensible (for such
> Their distance argues and their swift return
> Diurnal), merely to officiate light
> Round this opaceous earth, this punctual spot,
> One day and night; in all their vast survey
> Useless besides; reasoning I oft' admire
> How Nature, wise and frugal, could commit
> Such disproportions."—*Paradise Lost*, viii. 15.

An opposition to the established analogy of nature is that which in natural things constitutes an *improbability*; and there is somewhere a limit where that which is improbable merges in *impossibility*—that limit is passed when the first of these hypotheses, in itself greatly improbable, is placed by the side of the other.* But it may be asked, improbable as it may be that the sun and stars should have the motions which they appear to have, has not the opposite hypothesis, too, its improbability? Is it probable that a huge mass like the earth, 8,000 miles in diameter, should be *in motion*, and with the *twofold* motion which this hypothesis assigns to it. There is a conclusive answer to this objection. It is more probable that the earth is in motion than that it is at rest; and being in motion, it is more probable that it should *rotate* than not. The fact that it exists a mass *isolated* in space, resting upon no other, having no friction against any other, resisted by nothing, constitutes in itself an independent probability that it is in motion; and, being in motion, that its motion is *twofold*—that it spins round an axis within itself, and at the same time advances forward in space.

It is a law of motion, founded upon observation, that when once communicated to a body, *it can never cease to exist in that body* in the same quantity and direction as it existed at first, provided there be not, or have not been, some resistance or other force tending to destroy or divert it.

It is another principle of motion, that if it be communicated, by impact or otherwise, to a mass in any

* The discoveries of Newton have not here been alluded to. It may, however, be mentioned, that when the theory of gravitation is thrown into the argument, a revolution of the sun about the earth becomes a mechanical impossibility. There are, moreover, proofs drawn from other phenomena, which do not come within the scope of a popular discussion, which are equally unanswerable evidence of the earth's motion. The aberration of light is one.

other direction than through its centre of gravity, this mass when left to itself will have two motions—one a motion of translation, in which all its parts, including its centre of gravity, will partake equally; the other a motion of rotation, which will ultimately become steady about a certain axis passing through its centre of gravity, and in which its different parts will partake differently as they are at different distances from that axis. And it is a remarkable fact, that these two motions of rotation and translation will be quite independent of one another; so that the motion of translation will be the same as though there had been no rotation, and the motion of rotation the same as though there had been no translation.

To illustrate this, let the reader tax his imagination to *conceive* gravity to have become extinct, and the atmosphere to be removed from the earth's surface—as, indeed, it would then remove itself; and let him suppose that under these circumstances I were to take a ball into my hand, and, holding it up, that I were to place it in the void before me, releasing my grasp from it. It would be impossible that in so releasing my grasp I should not communicate to it *some* motion—With that motion (by the first of the two principles just stated) it would *move on for ever.*

Moreover, it is in the highest degree improbable that this motion shall have been communicated to the ball by my hand precisely through its centre of gravity; and this not being the case, the sphere would (by the second principle) begin instantly to spin round some axis passing through that point—that is, through its centre—and would thus move continually forward in a straight line, spinning at the same time on an axis within itself, until it was lost in immensity.* It has been stated that it would be *impossible* to release the ball from the hand without communicating some motion to it; and this is perfectly true, as any body may convince himself who will try to place a ball of wood in the water without making it turn round or move to the right or left of the place where he puts it; but it is equally true, that with care he may so release his hold as to cause this motion to be very small; and, it may be urged, that if that care were *perfect*, the ball might be released and yet left perfectly at rest. This, again, is very true; but, then, it must be remembered, that the care spoken of, with a certain exercise of judgment, supposes the development of a certain force; for the *act* of placing the ball in space supposes the communication of a certain motion to it which has a tendency to continue, and which must be checked by the hand before it can leave it at rest: so that even were we to suppose it to be placed in the void by that hand which acts under the direction of Infinite Wisdom, yet still, supposing it to operate subject to laws of matter and motion before established by it, there would be required a second and further operation of that hand that the ball should rest. It is scarcely necessary to apply this illustration. That the hand by which the materials of our globe were brought together, and then placed in the void space, *might* have been withdrawn, and yet the mass left

* An illustration will suggest itself to the mind of the reader in the motion of a stone. It is impossible so to throw it into the air that it shall not spin round as it moves forward.

quiescent in space, who will venture to deny? That it *should* thus *rest* supposes, nevertheless, a *second* operation of that hand. It is a *simpler* thing that the earth should be in motion, than that it should be at rest; and, being a simpler thing, it is according to the analogy of nature, a more *probable* thing.

The quiescence of the earth has been shewn, from other considerations, to involve an improbability of an infinite order; and the supposed improbability of its motion has been converted into a probability now to be thrown into the scale of evidence, and to complete it.

We have thus seen the first rude speculations of science connecting the irregular motions of the planets with an independent will and a supernatural agency; following the progress of events, we have next found recognised the indications of a *law* in the planetary motions—a law which, at first confused, broken, and unconnected, was at length perfected into the theory of epicycles. Lastly; the mystery of the universe presented itself to us *resolved*, and the wisdom and simplicity of God's laws in creation vindicated, in the system of Copernicus.

In reviewing this painful and tedious progress of the human mind through one page of the book of nature, it is impossible not to anticipate with joy a time when the whole shall be revealed, and, under the same mighty scheme, our knowledge shall comprehend with the mysteries of nature the dispensations of Providence.

There are providential manifestations of God's hand plain as are the stars in heaven, but out of the ordinary course, opposed to the usual order of its operation —perplexed, irreconcilable, inexplicable. And there are times when—like those who, observing the uncertain and tortuous motions of the planets, believed them to move subject to no law, but capriciously and by a wild ungovernable will—*we* are tempted to ask, "How doth God know? and is there knowledge in the Most High?" (Ps. lxxiii. 11.) Or when, with an impatience scarcely less presumptuous, we venture to prescribe schemes and systems for the Almighty unworthy of his perfections; as by the astrologers of old the heavens were

"With centric and concentric scribbled o'er,
Cycle and epicycle, orb in orb."—*Paradise Lost*, viii. 80.

Let us remember that there is a knowledge too wonderful and excellent for us—we cannot attain unto it; and that while the revelation of nature has no other limit than the inadequacy of human reason, that of God's word is limited to the necessities of our condition as sinners. For all the practical purposes of life this is enough; as—to carry on the analogy—for all those practical uses, by reason of which men consult the heavens, the theory of the old astronomers was sufficient:—

"Heaven
Is as the book of God before thee set,
Wherein to read his wond'rous works, and learn
His seasons, hours, or days, or months, or years.
This to attain, whether heaven move or earth
Imports not, if thou reckon right."
Paradise Lost, viii. 66.

Let us not, then, seek to know more than is revealed—to be wise beyond that which is written.

"And for the Heav'ns' wide circuit let it speak
The Maker's high magnificence, who built
So spacious, and his line stretch'd out so far;
That man may know he dwells not in his own;
An edifice too large for him to fill,
Lodg'd in a small partition, and the rest
Ordained for uses to his Lord best known."

Paradise Lost, viii. 100.

Ere long light will be thrown on the mystery that surrounds us; its anomalies will then pass away, and its perplexities vanish.

CERTAIN MODES OF HUMAN EXISTENCE ASCRIBED IN SCRIPTURE TO THE ALMIGHTY.

Revelation does not clear up the mystery which Nature has thrown around that act—filled with the immediate glories of the presence of God—in which she had her origin, when the foundations of the earth were laid, and when the morning stars sang together, and all the sons of God shouted for joy (Job, xxxviii. 7). It concerns truths of infinitely greater importance to us.

In numerous passages of Scripture, there is, however, ascribed to the Almighty, in the great work of creation, the exercise of faculties and powers analogous to those which we are accustomed to associate with the operation of *our bodily organs.*

We read that in the beginning, when the earth was without form and void, and darkness was upon the face of the deep, the voice of God was heard in the stillness of the universe, and there was light; and it was divided from the darkness. Every subsequent act of creation was accompanied by a *command,* and their names declared by the *voice* of God, were re-echoed from the firmament of heaven, and from the dry land, and from the gathering together of the waters (Gen. i. 8, 10).

We are ourselves said to have been the work of God's hand, by which we were fashioned as clay by the hand of the potter (Is. lxiv. 8), and clothed with skin and flesh, and fenced with bones and sinews (Job, x. 11).

He is represented to have measured the waters in the *hollow of his hand*, and to have builded up the world as an architect. "Every house is builded,' saith the apostle, "by some man; but he that built all things is God" (Heb. iii. 4).

His EYE is said to look to the ends of the earth, and see under the whole heaven (Job, xxviii. 24); and to have seen our substance yet being imperfect (Ps. cxxxix. 16).

His EAR is described as open to the cry of the righteous (Ps. xxxiv. 15); and when he planted the ear, he is said to have *heard*.

Nevertheless, God is a Spirit (John, iv. 24). He is invisible; whom no man hath seen at any time, nor can see at any time; neither hath any man heard his voice at any time, or seen his shape (Heb. xi. 27; 1 Tim. vi. 16; 1 John, xviii. 37).

Having no corporeal parts, or bodily nature, it is impossible to associate his actions with the operation of any bodily organs.

It may be, that terms expressive of these actions are used in Scripture only in a figurative sense—from a necessity of our ignorance, and, as it were, in compassion to it—actions of a like kind with those we ourselves perform being the only ones of which we can as yet conceive: or, it is possible, that the actions ascribed to him are strictly such as we are accustomed to associate with the words used, only separated from those bodily organs through which we perform them.

May we not venture to speculate so far as to assume that the second of these suppositions derives an independent probability from that image and resemblance in which man was originally created to God, and which is to be traced in a corresponding resemblance between God's works in creation and the works of man—between nature and art?—a relation of qualities alike in *kind*, although infinitely removed in *degree*; the resemblance of that which is infinitely weak and imperfect to that which is infinitely powerful and perfect.

If thus it be, how wonderfully is art elevated by the reflection that it is but nature on a diminished scale, and operating with a less perfect skill; a thing done by a creature of God—a creature *made in his own image*, and operating upon matter governed by the same laws which he in the beginning infixed in it, and to which he subjected the first operations of his own hands—a creature in whom is implanted reason, but as the feeblest ray in comparison with the whole light of the sun, but still of a like nature with that by which the heavens were stretched forth; living power as that of a worm, and as a vapour that passeth away, but an emanation of *Omnipotence*; a perception of beauty and adaption infinitely removed, but *akin* to that whence flowed the magnificence of the universe; and to control all these a volition, whose freedom has, with an inconceivable separation, its analogy, and, afar off, its source, in that of the first self-existent Cause.

How full of dignity is the thought, that in every exercise of human skill, in each ingenious adaptation, in each complicated contrivance and combination of art, there is included the exercise of faculties which, though separated by an infinite interval, are yet allied to those in the operation of which creation had its birth! And how full of humility is the comparison, which, placing the most ingenious and the most perfect of the efforts of human skill by the side of one of the simplest of nature's works, shews us but one or two rude steps of approach to it! How full, too, is it of profit and instruction to see God thus in *every thing* around us, in every object of *art*, as well as in nature—to find him working with us in the daily operations of our hands, wherein, under different and infinitely inferior forms, we do but reproduce his own delegated wisdom and creative power!

A man may thus *sanctify* the daily exercise of his mechanical skill, hold converse with God as intelligibly in art as in nature, and live under as open a manifestation of his presence in his workshop as when he goes forth, among the green fields and upon the hills.

And when he thus reflects on the manifest but infinitely remote analogy of his physical and intellectual nature to that of Him in whose image he was made, *can the contrast of his moral nature escape him?* Can he but reflect that, with all this dignity of the intellectual and physical being, there must once have corresponded an equal standard of the moral being? *that, with all these faculties for the recognition and worship of God, there must once have united a corresponding elevation of the religious being?*

THE GREAT ARTIFICER

"The heavens declare the glory of God; and the firmament sheweth *his handy work*."—*Ps.* xix. 1.

THE reference made in the commencement of this paper to those passages of Scripture in which the operation of God in creation is associated with actions which we can only understand to be performed by the agency of corporeal organs, has led us into speculations about which there may possibly be differences of opinion. There can, however, be none as to the propriety of using, under the sanction of those passages, similar terms in speaking of the agency of God in natural things, and leading the mind to a conception, however imperfect, of his wisdom and goodness, as manifested in that distribution of temperature on the earth's surface of which we are about to speak, by the analogous supposition of an ARTIFICER modelling in succession different parts of the surface of a globe.

Let, then, an artificer be imagined to be occupied in sculpturing on the surface of a globe, a work of exquisite delicacy and beauty— a landscape into which there enter as parts mountains and valleys, rivers and lakes—a tissue of foliage, trees, herbage, flowers, fruits, and figures. For its perfection, let it be necessary that every part of it should be subjected to certain varieties of temperature, and that certain intensities of light should fall upon it; and especially at those places on the globe where he is at any time more particularly working, let there be required a *powerful* heat and a *strong* light. Let this heat and light be radiated* from a furnace, before which, but at some distance from it, the globe is placed.

One-half of the globe will, at any instant, be receiving the light and heat of this furnace; and the opposite half will, at that instant, be receiving no heat, and be in darkness.

Of the enlightened and heated side, there will be one particular spot upon which the *direct* light and heat will fall; it will easily be distinguished from the rest by its greater brightness.

On all other points the rays of light and heat will fall *obliquely*, and the more obliquely as they are *the more distant from this point*,—enlightening and heating the surface, by reason of their increasing obliquity, less and less; until, beyond the boundary of the two hemispheres, the light and heat are wholly intercepted by the mass of the globe.

There are two methods by which the artificer may obtain light and heat on the unenlightened and unheated portion of this globe. He may alter the posi-

* The verb *to radiate* will readily be understood to apply to the emission of rays. There are such rays both of light and heat, and bodies in a state of combustion emit and radiate both. There are, however, other bodies which emit or radiate only rays of heat. of this class are all heated bodies when not heated to redness. This separate radiation of heat, or emitting of rays of heat, a property possessed in a greater or less degree by all heated bodies will often be referred to in the following paper; it is here explained once for all.

tion of his furnace to the other side of the globe, or he may turn his globe round, so that the other side of it may face the furnace. In either of these cases the spot on the globe where the *direct* light and heat fall, and which is the most enlightened and heated, will be altered; and, by continually turning the globe, or by continually varying the position of the furnace, this spot may be made to traverse the whole surface of the globe, so that every point upon it shall receive, in its turn, the direct light and heat.

But the artificer seeks to *economize his labour;* he is impelled to that economy by a law of his nature. To move about his heavy and cumbrous furnace will therefore not enter into his thoughts, and he will at once decide to effect his object of obtaining a powerful light and heat on the points of his globe, on which in succession he is about to work, by *rotating* it.

He will perhaps suspend it by a string from the ceiling of his room, or he will place it upon an axis by passing an iron rod through its centre, and supporting this rod at its extremities in such a way that it may turn on the points of support. But he will soon find that by this simple contrivance he cannot receive the *direct* light and heat on *every* point of his globe. Whatever is the position of the axis on which he has supported it, when he turns it round upon that axis, he will see the bright and heated spot to traverse, not the whole globe, but only one narrow circle or zone of it. That it may fall on other points than those included in this zone, the position of the axis must be changed.

Let us now imagine *this* change to take place in the position of the axis. From an upright position let it slowly and uniformly incline, round its middle point, until one extremity is turned directly towards the furnace; let it then revolve back again with the same uniform motion past its first position, and until the other extremity is directed towards the furnace. Whilst the axis is thus vibrating backwards and forwards, turning alternately its two extremities towards the direction from which the light and heat come, let the sphere be continually and rapidly rotating upon it. And to fix in the mind an idea of the relation of these two motions, let it be supposed to rotate about its axis 365 times, whilst the axis itself is slowly making one of its complete vibrations.

It is evident that as the globe thus rapidly revolves, and turns the two extremities of its axis (called its poles) alternately towards the fire, the point of direct heat and light will traverse, in order, every point of it; and that it will have traversed every point twice when the axis has completed a vibration.

The artificer is now enabled to work on every point of his globe in succession under the *direct* light and heat of the furnace. But has every part of his work thus been equally *heated?*

This is another question, and an exceedingly complicated one.

In the first place, let it be observed, that as the one pole (say the upper one) inclines towards the fire, the region immediately round it does not at each rotation pass at all from the heated and lighted side of the globe to the cold and dark side, so that it receives the heat *continually*,—that the region about the equator (which is mid-way between the two poles), and for some distance, more or less, from it, *does pass* at each rotation out of the heated hemisphere, and receives the heat only at *intervals*,—and that the region about the other (or lower) pole does not pass by its rotation at all out of the cold and dark, to the heated side of the globe, and does not, therefore receive *any heat at all*. Thus, then, by this arrangement, the regions about that pole which is in the act of inclining towards the fire will be receiving oblique heat, without intermission, until at length, in their turn, they receive also direct heat; whilst the equatorial regions receive their heat with a continual intermission; and the regions about the opposite pole receive no heat at all.

Moreover, let it be observed that, describing less circles at each rotation, the polar regions rotate under the heat more slowly than the equatorial regions do, and therefore imbibe more of its influence.

On the whole, then, it is evident, that by this arrangement the regions immediately about the pole which is inclining towards the fire will receive an immense accession of heat, and become intensely heated as compared with the equatorial regions; whilst the opposite polar regions will be receiving no accession of heat at all, and become intensely cold

Those remarks which apply *strictly* only to those points which are in the *immediate* vicinity of the poles and the equator, may be extended, with the requisite modifications, to the distribution of the temperature through all the intermediate regions.

Thus, instead of the artificer obtaining by this variation of the position of his globe, the same heat at each spot of its surface where in succession he seeks to work, and at the same time so ordering it that the other parts shall be protected from that extreme vicissitude of cold which might be injurious to the work which he has sculptured upon them,—he will, in fact, work at some points under a heat intensely greater than at others; and precisely those parts which are thus subject to the greatest heat will be those afterwards to be subjected to the greatest cold. The distribution of temperature thus brought about will then be characterized by the greatest varieties of heat and extreme vicissitudes of cold; a distribution the most unfavourable to the purposes of the artificer.

How shall he equalize it? The polar regions accumulated more than their share of heat: *first*, because they receive the oblique heat continually: never, during the inclination of the axis in one direction, passing out of the heated hemisphere, as the equatorial regions did; and, *secondly*, because, in addition to this continual oblique heat, they, in their turn, also received the *direct* heat of the fire, and rotated under it more slowly than the equatorial regions did. Both these causes tended to accumulate heat at the *pole*. Let, then, one of them be removed, and made to operate elsewhere; let the pole never receive the *direct* heat at all: and to effect this, let the axis never incline from its vertical into a horizontal position, but, inclining a certain distance towards the fire, let it return and incline an equal distance in the opposite direction, vibrating about its centre as before, not only from the horizontal into the horizontal position again, but from a certain inclined position into the same inclined position again. The *direct* heat will thus never be made to fall upon the pole, or upon a region for some distance round it, as it does apon the equatorial region; but the absence of this direct heat there, will be fully compensated by the fact, that this region never, for a long period, passes from under the influence of the oblique heat, as the equatorial region does at each rotation.

The degree of this equalization will manifestly depend upon the extreme inclination of the axis; and such an inclination might be fixed upon as should make the equalization perfect; that is, as the sphere rotates, the axis might be made to incline, until there had been communicated to every point in succession, from the equator to the pole, precisely the same extreme of temperature. Such an arrangement would probably be that best suited to the purposes of the artificer. But whilst he had so arranged it that the parts on which he is to work should all, in their *succession*, acquire the elevated temperature at which he might wish to work upon them, he could not by that arrangement have so ordered it that the opposite extremes of cold to which all would afterwards in their turn be subjected should be similarly equalized. When the axis takes its opposite inclination, the polar regions, which were before continually in the light and heat, will continually be in the cold and darkness, whilst the equatorial regions will continue to pass at each rotation into the heat. Thus the latter will be subjected to the influence of the heat at each rotation, and the former will not. Whilst the polar regions had then acquired, during the first inclination of the axis, the same maximum degree of heat as the equatorial regions, they will now be subjected to a much greater maximum of cold. Thus, then, it appears that the arrangement by which the same maximum of heat is brought about in succession upon the different points of the globe, is necessarily one accompanied by unequal extremes of cold, and therefore great and unequal vicissitudes of temperature.

Let us now suppose that our artificer finds these vicissitudes of temperature destructive of his sculpture, and that, retaining the equalization of maximum heat, he is desirous of diminishing them. He will at once perceive that they result from the inclination of the axis, and that they would be less if he could make the extreme inclination less. But that inclination was chosen as necessary to bring about the required equalization of maximum heat; how, then, retaining this equalization shall he diminish the inclination? Thus: the axis was before supposed to incline *uniformly*. Let it now incline itself more slowly as it approaches the extreme of its inclination; the same effect will then be produced as though, inclining uniformly, it had inclined farther; for although the point of direct heat will not now so nearly approach the pole as before, yet, when it has approached the nearest to it, it will remain longer there.

It is true that, in order to preserve accurately the equalization of the maximum temperature, under these circumstances, a very accurate adjustment of the motion of the axis will be necessary. But let us suppose that our artificer, by persevering observation and experiment, has arrived at a knowledge of the true law of this motion, so that without sacrificing the equalization of the maximum temperature he may, to the greatest possible degree, diminish the vicissitudes of temperature inseparable from that equalization. Already we have, it is true, supposed a case of admirable knowledge, discernment, and skill; more, perhaps, than it lies within the compass of the human understanding to realize. Let the imagination, however, pass on.

This well-measured and adjusted motion of the axis of the globe is to be *given to it.* By what complicated appliance of machinery shall it vibrate, with a motion varying from instant to instant, according to so perplexed a law, and, at the same time, rotate incessantly and uniformly? After an infinity of fruitless attempts to construct it, let our artificer at length perceive that the vibration of the axis may be wholly dispensed with, and yet that it may be brought precisely into the same positions with regard to the boundary of light and darkness, and heat and cold; and that the direct heat may thus be made to fall upon the globe precisely in the same way, if, its axis remaining always at its extreme inclination, and always parallel to itself, the position of the globe be continually altered, and it be made to move in a circle round the fire.* An idea which will probably have been suggested to him by the consideration, that the parallelism of the axis being thus preserved, the superior pole will, in one position of the sphere in its circle, be made to point—with the supposed extreme inclination—directly from the fire, and in the opposite position in the circle directly towards

* The fire is here supposed to throw out its heat equally in all directions.

it, and that the opposite relation will obtain with respect to the other pole.

Proceeding from this idea, and carefully examining the particulars of the two cases through all the intermediate positions, he will perceive that by this arrangement he brings about precisely the required positions of the axis in respect to the boundary of light and darkness, and precisely that motion of the point of direct heat on the globe which has been shewn to be requisite for the proposed distribution of temperature; being a slower motion of that point, continually, as it approaches the pole; and slower according to the required law.

This revolution of his globe in a circle about the fire, accompanied by a continued parallelism of its axis, and an uniform rotation of it about that axis, he will discover a very simple mechanical contrivance to effect;* and his globe will thus have communicated to each part of its surface in succession precisely that degree of heat at which it suits him to sculpture it there, the other portions of it being at the same time subjected to the least vicissitude of temperature consistent with this arrangement.

The contrivance is now one of admirable simplicity: the artificer works at his ease; the required heat presents itself at every point of his globe precisely when he requires it there, and the whole of his finished work is preserved as far as it is possible from the opposite extremes of cold. Mechanical skill would seem to

* This contrivance is that which gives its motion to the earth in an orrery: it is at once one of the simplest and most beautiful in mechanics.

have exhausted itself in the perfection of this arrangement—let it, then, remain; but conceive the motionless sculpture of the globe to convert itself into living mechanism; let each modelled tree, and sculptured flower, and blade of grass, have its *growth*,—a putting forth of its leaf, of its bud and blossom; for the perfecting of which process of mechanical vegetation let a certain maximum temperature be every where necessary. Imagination is, however, here *deserting* her legitimate sphere—the boundaries of art are already *passed*, and the domain of NATURE has been entered upon; for if its dimensions be increased to a diameter of 8000 miles, what is that modelled sphere but the mighty globe of the earth on which we live, poised in space, and on which was destined to be wrought the visible creation? And what is that ARTIFICER but HE who founded the earth and hung it upon nothing (Prov. iii. 19; Job, xxvi. 7); who gave the sun for a light by day, the ordinances of the moon and stars for a light by night (Jer. xxxi. 35); who made summer and winter, the north and the south (Ps. lxxiv. 17; lxxxix. 12); and who created it not in vain, but formed it to be inhabited (Is. xlv. 18).

> "Great Artist! thou whose finger set aright
> "This exquisite *machine*, with all its wheels,
> Though intervolved, exact; and pointing out
> Life's rapid and irrevocable flight,
> Open mine eye, dread Deity! to read
> The tacit doctrine of thy works; to see
> Things as they are, unaltered, through the glass
> Of worldly wishes. *Time*, eternity!"
>
> *Night Thoughts*, ix.

THE ASTRONOMICAL DISTRIBUTION OF TEMPERATURE ON THE EARTH'S SURFACE.

> "Full ample the dominions of the sun!
> Full glorious to behold, how far, how wide
> The matchless monarch from his throne,
> Lavish of lustre, throws his beams about him!"
>
> *Night Thoughts*, IX.

FROM the poles to the equator, from the torrid to the frigid zone, were destined to be wrought upon the earth's surface the infinite forms of vegetation and of animated being; "beast and cattle, and creeping thing of the earth; every winged fowl, and moving creature which the waters bring forth; and every plant of the field before it was in the earth; and every herb of the field before it grew" (Gen. i. 21, 24, 25; ii. 5). The portion of *life* was reserved to this fair creation, and beauty was to surround it (Ecc. iii. 11), and happiness. Of these, the ministers were to be light and heat. Far off, therefore, in the trackless realms of space, God "set up his tabernacle for the *sun*, whose going forth is from the end of heaven; neither is there any thing hid from the light thereof" (Ps. xix. 4, 6). This vast sun, with its train of planets, might, by other laws of force and motion, and other and more complicated machinery than that which exists, present the same appearances as those of the heavens, pour forth the same heat and light upon the earth's surface, and distribute them in the same order through every season,—as, by a more complicated contrivance, the artificer spoken of in the last paper might have obtained the same distribution of temperature upon his modelled globe. But there is an *economy* of creative energy which appears to us as a *law* of its operation. And in obedience to this law of economy* it is, that the earth revolves every year round the central sun, rotating continually upon its axis, and preserving the position of its axis always parallel to itself.

> "With inoffensive pace that spinning sleeps
> On her soft axle, while she paces even
> And bears thee soft with the sweet air along."
>
> *Paradise Lost*, viii. 164.

To bring about the change of the seasons, this axis, thus preserving its parallelism, preserves it in a position not perpendicular, but *inclined* to the plane of the orbit in which the earth revolves, as the position of the axis of the artificer's globe was inclined to the floor of his workshop. The angle of this inclination is 66° 32′ 19″. By reason of this constant inclination to the plane of its orbit, and this parallelism, it comes to pass, as explained in the case of the artificial globe, that the earth's axis is made in the course of each revolution to place itself in a great number of different positions in respect to the sun—bringing it into precisely the same positions in respect to the boundary of light and darkness as though, keeping always at one

* This has been shown in a preceding paper.

point of its orbit, it had vibrated its axis through an angle of 23° 27′ 41″ towards and from the sun, vibrating it *more slowly*, however, as it approached the limit of each vibration. By reason, again, of this varying position of the earth's axis in respect to the boundary of light and darkness, it happens, that the point of direct heat and sunlight is made alternately to approach the two poles of the earth, approaching nearest to the north pole when the northern extremity of the earth's axis is most inclined *towards* the sun, which is on the 22nd of June; and approaching most nearly to the southern pole when the northern extremity of the axis is most inclined *from* the sun, which is on the 22nd of December. It is at the *former* period, when the point of direct heat and sunlight most nearly approaches us, that in our hemisphere we have summer; and at the latter period, when it is most remote from us, that we have win' r

THE POINT OF DIRECT HEAT LINGERS AT THE SOLSTICES.

"When now no more th' alternate Twins are fired
And Cancer reddens with the solar blaze,
Short is the doubtful empire of the night;
And soon, observant of approaching day,
The meek-ey'd morn appears, mother of dews."
Seasons—Summer, v. 43.

As the point of direct heat and sunlight gains its extreme limit of approach to either pole, it lingers, as though it were to minister a longer influence to the regions north and south, which—travelling in an appointed path—it cannot reach. If the ecliptic, as shown on a terrestrial globe, be examined, it will be seen that towards its northern and southern limits for a considerable distance it neither approaches nor recedes from the equator or the pole, but has a direction due east and west. This ecliptic is, in point of fact, the path of the point of direct heat and sunlight over the earth's surface. Thus, then, it appears, that when this point has reached its nearest approach to either pole, it does not immediately turn back towards the other pole but remains at that nearest distance for a considerable time, or, as it were, *lingers* there. It has been calculated that if the space between the tropics be imagined to be divided into three equal bands of the earth, the point of direct sunlight would be found to linger in *each* of the two outer bands $3\frac{1}{4}$ times as long as in the middle band.

This *lingering* of the point of direct heat and sunlight at its nearest approach to the poles, is a necessary result of that simple and admirable provision by which the earth is made to revolve round the sun, rotating at the same time round an axis which has an inclined position, and which preserves its parallelism. The object of it is obviously to minister to the polar regions, in their due proportion, light and heat; as I have more fully explained where I have spoken of the artificial globe. What, indeed, was that artificial globe and central fire but a fiction, by the aid of which it might be seen how admirably God has provided that the sun's heat should distribute itself over the earth's surface, so as best to minister to those great purposes of his wisdom and goodness in creation which were to be wrought out upon it? By her rotation he made the day and the night, and bade the light to be divided from the darkness. "The morning is spread upon the mountains" (Joel, ii. 2), and "man goeth forth to his work and to his labour until the evening" (Ps. civ. 23); and night follows, with a measured interval, in the footsteps of day across the earth, surrounded with darkness and with the merciful influence of sleep.

During the silent hours of the night, the burning regions of the tropics cool themselves from the heat of the noonday sun; and the parched vegetation is refreshed with dew. And thus "day unto day uttereth speech, and night unto night showeth knowledge.

There is no speech nor language where their voice is not heard" (Ps. xix. 2, 3).

As in the artificial globe, so on the earth, the point where the direct heat falls is made to approach alternately towards either pole, and to carry with it summer, and to leave behind it winter; and to linger there until its mission is completed and its work done. And thus it is that "God maketh the outgoings of the morning and evening to rejoice" (Ps. lxv. 8); that he visiteth the earth, and blesseth the springing thereof; that he reneweth the face of the earth, and crowneth the year with his goodness; so that the pastures are clothed with flocks, and the valleys are covered with corn" (Ps. lxv. 9, 10; cxiv. 30; lxv. 11, 13).

THE FIRST IMPULSE.

"Now heaven in all her glory shone and roll'd
Her motions, as the great first Mover's hand
First wheel'd their course."

Paradise Lost, vii 500.

Let it be repeated, that there is an *economy* of creative energy in that particular provision by which the distribution of the sun's heat upon the earth is thus brought about. According to the pre-established laws of motion, one *single* impulse, having a certain determinate amount and direction in space, was sufficient to have produced it; and no other state of things could thus have resulted from a *single* impulse.*

A *single* impulse could not have given to the earth a rotation about its axis in a *fixed* position in space,

* It will be borne in mind, that for the sun to have revolved round the earth, being so greatly larger a mass than it is, would have been, according to the pre-established laws of motion and force a mechanical impossibility. Moreover, that it should be of these vastly greater dimensions, and thus far distant from us, was necessary to that degree of uniformity in the diffusion of its heat over so great a globe which we experience; but especially these things were necessary to that like ministry of light and heat to the other planets of our system which was assigned to it.

and an infinitely *complicated* mechanism of nature; impelled by an infinitely complicated development of power, would have been required to give to its axis that *vibratory* motion which I have shewn, by the case of the artificial globe, to be necessary, under these circumstances, to the equable distribution of heat upon it.

To constitute the most perfect manifestation of creative wisdom, and to result from the most perfect economy of creative power, the earth must have revolved, as it does, round the central sun, and rotated upon an axis within itself — an axis always retaining its parallelism, but inclined to the plane of the earth's orbit, as the axis of the artificer's globe was inclined to the floor of his workshop in a circle on which he made his globe to revolve.

This may appear incredible; and it may be asked, Are not the existence of the earth in space, its rotation upon its axis, and its revolution in its orbit, *distinct* and *separate* phenomena? Does not each suppose an *additional* development of the creative power of God, and their co-existence a *complication* of means to an end? No. Such were the laws in the beginning assigned to force and motion, that the force of motion which accompanied the act of placing the earth in space must in that act, by a *second* effort, have been *checked*, or the earth could not have existed there motionless; *two* developments of the power that placed it there would, in like manner, have been necessary that it should retain the same position in space *rotating;* but *one* was required that, rotating, it should *move onwards* through the fields of space, and that gravitating towards the central sun, it should take its path in an eternal gyration round him.*

But, will it be asked, Is not some new provision, some additional manifestation of God's power, required to account for the continued parallelism of the earth's axis at that particular inclination to its orbit which it has received? The answer is this: Thus rotating and revolving, that it should *not* preserve the parallelism of its axis of revolution is, under the existing form of the earth, and subject to the existing and pre-established laws of motion, an *impossibility*.

The fiat which gave to matter its existence, and to force and to motion their laws, was dictated by "the wisdom of Him who possessed it from the beginning of his ways, before his works of old, while he had not as yet made the earth, nor the fields, nor the highest part of the dust of the earth" (Prov. viii. 22). In the scope of that wisdom were included all the infinite manifestations of goodness and of power in creation to which these laws should be made subservient; and to these they were *adapted*, with a perfect adaptation. And thus it was that the presence of the earth in that region of space where it exists—its rotation upon its axis, wherein is involved the vicissitude of day and night—and its revolution, with a parallel axis in an orbit round the sun, whence result the seasons,—were things vast though they be in the scale of nature, which were developed by a *single impulse*.

But that original impulse to which the double motion of the earth was due must have had a *direction*,

* The discussion of this subject will be resumed when I come to speak of gravitation.

and a definite amount of force; and upon that direction, and that amount of the force then exerted, have depended ever since, and will depend to the end of time, the great features of the distribution of the earth's temperature—especially as on the direction of that impulse has ever since depended the inclination of the earth's axis to the plane of her orbit. An inclination more or less than that which actually exists, would have produced a distribution of temperature widely different. Why, then, was the existing inclination of 66° 32′ 19″ chosen out of an infinity of others? What was the distribution of temperature that it was intended to bring about? Can we see in this, as in so many other things, the wisdom and goodness of God.

What are the facts of the case? By what is the actual distribution of temperature characterized? Is there any such marked and characteristic feature of this distribution, that we may be authorized to consider the inclination of the earth's axis to have been fixed with a reference to it.

There is such a feature. *It is the remarkable uniformity of extreme summer heat.*

THE UNIFORMITY OF EXTREME SUMMER HEAT.

> "Th' unwearied sun, from day to day,
> Does his Creator's power display,
> And publishes to every land
> The work of an Almighty hand."

OVER eight-ninths of the habitable surface of the globe, and to 30° of the pole, the thermometer attains in summer within a few degrees of the *same height*.* It rises every year at St. Petersburg above 90°; and on the coast of Guinea, and on the Senegal, it is rarely observed to exceed 95°.

There is no greater error than to suppose that cold summers are everywhere associated with cold winters. Moscow has the summer heat of Nantes, Tobolsk that of Cherbourg, and Astrachan that of Bordeaux; and even in Norway, in lat. 70° or within 20° of the pole, the thermometer not unfrequently rises to 80°.†

* This remark is intended to apply to that portion of the surface of the globe only which is land, and to extend through the northern hemisphere to within 30° of the pole. It will be remembered, that in the northern hemisphere is collected more than three-fourths of the land, and that it reaches to the immediate vicinity of the pole; whilst none of the continents of the southern hemisphere approach the pole by more than 50°.

† Captain Scoresby speaks of an influence of the sun's rays at Melville Island, lat. 74° 30′, under which the pitch on the side of his vessel was melted; and a thermometer placed against it indicated 80° or 90°. And in his last voyage to Greenland, in lat. 80° 19′, he speaks of the paint-work of the side of his vessel

Under the influence of this genial summer's heat vegetation spreads itself, as the sun advances northward from the equator to within a narrow circle surrounding the pole.* On Melville Island, within 15° of the pole, where winter reigns during nine or ten months of the year, the heat of the remaining two or three months of summer is sufficient to bring into active vegetation mosses, lichens, grasses, saxifrage, poppies, the dwarf-willow, and sorrel; and in a sheltered spot, Captain Parry observed a ranunculus in full flower in the second week in June.

As on the artificial globe the artificer required the *same* temperature at the different points where he worked, at the time when he was working there, so on this vast globe of the earth the GREAT ARTIFICER in those regions where successively he *perfects* the process of vegetation, *perfects* it under nearly the same solar heat; and for this purpose it is that the same *extreme* of heat is made to travel the earth's surface from the equator to the poles.

Let it, however, be understood, that the law according to which fructification appears to be thus controlled every where by nearly the same temperature, is only approximate, and subject, within certain limits, to in-

being heated to 90° or 100°, and the pitch about the bends becoming fluid. The summer comes upon these northern regions with marvellous power; in three or four days the snow is dissolved, and the flowers almost immediately begin to blow.

* The rapidity and vigour with which vegetation bursts upon these regions is described as most remarkable. Three or four days after the snow is melted are sufficient to bring the flowers into blossom.

numerable modifications.* Moreover, that the law of the equal *distribution* of extreme summer temperature is subject to numerous and great modifications; that a variety of local circumstances of aspect and elevation, and that continual interchange of the heat of different tracts of the earth's surface which is made by means of currents of the air and ocean, affect it.†

Important as is the discussion of these disturbing causes, when we would compare the variations of temperature at places otherwise similarly situated, and its lesser anomalies,—the great controlling cause is still however, the *position of the earth's axis.* What, in fact, are the varieties of elevation of the earth's surface but as the elevations of scattered particles of dust on the artificer's sphere? What are its varieties of aspect but as the sunny and shady sides of those particles of dust? And what is the atmosphere which envelopes the earth but as the thickness of the coat of varnish with which the artificer has overspread it? and its currents but as the movements which the parts of that covering of varnish might, under the influence of its different temperatures, have had when it was fluid?

* One of these, having reference to the case of the birch and pine, will be stated in a subsequent part of this paper.

† The influence of these various causes will form the subject of a subsequent paper.

A VARIATION IN THE DIRECTIONS OF INCIDENCE OF THE SUN'S RAYS COMPENSATES FOR THE DIFFERENT LENGTHS OF SUMMER DAYS AND NIGHTS.

"The vegetable world is also thine,
Parent of Seasons! who the pomp precede
That waits thy throne, as through the vast domain,
Annual along the bright ecliptic road,
In world-rejoicing state, it moves sublime."

Seasons—Summer, iii.

SUBJECT to all these variations, the position of the earth's axis may be safely stated to be so taken as that the varying obliquities with which the sun's rays fall on different places from the equator to within 30° of the pole—that is, through eight-ninths of the earth's surface—*compensate* with a remarkable accuracy for the different relative lengths of the summer days and nights at those places. Who will believe that it was not so selected *with a view* to that compensation, and the resulting uniform diffusion of the *same* extreme summer heat in succession to every place, at which heat vegetation was destined to fructify—vegetation, the basis of the whole superstructure of life? "The Lord possessed *wisdom* in the beginning of his ways, before his works of old. By his *wisdom* hath he founded the earth; by *understanding* hath he established the heavens."

It is not by any marked variation in the extremes of *heat*, but in their *continuance*, and in the extremes of *cold*, that the different climates of the earth are characterized.*

Thus although the extremes of heat may be the same at two places, the whole amounts of heat which they receive in the course of a year may be very different.

If a place be imagined to receive the same quantity of heat every day that it radiates so that the temperature of that place may remain throughout the year the same; and if the heat which in this imaginary and impossible case would be received by that place amounted in the whole year to that which it actually does receive,—then would that place have what is called its *mean* temperature.

Now, it is to the whole amount of heat received in the course of the year, or, perhaps, the season, and therefore to the amount of the *mean* temperature of each place, that the forms of vegetation appear to have a special adaptation. So that, whilst to the fructification of all the forms of vegetable life nearly the same extreme heat† would seem to be requisite, there are

* Thus, between the tropics the extreme heat of about 90° appears to remain nearly the whole year long—the seasons being there characterized rather as wet and dry than as hot and cold. Frost does not make its appearance in Europe beyond the 40° of latitude; and the *cold* felt from lat. 35° to lat. 60° is that which distinguishes it from the torrid, as the temperate zone. It is here only that four seasons prevail; within the tropics there are none; and within the frigid zone but two.

† Let it be repeated that this must be taken only as an approximate law. Whilst the great characteristics of vegetation

different classes which affect different limits of *mean* temperature.

If a traveller be supposed to set out eastward, and to visit in succession all those places which have the same mean temperature, he will trace out on the earth's surface what is called an *isothermal* line; and he will every where encounter analogous features of vegetation.*

undoubtedly depend upon the *mean* temperature, there are others in which differences of extreme temperature are concerned. The birch and pine are examples. The fructification of the birch requires a higher temperature than that of the pine; but the pine requires a greater continuance of heat, that is, a higher mean temperature. The birch for this reason finds its way much farther north than the pine; for it receives the extreme summer heat necessary to its fructification in latitudes where the pine would not obtain that continuance of heat, or that mean temperature, which it requires. Thus, "at Enontekies, in Lapland, where the mean temperature is only—2·78, magnificent forests of birch are seen; whilst at the island of Megaroe, where it is above zero, only a few scanty shrubs will grow." The reason is that in the former place the summer heat reaches 15°; whilst in the latter it only rises to 7° or 8o.

* Vegetable forms are said "to present, under the same isothermal lines, such constant relations, that when upon any point of the earth, we know the number of species belonging to any one of the great families, both the whole number of phænogamous plants, and the number of species composing the other vegetable families, may be estimated with considerable accuracy."

THE FIRST IMPULSE DIRECTED BY THE OMNISCIENCE OF GOD.

"What hand behind the scene,
What arm Almighty, put these wheeling globes
In motion, and wound up the vast machine?
Who rounded in his palm these spacious orbs?
Who bow'd them, flaming, through the dark profound?"
Night Thoughts, IX.

LET the imagination now fall back upon that single impulse, upon the direction of which has depended from the beginning of time the position of the earth's axis, and by reason of which it shall come to pass that while the earth remaineth, seed time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease (Gen. viii. 21, 22); let it be seen poised in reference to that distribution of temperature which it was thus to determine to the end of time, and to the forms of vegetation whose varieties that temperature was destined to control, from the gigantic palm, the mimosa,* and the baobab of the tropics, to the cedars, chestnuts, beeches, oaks, pines, and birches, of the temperate zone, and the lichens of arctic regions.

* Humboldt speaks of a mimosa near the village Turmero, south-west of the city of Caraccas, whose hemispherical head is 600 feet in circumference. The trunk of the baobab (an African tree) has been known to attain a diameter of 34 feet, and a circumference, therefore, of more than 100 feet.

Let each bud, from the evanescent germ and unseen vegetation of mildew, to the huge bulb whence expands the giant *Rafflesia Arnoldi;** each blossom from that of the minutest of the *Algæ*† to the magnificent flower but recently discovered floating on the surface of a stream in the solitude of the forests of Guiana;‡—let each have some given temperature at which it is bidden to expand its leaves, to open its cup, and thrust forth its petals; and every fruit a warmth which is destined to ripen it and a heat fatal to it. Extend this influence of temperature to all the various forms of vegetable life which clothe the green earth—families and species, whose numbers are counted by hundreds of thousands. Multiply them then by the countless myriads of individuals which compose every species. Join to these the myriads of forms of *animal* life whose existence connects itself with vegetation: the insects whose countless species crowd each to its appointed repast, in the leafy forest, or upon the herbage; the reptiles, who feast upon the roots of trees; the birds who live among their branches, and upon their fruits; and the cattle upon a thousand hills—the antelope, the ox, the horse, the camel, and the elephant: to these, again, add those thousands of

* This flower, discovered in 1818 in Sumatra by Dr. Arnold, is one yard in diameter; and its nectarium would hold twelve pints. That minute vegetation which we call mildew, and the plant which produces this flower, both belong to the class of *Fungi*.

† The crimson snow, which so long astonished the voyagers to arctic regions, is now ascertained to be a minute form of vegetation of the order *Algæ*.

‡ The *Victoria Regina*.

orders of carnivorous animals that prey upon them. Carry this prospect through the predacious insect-tribes; and from that owl, whose solitary wing it is that cleaves the frozen air of the pole, to the ravenous birds in innumerable tribes that crowd to their banquet of flesh in the tepid seas, and amidst the prurient vegatation of the tropics—the condor and the albatross, and the eagle; include, too, the quadrupeds of prey—the arctic fox, and wolf, and bear; the lion of Africa, the tiger of Asia, and the jaguar of Southern America. That nothing may be wanting to the picture, embrace in it the inhabitants of the deep, to whose dwelling is reserved seven-eighths of the whole surface of the globe; those that pasture quietly in its unfathomable depths, and those that traverse the wide expanse of its surface in cearch of prey: join to these the slimy and unsightly tribe, whose habitation is partly on the land, and partly in the water—the turtle, the lizard, the crocodile, and the hippopotamus—"leviathan and behemoth" (Job, xl. xli.). Let the imagination summon before it all these in countless myriads—"every living creature, beast and cattle, and creeping thing of the earth; every winged fowl, and moving creature which the waters bring forth; and every plant of the field which God made before it was in the earth; and every herb of the field before it grew" (Gen i., ii.): animal life in all its forms depending ultimately on the distribution of vegetable life; this, again, upon temperature; and temperature for all its great modifications upon the direction of that one primeval impulse. Let all these things be seen comprehended in it, and included in the scope of that vision which directed it;

let the mind have elevated itself to the conception of these things in all their visible forms and modifications, yet will it but have *approached* the threshold of the wisdom and knowledge of the mighty Artificer As yet the soul but worships in the vestibule of the temple of the universe. "Verily, O God, as yet thou *hidest* thyself; dwelling in the light no man can approach unto" (Is. xlv. 15; 1 Tim. vi. 16). For of the forms of organized being which people this earth of ours, but a portion are yet known to us; this earth is moreover but one of an unknown number which circulate round the same sun and belong to the same system, and of such suns and systems the number cannot be counted, or the space conceived through which they urge their flight.

> "Why has the mighty builder thrown aside
> All measure of his work; stretch'd out his line
> So far, and spread amazement o'er the whole?
> Then (as he took delight in wide extremes)
> Deep in the bosom of the universe,
> Dropt down the reasoning mite, the insect man,
> To crawl and gaze, and wonder at the scene."
>
> *Night Thoughts*, ix.

CAUSES DISTURBING THE ASTRONOMICAL DISTRIBUTION OF TEMPERATURE.

> "These, as they change, Almighty Father, these,
> Are but the varied God. The rolling year
> Is full of thee." *Hymn to the Seasons.*

THE Lord possessed *wisdom* in the beginning, before his works of old. While as yet he had not made the earth (Prov. viii. 22, 26) he infixed in the great elements of matter those laws under the control of which they were to congregate, and the mighty mass take its existing form and substance; and by reason of which the earth, *spinning upon her axle,* with a changeless motion, and in an appointed path, should, to the end of time,

> "roll
> Her motions, as the first great Mover's hand
> First wheel'd their course." *Par. Lost,* vii. 500.

Moreover, from the beginning his *goodness* took part in the counsels of his wisdom. He so *poised,* therefore, that primeval impulse, that there should be given to the earth's axle a position, in respect to the plane of her orbit, by which should be brought about the vicissitude of our seasons—having first so moulded her shape, that this position of her axle should remain unchanged for ever.*

* The earth is not strictly a sphere, but an *oblate* spheroid, being a geometrical solid, which may be imagined to be gene-

Thus it has come to pass that "cold and heat, summer and winter, seed-time and harvest, cease not, and shall not cease, while the earth remaineth" (Gen. viii. 21).

In very deed the earth is "full of the goodness of the Lord" (Ps. xxxiii. 5), and it endureth continually (Jam. i. 17); he "blesseth the springing of it, and reneweth the face of it, and enricheth it with the river of God" (Ps. lxv. 9, 11). Vegetation is spread upon it as a garment, and life *throngs* it—

> "Air, water, earth,
> By fowl, fish, beast, is flown, is swum, is walk'd."
> *Par. Lost*, viii. 703.

God "openeth his hand liberally, and filleth all things living with plenteousness." "He causeth grass to grow for the cattle, and herb for the service of man;" "so that the pastures are clothed with flocks, the valleys also are covered over with corn" (Ps. lxv. 13).

That position of the earth's axle on which this distribution of temperature upon its surface depends is so chosen as to make *nearly** the *same* extreme summer

rated by the revolution of an ellipse about its *shorter* diameter. Had her form been that of a perfect sphere, or of a *prolate* spheroid —a figure generated by the revolution of an ellipse about its *longer* diameter—the position of her axis would have been perpetually changing and the climate of every place continually varying. Her existing form of an *oblate* spheroid would have been given to the earth had she first been made to revolve when in a *fluid* state.

* The reader may here be reminded of the fact stated in a preceding paper, that at St. Petersburg the thermometer rises almost every year to above 90°; and that on the coast of Guinea

heat to traverse almost eight-ninths of it, probably that it may minister every where in succession, and with a like influence, to the great perpetuating effort of vegetable life—*fructification*.

In this equality of extreme summer heat the extreme winter cold does not, however, partake. Within the tropics the seasons are scarcely distinguishable by any difference of temperature; whilst there are places within the temperate region* where the *mean* temperature of the hottest month rises to $84\frac{1}{2}°$ and that of the coldest month sinks to $24\frac{1}{2}°$.

Were the distribution of temperature limited, however, to these *astronomical* causes, its isothermal lines would all lie parallel to the equator, and its effects would manifest themselves, in zones extending uniformly to the poles. Each region having its own temperature would have its own uniform vegetation; and that *variety* which enters, it would seem, as a constituent element into the exercise of creative power, would be *straitened* in its development.† And, despoiled of its

it rarely exceeds 95°. In this country almost every summer brings a few days of tropical heat. There are, of course, many exceptions to the rule stated in the text—they are cases of *remarkable* heat, and serve but to confirm it.

* At Pekin, the extreme heat was observed by the embassy, in 1816, to vary in September from 90° to 108°

† When we contemplate a collection of plants, or of insects, or view an assemblage of animals belonging to various orders of creation and from different regions—having made large allowance for those varieties of colour, size, and especially of forms which connect themselves with the particular wants and economy of the life of each,—it is impossible not to be struck with the fact, that a variety remains not assignable to any of these

boundless *variety*, the existing economy of nature would be shorn of half its beauty. But it is not thus: causes other than the original impulse, and the inclination of the earth's axis, and the lengths of the day and year, dependent upon that impulse, operate in the production of climate; and these with so extensive an effect, that the climate proper to every zone, accompanied by its vegetation, is not unfrequently brought about within a few miles of the same spot.* "*Many*, O Lord, are thy wondrous works which thou hast done; they cannot be reckoned up in order unto thee: if we would declare and speak of them, they are more than can be numbered. When thy word goeth forth, it doth not return unto thee void, but accomplisheth that which pleaseth thee. As thou hast thought, so doth it come to pass; and as thou hast purposed, so doth it stand."

The better to understand how, in the order of Providence, creative power is developed under an infinitely disseminated *variety*† of form and circumstance; and in what way the distribution of temperature *adapts itself* to this variety and *ministers* to it; let us return to the supposition of the artificer, and let us

causes; a variety to the operating principle of which no other analogy presents itself than the exercise of the faculty of imagination in man.

* On the Peak of Teneriffe five zones of temperature may be traced at successive elevations by corresponding zones of vegetation. Vines form the first; next are laurels; then pines; afterwards the alpine broom; and lastly the arctic grasses.

† This principle of infinite variety in nature we are all perfectly familiar with. It is even implied in the meaning we usually attach to the word *natural* as distinguished from artificial.

imagine that, wishing to distribute his work, not with a measured and artificial uniformity, but by a natural *variation* and intermingling of its forms, he finds himself straitened by that accurate distribution of temperature upon his globe in parallel zones, which results from its uniform return to similar positions in respect to the central fire. He requires to be able to introduce, at will, variations in the great features of this distribution. How shall he command them?

ASPECT.

"Thou crownest the year with thy goodness; and thy paths drop fatness.

"They drop upon the pastures of the wilderness and the little hills rejoice on every side."—*Psalm* lxv. 11, 12.

THE existing variations of temperature depend, *first*, upon this, that the rays of light do not fall upon different points of the surface of his globe with the same inclination or obliquity. *Secondly*. Upon the difference of the times during which different portions revolve in the heat and in the cold, causing them to heat and cool differently.

Both these causes are uniform, and independent of the artificer. How shall he control their operation, and vary them?

He may diminish the obliquity with which any portion of the surface receives the rays of heat, and indeed cause it to receive them as *directly* as though it were within the tropics, and under the point of *direct* heat itself, simply by elevating it from the general surface of the sphere, and inclining it towards the incident rays. In the like manner, he may cause it to receive the rays less obliquely by inclining it *from* them. This is a variety of temperature which our artificer will, in point of fact, of necessity have introduced in every portion of the sphere which he has modelled. Every such raised and modelled part will have an aspect in reference to the light and heat, dependent upon its form and independent of its position; and thus that character of the distribution which depended upon the spherical form of the surface will of necessity be infinitely modified.

It is precisely thus with the earth's surface; for this reason, no doubt, amongst others, it is ploughed into deep fissures in some parts; sunk through large tracts into hollows* in others; here, elevated into table-lands, whose sides slope gradually towards the north and the south towards the rising and the setting sun; every where broken into hill and dale, mountain and valley. Thus, under a vertical sun, the sides of the Andes receive the sun's rays as obliquely as they fall in our latitudes upon the earth's level surface—nay, as obliquely, perhaps, as they fall in summer upon the level surface of the snows of Spitzbergen; whilst the Alps encounter on parts of their southern slopes as *direct* a heat as that which burns up the desert of Sahara; and on their northern they are as much hidden from the sun's influence as are the level snows of Lapland. In the Alps of the Vallais, on the one side you may see the vine in luxuriant growth when the other is thick ribbed with ice. Thus, too, the terraces and sloping planes which descend from the vast table-land of central Asia, where inclining from its *northern* limit, they pass into the *steppes* of Siberia, present, under the latitude of Edinburgh, a cold intense enough

* As in the country surrounding the Caspian, many hundreds of square miles of which are from one to two hundred feet beneath the level of the sea.

to freeze mercury; whilst, upon the southern terraces of the opposite Himalaya slope, flourish at different elevations the pine-apple, the mango, the gigantic cotton-tree, and the saul. This tropical vegetation ascends them to an altitude of four or five thousand feet,* mingling itself, and by degrees giving way to the plants of a temperate region—elms, willows, roses, and violets, destined in their turn, at a yet higher region, to yield to alpine forms of vegetable life.

Every possible variety, so far as the greater or less obliquity of the sun's rays is concerned, is thus actually introduced by varieties of *aspect*. Were this cause of obliquity, indeed, the only one affecting the temperature, the same region would frequently be found to present, by its northern and southern aspects, the climates of the equator and the poles. The southern side of a mountain-chain in a high latitude, presenting itself under as direct an incidence of the sun's rays as though it were a level surface under the equator,† and remaining in the summer during a longer time every day under its influence, would soon be burned up with at least an equal heat, were it not that there is a cold *proper* and *peculiar* to mountain regions—a cold arising out of a distinct cause hereafter to be explained—mercifully spread upon them by Him who "possessed wisdom in the beginning," "before the mountains were brought forth, or ever he had formed the earth and the world" (Prov. viii. 22-26),—

* According to Dr. Royle, Illustrations of the Botany of the Himalayan Mountains.

† That it may do this, no more is required than that the inclination of its slope to the horizon should equal its latitude.

to temper the heat of those direct rays, to cover them from time to time with vapours, to make the rains descend upon them, to "water the hills from above" (Ps. civ. 13), and give birth to the streams. So far as the greater or less obliquity of the sun's rays is concerned, every possible variety of temperature is thus introduced by varieties of *aspect*.

RADIATION.

"Great source of day! best image here below
Of thy Creator, ever pouring wide,
From world to world, the vital ocean round,
On Nature write with every beam His praise!"
Hymn to the Seasons, 66.

Another great cause of variation from an uniform distribution of temperature is to be sought in the great variety of the substances which compose the earth's surface, and their different capabilities for the receiving and radiating of heat. All the varieties of soil,—light and open vegetable moulds, gravelly and rocky tracts, stiff wet clays, and sandy plains, have, it cannot be questioned, their different powers of radiation and absorption; and whether a district be clay or sand, bare or covered with vegetation, for a like cause, greatly affects its temperature. It appears from experiment that the *slightest* difference in the sensible qualities of the surfaces of bodies are sufficient to give them different properties in respect to the radiation and absorption of heat; differences, for instance, of polish, of roughness or smoothness—of colour, whether they be white or black—of material, whether they be metallic, or vitreous, or vegetable substances—moist or dry. It cannot, therefore, be doubted, that the difference of surface so observable in different kinds of foliage—their darker or lighter colours, their more or less glossy leaves, the filamentous downy* substance which sometimes covers them—are all things affecting the radiation of their heat with an infinite variation. It is as though the artificer, to introduce variety into his work, had brought about the various temperatures which for this purpose he required by forming its surface of materials of different shades of colours, different degrees of roughness or smoothness, different degrees of moisture, different physical structures. Thus the same night which greatly depresses the temperature of a track whose surface is a humid clay, or a dark vegetable loam—substances which may be imagined to radiate heat freely—would have a much less influence on a district of sand; and thus—to take an example on a smaller scale—the same morning which found the temperature of the surface of a grass field greatly reduced below that of the preceding day, would exhibit a less reduction of the surface of an adjacent ploughed field, and a yet less of the hard covering of a neighbouring high road.†

* Downy filamentous substances are peculiarly favourable to the radiation of heat. Dr. Wells found black wool among the best radiators.

† Dr. Wells found the temperature of a gravel-walk to be greatly less reduced than that of the adjacent grass-lawn by the radiation of the same night. The different depressions of temperature of different substances by the radiation of the same night is strikingly illustrated by the deposition of *hoar frost*. When no traces of it can be seen on a winter's morning on the general surface of the road, it will be observed deposited in abundance on the straggling tufts of grass which border it, or are scattered here and there upon it, and it will cover the surface of the neighbouring grass fields. After a severe frost it

SHELTER.

> "I cannot go
> Where Universal Love not smiles around;
> From seeming Evil still educing Good,
> And better thence again, and better still,
> In infinite progression."—*Hymn to the Seasons*, iii.

A SECOND cause of variation of temperature, as it affects vegetation, is to be sought in the varieties of shelter under which its various forms and its different individuals exist. We are sufficiently aware that shelter is a protection to ourselves against heat and cold: in the first case, it acts by receiving the *sun's* rays, absorbing and radiating back certain of them, which for that reason never reach us; in the last, by receiving the rays of heat which we ourselves radiate, and radiating them back to us. It is thus precisely that vegetation is protected by shelter. To effect this protection in a degree, it is by no means necessary that the space which affords the shelter should be closed. The

may, indeed, be seen sometimes upon the frozen edges of the carriage-tracts, or upon small frozen lumps of earth—a circumstance which is easily explained by the greater radiating surface which these present as compared with their bulk than the general material of the road does. Thus it is, too, that whilst the glass of the windows of a house—glass radiating heat freely—have their temperature so reduced as to receive a deposition of ice from the moisture of the atmosphere, none is to be seen on its walls.

intervention of any object between a radiating body and the clear sky is sufficient to produce a continual return to it of its radiated heat. A thin awning of muslin has been found sufficient to protect a delicate plant from the cold of a frosty night—nay, the very interposition of a fleecy cloud is enough to cherish all night with warmth the track which it screens from the open sky.*

Of the shelter which vegetation supplies to itself from the cold of night, some idea may from these facts be readily formed. The shelter of every leaf, no doubt, cherishes the heat of some other; every blade of grass reciprocates warmth with others that grow around it; and of the heat which day has given to the trees of the forest no inconsiderable portion remains during the night entangled among their foliage. Were it not indeed for this mutual shelter, the large radiating surfaces which vegetable forms present in comparison with their bulk would subject them to much

* When the sky of a clear night suddenly became clouded, Dr. Wells always found the temperature of the grass instantly to rise: on one occasion, he observed it, under these circumstances, to have elevated itself from 32° at nine o'clock to 39° at twenty minutes past nine; and in twenty minutes more, the sky having cleared, to have sunk again to its first temperature. On another occasion, the night clouded over, and it rose 15° in forty-five minutes. It is to the exceeding *clearness* of the sky that the coldness of the nights of certain hot countries is to be attributed. In Palestine, when the night is sheltered by no cloud the cold is intense. Allusion is made to this circumstance in Gen. xxxi. 40, where Jacob, expostulating with Laban, declares that by "day the drought had consumed him, and the frost by night."

greater depressions of temperature in comparison with the surface of the soil than those which they actually experience, and destroy them. No less useful is this mutual shelter to protect them in certain regions from the *heat* of day than from the cold of night. The same property which gives them a great power of *radiating* heat gives them a corresponding facility for *absorbing* it. Were all their parts equally exposed to the sun's rays, the heat thus absorbed would probably exceed the measure assigned to the economy of vegetable life. The *external* foliage then only receives it; and from the external leaves it is partly radiated back, and partly absorbed and radiated *inwards* to those which they shelter.

The effect of shelter in ministering to the purposes of vegetation a subdued heat under the burning day of the tropics, and a moderated cold during the frosty nights, may be conceived from the fact stated by Lieut. Wellsted,* that in the Tehama of Arabia—perhaps the hottest region of the globe—the fierce rays of the sun descending upon the topmost foliage of one of the islands of verdure in that vast ocean of sand, called Oases, raised the temperature of a thermometer placed six inches from the ground only to 45°.

Under the varied temperature of this shade, scarcely covering an area 300 yards in diameter, and fed by that clammy state of the atmosphere which in these regions always accompanies cold, flourish an inconceivable variety of vegetable forms. There is to be

* Travels in Arabia.

seen the shady and towering date-palm;* and beneath it grow almond-trees, fig-trees, and walnut-trees, of enormous size, and orange and lime-trees, whose fruit clusters so thickly, that scarcely a tenth part of it, says the traveller, can be gathered. This teeming vegetation claims for itself every spot where there are springs and running waters; and thus it was because it was "a land of brooks of water, of fountains and depths, that spring out of valleys and hills," that Moses described Canaan to the Israelites as "a land of wheat and barley, and vines and fig-trees, and pomegranates; a land of oil, olive, and honey."

* It is only from the descriptions of those who have visited Eastern countries that we can realize that idea of the magnificence of vegetation on which many of the most beautiful allusions of Scripture are founded. How intelligible, for instance, does that sublime metaphor in which the righteous is said to "flourish like the palm-tree" become when we have conceived a vegetative power lifting the vast umbrageous head and plume-like foliage of the majestic date-palm from one hundred to two hundred feet upon the clear sky!

CURRENTS.

"O Lord, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches; so is the great and wide *Sea*."—*Psalm* civ. 24.

If the whole surface of the earth were divided into ten equal parts, seven of them would be found to be occupied by the ocean, the land covering but the remaining three. Of all those various properties for the radiation, propagation, and absorption of heat, which belong to the different substances that compose it, and which affect the distribution of its temperature, the most important therefore—controlling all the rest—are the properties of water.

The ocean has properties for giving out and propagating heat essentially different from those of the land. Immediately that the heat of the stratum which forms its surface is thrown off by radiation, having become specifically heavier than the water beneath it, the surface sinks, and is replaced by another surface, in its turn to be in like manner renewed. On the land no change like this can take place; and radiation from strata beneath its surface is continually obstructed by the interposition of the surface-stratum.

Water has thus a remarkable facility for throwing off its heat; and thus every night the surface of the ocean gives out a much greater proportion of the heat it has received in the day than the land does. On the other hand, it derives from its fluid properties no additional facility for *absorbing* heat; for its surface water, when heated, becomes thereby *buoyant*, and is made by its buoyancy to *retain* its position on the surface. So that heat can no otherwise reach the strata beneath its surface than it reaches the parts beneath the surface of a solid, viz., by propagation.

What is the difference of the amount of heat absorbed by the ocean in the days of summer and that radiated in the summer nights—that is to say, what is the heating effect of the warm season upon it,—appears never to have been made the subject of experiment or observation. That it must be much less than the corresponding effect upon the land, and that the temperature of the sea must therefore be greatly more uniform throughout the year than that of the land, is evident.

This is not, however, the only way in which the sea tends to equalize the earth's temperature. The different portions of that mighty expanse *communicate*—its waters extend in an interrupted, but an *undivided* sheet from the equator to either pole. Thus are different parts of the same vast mass of the ocean subjected to all those varieties of temperature which properly belong to different climates of the earth.*

Now, when the different parts of the surface of a fluid are differently heated, they cannot remain relatively at rest as those of a solid do. The heated portions, becoming more buoyant, are immediately floated

* The temperatures of the ocean at the equator, in lat. 25°, and in lat. 50°, may be represented by the numbers, 80, 70, 60.

up above its general surface, and are replaced by the surrounding colder and heavier fluid which flows in beneath them. Thus raised above the general surface, the heated parts cannot, by the known laws of equilibrium, rest—their weight puts them in motion, and they spread themselves with a tendency to restore the general level of the surface. In the mean time, those portions of the fluid which displaced them, being in their turn subjected to the same heating influences, are, in a like manner, floated up, and moved off, to give place to others. Thus *surface*-currents are established in the ocean from the equator towards the poles, and *sub*-marine return currents from the poles towards the equator. And such currents are principal elements in the equalization of the earth's temperature, bearing with them the burning temperature of one country to the cold shores of another—the heat of the tropics perpetually towards the poles, and the cold of the poles towards the tropics.*

Now, let the reader be again reminded that the surface of the sea occupies seven-tenths of the surface of the whole globe. He will then see that in the peculiar properties of water for the absorption and radiation of heat, in the laws of its equilibrium, and in the fact of its being stretched in an undivided sheet between the two extremities of the earth's axis, there is an admirable provision for equalizing the earth's

* There is a vast current of the Atlantic, called the Gulf Stream, stretching between Cape Hatteras, in North America (lat. 35° N.), and the Azores, and forming in the midst of the Atlantic a lake of warm water, heated from 3° to 10° above the surrounding sea, and not less in dimensions, according to Rennel, than the Mediterranean.

temperature from season to season, and from place to place.* So that in his wisdom God "covered the earth with the deep as with a garment" (Ps. civ. 6), "gathered together the waters," and "compassed them with bounds" (Job xxvi. 10).

But it may be urged, that, whilst the properties of water for the radiation of heat, and its laws of equilibrium, have a manifest tendency to temper the climate of our summers by abundantly throwing off at night the heat received during the day, and to soften the cold of our winters by transferring to us some of the heat of the tropics, surely in higher latitudes, to which little heat can be carried by currents, and which endure during six months of the year almost a continual night, these properties of water, which are to us so beneficial, must be productive of an unendurable cold. For six months of the year the sea must there be perpetually radiating its heat, and perpetually changing its surface of radiation, until the warmth is abstracted from its deepest abysses, and the lowest degree of cold reigns through its mass. The regions about either pole must, in point of fact, in the alternate halves of the year, become, as it were,

* It is by reason of the equalizing effect of the sea that islands and maritime countries in general, and especially their coasts, have proverbially temperate climates; their summers are colder by reason of the more abundant radiation from the sea at night, and their winters are in our latitudes milder by reason of the transfer northwards of the heated waters of the equator. The climate of countries bordering the Mediterranean is peculiarly mild. It is, indeed, now ascertained that the temperature of that sea is 4° or 5° above that of the Atlantic. The polar under-current has difficult access to it by the Straits of Gibraltar.

vast outlets, whence heat from all parts of the earth escapes with every facility, and uselessly, into space.

Nature has provided against this result. In that region the properties which here give to the sea a marvellous facility for throwing off its heat *cease to operate*. When reduced to a certain temperature, water, instead of contracting by a further radiation of heat, begins to *expand*. This limit of temperature being then past, instead of the colder strata sinking, and taking their places in succession beneath the warmer, they have a tendency to rise, and take their places above them. The surface-water thus becomes the *coldest*, and below it the temperature *increases* until the limit is attained where water ceases to expand, and beneath which no subjacent temperature can sink. In the mean time, the surface-water has become *ice*, which, spreading over it in a continuous sheet, intercepts the farther radiation of its heat.

Here, then, in this property of water, we have a most wise and gracious provision of God. The outlet of the heat of the sun at either pole is *closed*. A seal of ice is put upon it, as, in the snow, a warm mantle is cast down upon the land.

Such are a few among the many manifestations of that wisdom which has been made to vary in an endless change the mighty family of God's creatures, and that goodness which carries a genial and sufficient temperature to all, and cherishes each individual thing with a warmth suitable to the particular economy of the existence which has been assigned to it. "O Lord, how manifold are thy works! in wisdom hast thou made them all: the earth is full of thy riches; so is the great and wide sea." (Ps. civ. 24).

THE EQUALIZATION OF TEMPERATURE BY THE ATMOSPHERE.

> "Air, and ye Elements, the eldest birth
> Of Nature's womb, that in quaternion run
> Perpetual circle, multiform, and mix,
> And nourish all things; let your ceaseless change
> Vary to our great Maker still new praise."
>
> *Paradise Lost*, v. 180.

The *equalizing* power, upon the earth's temperature, of the mass of *waters* which covers seven-tenths of its surface has been described. This, however, did no other cause co-operate with it, would only be felt on the *shores* of the ocean; and *thither*—driven from the inland regions by fierce vicissitudes of heat and cold—all the forms of organized being would congregate.

What power, then, equalizing the distribution of temperature, shall travel deep into the bosom of the vast continents of the earth, over tracks whose radiating power, their natural heat, and the heat they receive from the sun, are infinitely varied? What shall *barter* heat and cold, with a mutual advantage, between the sultry regions of the equator and the ice-bound pole, and *moisture* between the ocean and the desert—between the tepid marshes of the tropics and the arid *steppes* which stretch their vast expanse around the frigid zone?

That the scheme of the infinite wisdom of Him in whose "hand are all the *corners* of the earth" (Ps. xcv. 4,) may complete itself before the mind, it asks, how shall this equalizing power of heat, and cold, and moisture, climb the high mountains of the earth, penetrate its deep valleys, enter the hidden recesses of the forest, minister to every shooting bud and leaf a subdued influence, and temper itself to the feeble life of every tender plant and gentle flower? The answer meets us at once—In the *atmosphere.* "HE bringeth forth the winds out of his treasures" (Jer. x. 13.)

As the hills and valleys of the bottom of the ocean are covered by its waters, so is the whole surface of the earth—land and ocean, mountain and valley—covered by the fluid *air.*

> "The *firmament*, expanse of liquid, pure,
> Transparent, elemental air, diffus'd
> In circuit to the uttermost convex
> Of this great round."—*Par. Lost,* book vii. 263.

We exist at the bottom of that vast continuous sea; we are born in it; and when we cease to drink of it at every inspiration, we cease to *live.*

This ocean of the *air* possesses properties, in respect to the equalization of heat, which *include* all those of the ocean of *waters*, but are of *greater activity.* Its *elasticity* renders it far more *expansive* from any increase of temperature than water is, and therefore far more *buoyant.*

For this reason, when heated, it becomes more readily *displaced* by the surrounding colder and heavier air, and powerful CURRENTS are thus established in the fluid atmosphere, by variations of temperature which would scarcely cause them to be perceived in the fluid *ocean.* It is incorporated with these *currents* of the air that excessive *heat* is borne up and carried away high above the earth's surface with a prevailing tendency towards the frigid zones, and *cold* made to creep along in contact with it towards the region of perpetual heat.

Thus are the great astronomical varieties of temperature *intermingled* and *blended* by the atmosphere, nevertheless with an infinity of modifications, subject to an infinite variety of local causes, and suited to the boundless diversity of the scheme of God's creative providence.

To this blending and equalizing effect of the *atmosphere*, the *equal temperature of the ocean* largely contributes.

Seven-tenths of the atmosphere perpetually covers the ocean and thus partakes in that *uniformity* of temperature, in respect to the seasons, which peculiarly belongs to the sea.

Besides a more ready formation of *currents*, the elasticity of the air gives it yet another property, tending eminently to the equalization of temperature, and, in fact, necessary to the equalizing power of the wind.

The earth's surface may be considered as the *bottom* of the ocean of the air. The higher, therefore, is any portion of the atmosphere above the earth's surface, the less is its *depth* beneath the *surface* of this ocean, and the less, therefore, is the pressure upon it of the air which is *above* it; and being *elastic* and less *pressed*, the air is *there* less *condensed*, or more *rare*.

Thus, then, it appears that as we ascend higher, we *of necessity find the air rarer or lighter;* a fact which is at once verified if a barometer be carried to any elevated spot.

Now this, whilst it is a necessary result of that elasticity of the air which ministers to so many other useful purposes, is also a most wise provision for *this end*, that it keeps the great currents of the atmosphere down to the earth's surface. It causes them to flow at the *bottom* of the ocean of the air instead of at the *top*, as do the currents of the ocean of waters. Were it otherwise, these currents would range on the *extreme limits* of the atmosphere, instead of on the surface of the earth.

Immediately that the air becomes heated by contact with the heated earth, it would ascend in a vertical column until it reached the extreme surface of the atmosphere; along that surface it would determine a current, imperceptible on the earth's surface as are the surface-currents of the ocean in its depths. Thus we should experience no motion of the sluggish air from place to place, no "winds from the four quarters of heaven;" but a stagnant and perpetual calm unbroken except by continual exhalations and upward currents; a dense curtain of vapour would overspread us, beneath whose shade would reign fierce vicissitudes of temperature, and the pestilence spread wide her wings. But "the *goodness* of God endureth continually" (Ps. lii. 1).

"Near though remote! and though unfathom'd felt;
And, though invisible, for ever seen."—*Night Thoughts*, ix.

"Fire and hail, snow and vapours, and *stormy winds* fulfil," therefore, "his word" (Ps. cxlviii. 8); and are "turned round by his counsels, that they may do whatsoever he commandeth them on the face of the world in the earth" (Job xxxvii. 12).

The heated air ascends, indeed, by reason of the greater density of the cold air about it; but after a short ascent, it attains a region where the surrounding medium—although it may be colder—is but *equally* dense. There, then, its ascent terminates. It is *there*—instead of at the *surface* of the atmosphere—that it begins to spread itself, and *there* it determines its *current*. Along this region, comparatively near to the earth's surface, it distributes its heat, radiating part, and propagating the rest by contact—bearing it in a current, at first inclined downwards, to some point perhaps far removed from that where it arose, and disturbing the equilibrium of the subjacent air wherever it passes.

By the laws of hydrodynamics the motion of this current *above* necessarily brings about a motion of the air *beneath* it; a result which is favoured by its continual tendency, as it cools, to descend.

Moreover, the original displacement of this mass of air is brought about by a motion of the air around it, and the motion of this air supposes that of some other mass of air adjacent to *it*, *that* of a third, and so on. Thus every variation in the temperature of the lower air propagates a series of displacements of its mass along the earth's surface, and of currents in a region more or less elevated above it. *These are the winds.*

Higher than the region of the winds, the mass of the atmosphere is comparatively *untroubled*—they rage at the *bottom* of that mighty ocean, and do not ruffle its surface. By the marvellous wisdom of this disposition, the heat which the winds bear with them is made not to waste itself in the higher atmosphere, but to cherish the earth.* They carry it from the torrid zone not only, as do the waters of the ocean, to the *shores* of northern and temperate regions, but over the broad surface of the land—over hill and valley, through the deep forest into the matted foliage of the trees, and amongst the tangled grass; and no stunted shrub, or hidden flower, or weed, is too humble to be beneath their ministry.

With *us* each particular scheme and contrivance of our skill and judgment is directed to one particular object, or at most embraces two or three objects in its design. It is thus that *finite* wisdom of necessity guides the operation of *finite* power. With God it is otherwise. The same scheme of his creative wisdom is directed to an *infinity* of objects, embraces an *infinity* of results. *One* property of matter, for instance, works out the great purposes of nature in an infinity of different ways.

* It has been calculated that a current of air flowing over a warmer surface, whether of land or water, becomes in the space of an *hour* penetrated with the same temperature as the surface over which it travels, to the depth of eighty feet. Our easterly winds present a remarkable example of the circumstances under which the temperature of one region is borne to another. In the spring and early summer their direction is from the east and north-east, and, coming from the cold steppes of Siberia over the northern limit of the great central plain of Europe, they reach us *chilled* and *frozen*. In the autumn their direction is south-east, and they traverse the sultry region of Arabia and Asia Minor: they are then hot and thirsty.

Thus it is of the property of expansion by heat. Who shall number the phenomena which are included under that one property? The equalization of the temperature of the air and water is but one of a countless multitude. Take this other example. At every expiration breath leaves the body of every living creature, which a second time inhaled would be *poison.* There is, therefore, a provision that it may instantly be lifted up and carried away. That provision is in the *expansibility of the air.* Again; the breath has carried with it a constituent part of the living organization, a portion of the carbon of the blood. That this should be *lost* in the great system of nature, would violate that principle of *economy* which is its pervading law; the *winds* therefore bear the carbonic acid of the breath, eventually, not through the higher regions of the atmosphere, but so as to sweep it along in immediate contact with the earth's surface,* until, by an inscrutable process, it is taken up, and reincorporated with some form of vegetation; to become, perhaps, an article of food a second time, and to return, through the same cycle of changes—animal food, the chyle, the absorbents, the blood, the arteries, the veins, the respiration of some living animal, and the *winds*—again to assist in the process of vegetation. "O Lord, how excellent is thy name in all the earth!" "In thy hand is every living thing, and the *breath* of all mankind" (Job xii. 10).

* Carbonic acid gas is remarkable for its weight, and greatly heavier than atmospheric air.

THE PREVALENT WINDS.

"He was seen upon the wings of the wind."—2 *Sam.* xxii. 11.

THE air rotating eastward, as it sweeps from the polar regions, where it rotates with a *less* towards the equatorial regions where it rotates with a *greater* velocity, continually *hangs back* upon the earth's surface rotating beneath it; thus producing the perception of a wind partly from the poles, and partly westward, or from the east; so that

"to them who sail
Beyond the Cape of Hope, and now are past
Mozambic,* off at sea north-east winds blow
Sabean odours from the spicy shore
Of Araby the blest"—*Paradise Lost*, iv. 160.

These winds from the north and the east in the northern hemisphere, and from the south and the east in the southern, are the TRADE WINDS. They attain the earth's surface at, and begin to be felt about, 28° from the equator; being, before they reach that latitude, currents of the higher atmosphere. The counter currents by which the air returns from the equator to the poles being, on the other hand, as to their rotatory motion, continually *in advance* of the earth's surface, over which they are passing, produce, in the temperate regions, where they first come in contact with it, a wind from the south-west in the northern hemisphere, and from the north-west in the southern.

* And have crossed the equator.

The prevalence of such winds is well known to navigators; they are accustomed to calculate upon them in their voyages, and shape their course with reference to them.

To the prevalence of winds coming in a westerly direction from the tropics is to be attributed an extensive influence upon the climate of the temperate regions of the earth.

They gather heat the most readily and retain it the longest (for reasons assigned in a preceding chapter) when traversing the surface of the ocean. It is therefore to countries having a western sea-board and a wide expanse of ocean stretching westward and towards the equator, that they bring the greatest amount of heat and the most genial influence.

Thus it is that the western coast of Europe is, in the same latitude, greatly warmer than the eastern coast of America, and that there are yet more remarkable differences in the temperature of places having the same latitude but situated on opposite sides of the latter continent, or on the western and eastern sides of the great continent of Europe and Asia. At New Archangel, on the north-west coast of America (57° 3′ N. Lat.), the mean temperature of the year is 44° of Fahrenheit's thermometer, whilst at Nain, in Labrador, on the same parallel (57° 10′ N. Lat.) of the opposite *eastern* coast, it is only 27°. The mean temperature of the year in Paris, near the *western* coast of Europe, is 38°, whilst that of Pekin, situated nine degrees nearer to the equator, but on the *eastern* coast of the continent which comprises Europe and Asia, is only 26°.

THE COLD OF ELEVATED REGIONS ON THE ARTIFICIAL GLOBE.

"The strength of the hills is His also."—*Psalm* xcv. 4.

THOSE variations of temperature which arise from the *motion* of the atmosphere, although they may have a prevailing *character*, are nevertheless modified by so many occasional and local causes, that we know not their cycle, and are accustomed to consider them among the most uncertain elements of climate.* And although, no doubt, every wind that bloweth doeth the bidding of Him "who gathereth the wind in his fists" (Prov. xxx. 4), and "bringeth it out of his treasuries" (Ps. cxxxv. 7), and hath its especial ministration in the economy of nature; yet is it an agency which we find a difficulty in connecting with any of its greater characteristics or more general laws.

There are other properties of the air in the modification of climate, whose effects are still more striking. The better to comprehend the operation of these, let the imagination of the reader again sum-

* The effect of changes in the wind on the temperature is sometimes very sudden and remarkable. Captain Scoresby mentions an instance in the Arctic Seas, when, by a sudden veering of the wind, the thermometer was made to fall from $+32^\circ$ to -2°. Within the tropics the thermometer is rarely made to rise or fall more than 2° or 3° by a change in the wind.

mon into its presence the *artificer* and his *globe*. Suppose him to be desirous of introducing yet further modifications of temperature, independent of any of the causes before enumerated: and, with this view, let him have succeeded in mingling a substance such that, being translucent, and capable of being spread to a certain thickness over the whole globe, like a coat of varnish, it shall possess these properties—*first*, that (except under certain circumstances, hereafter to be explained) it shall give free passage to rays of heat as well as light, *not at all, or but very slightly absorbing them during their transmission*; *secondly*, that it shall be capable, in common with all other substances, of having its temperature raised by *contact* with any heated substance. Suppose, moreover, this transparent coating to be of a thickness greatly more than the height of the highest eminence modelled on the surface of the sphere; and, that its resemblance to the atmosphere may be complete, let it have been laid on in a series of different coats one above another each of a less density than the one put on before it.

The effect of the properties just described will be to cause the inner portions of this coating—that is, those more nearly in contact with the surface of the sphere—to be of *a higher temperature than the outer portions of it*. For the rays of heat pass through the transparent coating *without* heating *it*, but are absorbed by, and *heat* the actual surface of, the sphere; and this heated surface of the sphere, in return, heats *by contact* the lower strata of the coating, at the same time radiating off some of its heat into space. These lower strata, in like manner, radiate some of their heat, and communicate a portion of the remainder by contact to the strata above them, which, in like manner, radiate some, and communicate a portion of the remainder *to their* incumbent strata. Now, let it be borne in mind, that few or none of the rays of heat are supposed to be *absorbed* in the act of radiation through the medium, and that the medium is supposed to be heated by *propagation* only, from the surface of the sphere *upwards*, and from stratum to stratum. It will then be apparent that each stratum must of necessity be less heated than that beneath it; and that any portion of the moulded surface of the sphere which projects *above* its general surface, existing in a colder stratum of the surrounding medium, must itself be of a lower temperature than the general surface.

THE DEPOSITION OF MOISTURE ON THE ARTIFICIAL GLOBE.

> "Ye Mists and Exhalations, that now rise
> From hill or steaming lake, dusky or gray,
> 'Till the sun paint your fleecy skirts with gold,
> In honour of the world's great Author rise,
> Whether to deck with clouds th' uncolour'd sky,
> Or wet the thirsty earth with falling showers,
> Rising or falling, still advance his praise."
>
> *Paradise Lost*, v. 185.

A new element is now to be introduced in our hypothesis. Let it be required to the perfection of the work, that *humidity*, in various forms and various proportions, should be brought in actual contact with its surface. Suppose this humidity, under the form of a transparent* vapour, to enter as an element into the constitution of the medium which covers it. Let it, however, retain its properties as a *vapour* notwithstanding this union; so that, being subjected, in common with the medium itself, to a certain diminution of temperature, by which *both* are made to contract their bulk, beyond a certain limit, the vapour shall in that

* It is only when it is in the act of condensing that the vapour of water presents that *cloudy* appearance which we associate with our idea of it. As long as it is in the water, which is of the same temperature as itself, we see by the bubbles which contain it that it is perfectly transparent.

state of condensation separate itself from the medium, lose its transparency, and deposit moisture; and that, by an opposite process, when subjected to an increase of temperature, this moisture shall again pass into that form of transparent vapour from which it before condensed, and be taken up by the medium. Here, then, evidently our artificer will have contrived, by a scheme of marvellous ingenuity, to minister to every state of *temperature* of every part a corresponding variety of *moisture.*

Let the coating of the sphere now be imagined to pass from the state in which we have described it, of a transparent but solid medium, having some resemblance to a thick coat of varnish, into the form of an *elastic fluid* medium—a *gas*, or an *air*, held to its surface by some *attraction* which it exerts upon it,—an attraction which does not, however, prevent it from moving about freely upon the surface of the sphere,—in short, let it pass into the state of a medium having all the properties of the atmosphere, held by a like attraction to the *earth's* surface. And, in order to try the effect of his contrivance, suppose the artificer, looking through this transparent atmosphere upon any part of his work, to produce by some means artificial *cold* there. When this cold has passed a certain limit, the vapour which forms part of the atmosphere immediately about that spot will condense, a *cloud* will appear above it, and, stretched like a veil, will hide it from his eye. The immediate effect of this cloud will be to return a large portion of the heat which is in the act of radiating from the spot which it covers, and to check the farther depression of its temperature.

N 2

If the state of artificial cold be continued, the temperature of this cloud will be yet farther depressed by its radiation into space, and it will begin to deposit moisture in drops. This formation of cloud, and ultimate deposition of moisture, will be affected by the least depression of temperature, and be most apparent over those portions of the sphere which, representing the pointed summits and ridges of mountains, are worked into elevated points and angles; these presenting a much larger surface of radiation in proportion to their mass than the general surface of the sphere does; so that from a given mass a much greater quantity of heat is there radiated away.*

Yet more remarkable will be the effect of those portions of the covering which are intended to represent vegetation in producing a deposition of moisture. The leaves of a tree offer an immense surface of radiation in proportion to its bulk. The modelled resemblance of a forest would therefore have its temperature and that of its surrounding atmosphere far more reduced under the same circumstances of cold than even the pointed summit of the broken ridge of a mountain. Over these mountains and

* This effect of a broken surface in increasing the radiation in proportion to the mass, and therefore depressing the temperature, may be seen in the deposition of hoar frost upon a high road after a cold night. Whilst little or none is seen on the general surface of the road, the edges of the traces left by the carriage-wheels, and the surfaces of loose lumps of earth, will be found to be covered with it; and if tufts of grass are here and there seen, these, presenting a yet larger surface of radiation in proportion to their bulk, will be covered with a yet more abundant deposition.

forests of the globe clouds will first form themselves; and when by its rotation any portion of it has been subjected to a long-continued radiation in passing through its darkened side, moisture will on these first be deposited. At certain elevations it will collect itself on the summits of the hills, congealed into snow; at others it will accumulate in drops, descend in rain, and, trickling down their sides, collect into streams, and irrigate the valleys and plains.

The refrigerating influence of elevated portions of the surface of our mimic globe is not, however, the only cause active in the formation of clouds; nor is it only on those portions of it which are turned *from* the heat, that this process of formation is going on. Under the immediate influence of the rays of heat which fall upon it from the fire, the moisture is continually passing from its surface into the lower strata of its atmosphere, under the form of a transparent vapour; whilst those lower strata, heated and rarefied by contact with it, and loaded with its moisture, are continually ascending into higher and colder regions, where, in the act of condensing (if the condensation exceed a certain limit, dependent upon the degree of the previous saturation with moisture), their vapour becomes snow, or assumes the form of a cloud hung in mid air, and stretched, like a veil, over it—a veil which the surface of the globe thus *itself* gives out, and spreads wide, and which shelters it from the heat.

Under a different state of saturation of the air with water, and a different rarefaction of it, its vapour may ascend into such a region, and be so condensed by its ascent, as to pass from the state of *cloud* to that of *rain* or *hail* Moreover, this greater saturation and rarefaction will be especially likely to obtain under the point of *direct heat*. The temperature being there the highest, and the evaporation the greatest; we may indeed expect a cloud to be continually stretched over that point, and a perpetual rain to descend there.

THE COLD OF ELEVATED REGIONS OF THE EARTH'S SURFACE.

"Before the mountains were brought forth, or ever thou hadst formed the earth and the world, even from everlasting to everlasting, thou art God."—*Psalm*, xc. 2.

This artificial globe now presents a complete epitome of the surface of the earth, its atmosphere, and all the astronomical and meteorological varieties of its climate. We have its zones of temperature; its cold and heat, dependent upon elevation and aspect; its winds and storms; its clouds and sunshine; the vapours collecting around the summits of miniature mountains snow-capped; the rains descending on forest tracks, and hilly districts, and thence irrigating its plains and valleys, accompanying with a perpetual deluge the point of direct sunlight through the tropics, tempering the vertical heat, and ministering, there, to the boundless energies of vegetation.

The atmosphere has this quality, that, when *pure* and *free from vapour* it is wonderfully pervious to the rays of light and heat.* Very little indeed of the heat is, in a perfectly clear sky, absorbed in its transit through

* Bouguer has calculated that of 10,000 rays falling upon the atmosphere perpendicularly, 8,123 reach the earth's surface. There is, however, reason to believe that this is much *below* the true estimate.

it. Thus readily allowing the radiation of rays to the earth's surface from the sun, the air lends itself with equal facility to the radiation of heat in the opposite direction from the earth's surface into space. That heat which the air actually receives appears principally to be derived from its contact with the earth, and propagated by conduction from one part in it to the other. If it be asked, Why does not this heated air immediately desert the surface of the earth, and ascend and heat its higher regions, and, continually accumulating heat there, render them yet warmer than the lower air, which is notoriously contrary to the fact?—the answer at once meets us in the elasticity of the atmosphere; and therefore in its decreasing density at higher elevations, by which, as in the case of the artificial globe, it is made to contain, as in a *vase*, a stratum of warm air in close contact with the earth's surface, and to confine the heat around it.

The air of the higher regions, when freed from clouds, absorbs little or none of the heat radiated through it, either from the sun, or back from the earth, or from the subjacent atmosphere. Moreover, the air heated by *contact* with the earth, and ascending to these higher regions, loses its heat rapidly as it ascends by radiation and contact, and ascends but to that limited height assigned to it by the diminishing density of the surrounding air. All that remains to warm the higher regions of the air is the heat propagated to it by the *contact of parts*, as it is through solid bodies; and each stratum in succession, as it receives this heat, radiates a portion of it off into space, propagating only the remainder to the next stratum.

Thus each successive stratum above us receives a diminished amount of heat, and the air grows colder and colder.* Here there is that marvellous provision for the assembling of a variety of climates nearly upon the same spot of the earth's surface, by which it comes to pass, that within the compass of a few miles may sometimes be seen congregated every characteristic form of vegetation, from the giant plants of the tropics to the lichens of the Arctic zone. In the valleys of the Andes, for instance, are growing palm-trees, and the banana, and the coffee-tree, and the sugar-cane, and the cow-tree, whose trunk being pierced yields a vegetable milk—the majestic forests, the juicy fruits, the gorgeous flowers of the *tropics*. You ascend them 4,000 or 5,000 feet, and you find yourself in the *temperate zone*; fields of European grain wave around you, and there are forests of oak and pine. Climb those lofty mountains yet higher, and beyond the limit of 11,000 feet you are in a region where grow none but the *Arctic* lichens.

* Gay Lussac ascended in a balloon to a height of 7,634 yards above the level of the sea, and found the temperature diminished by 72½° of Fahrenheit's thermometer; or at the rate of about 105 yards for each degree. The depression of temperature at the same elevation is, however, different in different latitudes. Thus the height at which a perpetual frost commences its reign, and at which snow is found all the year round on the tops of mountains, is different in different latitudes. Throughout a zone of the earth, extending 20° on either side of the equator, it may be considered to vary from 16,000 to 17,000 feet, having the less elevation immediately beneath the equator, and the greatest at 20° from it. From this greatest elevation it appears to sink almost uniformly as the latitude increases, until under a latitude of 80° it touches the earth's surface.

In like manner, on the sides of the Alps, the forms of vegetation may be traced from the temperate zone to the region of pepetual snow, in the succession of forests of chestnuts, beeches, oaks, and pines, gradually becoming stunted and more scattered, until they disappear on the borders of the line of perpetual congelation.

By reason of the diminished temperature of mountain track, and the fertilizing influence of clouds, and dew, and rain, which the atmosphere accumulates upon them, they become, in sultry regions of the earth, the *refuge* of vegetation. It is with this allusion, that God, speaking by the mouth of Ezekiel, as the shepherd of his people, says, in the language of prophecy, "I will feed them in a good pasture, and upon the *high mountains* of Israel shall their fold be: there shall they lie in a good fold, and in a fat pasture shall they feed upon the *mountains* of Israel" (Ezek. xxxiv. 14).

THE DEPOSITION OF DEW.

"Hath the rain a fath ? or who hath begotten the drops of DEW ?"—*Job* xxxviii. 28.

THE agency of the air in the work of vegetation is not completed when it has brought about its various modifications of the *temperature* of the earth.

Moisture is another element of active vegetation, not less essential to it than heat. Whilst, therefore, the air is made to receive, with an ever-varying influence, those *temperatures* which minister to the different forms of a vegetable nature, it is made also, by a yet more marvellous provision, to *water them.*

To set before the reader in a clear light this beautiful provision of the wisdom and goodness of God, to which such numerous references are made in the word of God, he must be made to comprehend this property of the air—that in every form, and under all circumstances, it contains, mingled with it in greater or less quantities, *vapour*, in that pure and transparent state which it assumes when wholly *uncondensed.** In this

* We are accustomed to connect our idea of vapour with that of *steam*, as we see it escaping into the air. In this state it is in the act of *condensing* into moisture ; for this reason it is that it appears opaque and cloudy. Could we see it *before* its escape, when in the boiler or cylinder, for instance, of a steam-engine, we should perceive that it is a perfectly transparent fluid. It is easy to con

form of an unseen vapour, it is at all times and everywhere ministering to the exigencies of vegetable life. The vapour thus contained in the air, when, together with the air, its dimensions are contracted by cold beyond a certain limit, becomes condensed into minute particles of water, and assumes the appearance of a cloud. The quantity of contraction necessary to this condensation depends upon the quantity of water before contained in the contracted air; that is, upon the density of the vapour in it. If there be much in a certain quantity of air—that is, if the vapour in it be dense—then but little contraction or diminution of temperature will be necessary; if there be *little*, then a greater contraction and a greater depression of temperature will be required. Thus, then, there is a *certain* depression of the temperature of the air, which will always cause its vapour to condense into moisture;*

vince ourselves of this by experiment. Let water be boiled in a *glass* vessel (over a spirit-lamp, or otherwise); the bubbles of steam, as they ascend from the bottom of the water to escape at its surface, will be seen to be perfectly transparent.

* The circumstances under which the condensation of vapour in the air takes place will perhaps be more clearly understood by this illustration. Let a glass tube, closed at one end, be supposed to contain air, and let it be prevented from escaping at the other end by a small column of quicksilver poured in at that end, and holding down the column of air beneath it in the tube. Now apply artificial *cold* to this tube. The air in it immediately begins to contract; for you will see the column of mercury, which retains the air beneath it, sink in the tube to a certain point. If the depression of temperature be continued, a certain point of condensation will be attained, at which *dew* will begin to be deposited in the interior of the tube. The degree of temperature at which this begins to take place is the *dew-point*. It manifestly

and the amount of depression necessary to produce this condensation is dependent upon the amount of vapour contained in the air.

Here, then, we have the explanation of the formation and the deposition of dew.

By the radiation of the earth's heat into space, after the sun has gone down, and it is no longer renewed continually from him, its surface is rapidly cooled. The superincumbent air, cooled by contact with it and by its own radiation, has, in the act of cooling the volume of its contained vapour, contracted until it *condenses* and becomes cloud. Being most cooled immediately in contact with the earth's surface, it there exhibits its greatest condensation, and the vapour there deposits itself under the form of dew, but in different quantities according to the different radiating

depends upon the quantity of vapour there was contained in the air condensed. If the weight of the small column of mercury in the tube be supposed to represent the pressure of the barometric column, this case is precisely that of the deposition of dew by the atmosphere. Now the *elasticity* of the vapour, as it contracts its dimensions and condenses, remains under these circumstances *the same*; for it sustains throughout the same column of mercury. But we know, from independent experiments, what is the *elasticity* of any vapour of water, at the moment when *it is in the act of condensing into moisture at a given temperature.* Thus, then, we know the *elasticity* of the vapour in air, by observing the point of temperature, at which it condenses into cloud, or its *dew-point.* And this is, moreover, the same as the *elasticity* of this vapour in its *natural* state, and before its temperature was reduced. Thus, by observing the dew-point of the air at any time when artificially cooled, we can tell the *elasticity*, and therefore the density, of the vapour it contains in its natural state:—and this is the principle of Mr. Daniel's ingenious hygrometer.

properties of the substances on which it is deposited, and their greater or less consequent depression of temperature.*

Thus on bright metallic surfaces, which radiate heat with difficulty, but little dew is deposited.† Four or five times as much might be expected to be found on the surface of a paper blackened with Indian ink, and exposed to the air of the same night; yet more, on the surface of a piece of plate-glass; more still upon a surface covered with a film of water; and most of all on a surface blackened with smoke.‡

Animal and vegetable substances are among those which radiate heat with the greatest facility, and therefore cause the deposition of dew in the greatest

* The following table will show how great are the differences between the radiating powers of different surfaces. Representing by 100 the radiating power of a surface blackened by the smoke of a lamp, that of the same surface covered with

Water will be found to be	100
Writing-paper	98
Crown-glass	90
Indian ink	88
Ice	85
Mercury	20
A bright surface of lead	19
Ditto of iron	15
Ditto of brass, silver, copper, gold	12

† A metallic plate whose brightness is tarnished attracts an abundant deposition of dew, whilst an exactly similar one with an untarnished surface attracts none.

‡ That this comparison may be accurate, the bodies which receive these artificial surfaces should be, as nearly as possible, of the same size and material; and the surfaces should be very thin, and made to *adhere* to them.

abundance.* No substance appears, by the experiments of Dr. Wells, to have a greater radiating power, and therefore a greater attractive power upon dew, than wool, especially when used attached to the skin.† There is a beautiful illustration of this fact in the miracle of the fleece of Gideon. He stretched it upon the ground; and the dew fell upon the fleece only, and it was dry on all the earth besides: and "he rose up early on the morrow, and thrust the fleece together, and wringed the dew out of the fleece, a bowl full of water." And the next night he stretched the fleece again; and "it was dry upon the fleece only, and there was dew on all the ground" (Judges vi. 37-40). The dryness of the fleece on the second night, as it lay upon the ground, was in direct opposition to the existing economy of nature.

Differences of colour in bodies, of roughness or smoothness of coarseness or fineness of texture, as well as differences of substances, are sufficient, however, to produce essential differences between them in this respect. If equal parcels of white and black wool, and of swan's down, for instance, were exposed, under the same circumstances, to the air of the same night, they would be found, by weighing them after

* Dr. Wells found, on a fine evening in August, at half-past seven o'clock, that whilst the heat of the surrounding air was 59°, that of the surface of a board raised four feet from the ground was 55½°, that of a small parcel of wool placed on it 51½°, that of a similar piece of swan's down 51°, and that of the grass of an adjacent grass-plot 49½°.

† Except, it seems, swan's down, which is of a similar nature but of a finer texture.

the same time, to have received unequal depositions of moisture; and the deposition of dew on the surface of a piece of wood, or of glass, would be greatly affected by taking away its polish.

Now the leaves of no two descriptions of plants have surfaces precisely of the same colour, smoothness, and dryness; no two therefore radiate heat precisely alike, and no two attract equal depositions of dew. Thus, not only is it ordered, by a wonderful provision, that the atmosphere should temper the heat to every plant, but that in the season of drought it should *water* it at eventide, and in the morning; and water each, as it were, with a different *hand*, and a different abundance. Who shall doubt that this varying abundance is proportioned to the *thirst* of each.

The great radiating power of vegetable surfaces may be seen in the deposition of dew on a track covered with vegetation as compared with that on the unclothed surface of the soil. Thus on an evening of summer, whilst the white surface of the road is still dry and dusty, if we pass into an adjoining meadow we shall find it covered with dew. In the winter the same field will be found covered with hoar frost, whilst there is no appearance of it upon the road.*

Frequent allusions are made in Scripture to this abundant deposition of dew upon the herbage. God thus comforts his people by the mouth of Isaiah:

* Glass radiates heat with remarkable facility. Thus is explained the deposition of frozen moisture on panes of glass in a window, whilst little or none is to be seen on its wooden frames, or on the brick walls of the house.

"Awake, and sing, ye that dwell in dust; for thy dew shall be as the *dew of herbs*" (Isa. xxvi. 19); and Solomon compares the plentifulness of a king's favour to "dew upon the grass" (Prov. xix. 12).

Although the cold of the *evening* may not be sufficient, under the existing state of the atmosphere, to cause the formation of dew, yet that degree of cold may be attained as the night advances, and as more and more of the heat of the surface is radiated. The greatest cold appears to be attained about an hour after sunrise.* The dew may not, therefore, be deposited all night, and yet the temperature may at that hour be low enough to cause its deposition; and if the deposition has *commenced* before, it will, in all probability, *continue* until then. Thus is explained the profuseness of the dew which is continued all night, and the scantiness of that which begins only to be deposited in the morning—*the morning dew*. With this allusion it is that Job, declaring the glory and the happiness of his lot before the hand of God's chastisement was laid upon him, says, "My root was spread out by the waters, *and the dew lay all night upon my branch*" (Job xxix. 19): and that God, by the mouth of his prophet Hosea, expostulates with his people as

* Every portion of the earth's surface is radiating heat into space continually day and night. During the middle of the day it receives from the sun more than it radiates, and its temperature rises; in the evening it receives less than it radiates, and its temperature falls; at night it receives *none*, and its temperature continues to fall rapidly; in the morning it begins again to receive heat, but for some time after daybreak it receives less than it radiates—its temperature *continues* therefore to fall.

those "whose goodness is as a morning cloud, and as *the early dew goeth away*" (Hos. vi. 4).

The formation of dew depending upon the reduction of the temperature of the earth's surface by radiation depends upon the *clearness of the sky;* for if there be clouds upon the sky, these intercept and absorb the heat which the earth radiates towards space, and then radiate it again in all directions, and therefore, partly, back again to the earth, whence a second time it is returned to the clouds. Thus a portion of the heat which any region, thus covered by a cloud, has received from the sun during the day, is continually passing between it and the cloud; and it does not cool so rapidly, or to the same degree, in the course of the night as when the sky is clear. As early as 1776, it was observed by Wilson, that a thermometer, exposed during a night in which great masses of cloud were passing over a clear sky, always *rose* when the sky was obscured, and sank when it became open.* It would appear remarkable how very thin,

* If the sky became cloudy, says Dr. Wells, after having been clear, though there might be no change in respect to calmness, a considerable alteration in the temperature of the grass always ensued; and this sometimes very suddenly. Upon one such night, the grass, having been 12° colder than the air, became only 2° colder than it, the temperature of the air being the same at both observations. On a second night, the grass became 9° warmer in the space of an hour and a half. On a third night, in less than forty-five minutes the temperature of the grass rose 15°, while that of the neighbouring air increased 3¼°. During a fourth night the temperature of the grass at half-past nine o'clock was 32°; in twenty minutes afterwards it was found to be 39°, the sky having in the mean time become cloudy. At the end of twenty minutes more, the sky being clear, the temperature

and almost imperceptible, a vapour is sufficient thus to interfere with the radiation of heat, and affect the thermometer, were it not that we know heat and light to pass together, and a very thin cloud perceptibly to interfere with the transmission of *light*.

Clouds are, in point of fact, a *garment*, a *coverlet* for the earth. When spread over it at night they retain in it a large portion of the warmth which it has absorbed during the day; as a covering for the body retains the animal heat.*

Thus obstructing the radiation of heat from that portion of the earth's surface which they cover during the night, the clouds obstruct the deposition of *dew* upon it; and we have it thus explained by what provision of infinite Wisdom it is, that in the temperate and colder regions, over whose sky clouds are con-

of the grass was again 32°. In illustration of these observations, Dr. Wells made the following experiment:—"I bent," says he, "a sheet of pasteboard into the shape of a house-roof, making the angle of flexure 90°, and leaving both ends open. This was placed one evening with its ridge uppermost upon the same grass-plot in the direction of the wind, as well as this could be ascertained. I then laid ten grains of wool on the middle of that part of the grass which was sheltered by the roof, and the same quantity on another part of the grass-plot fully exposed to the sky. In the morning the sheltered wool was found to have increased in weight only two grains; but that which had been exposed to the sky sixteen grains.

* It is precisely on this principle that any other covering operates in the retention of warmth. There is a perpetual radiation of it backwards and forwards between the covering and the body covered. And in the same way it is explained why the covering of a plant or tree in blossom with a slender gauze or netting, or sheltering it with boughs, or causing a cloud of smoke to pass over it, greatly protects it from the night cold.

tinually passing, and where there is abundance of rain, the earth is not watered with dew except in the heat of summer; and why in tropical countries, and especially under the arid, cloudless, and transparent atmospheres of *desert* regions, the nights are proverbially cold,* and the dew is deposited with the abundance of a shower.

The allusions of Scripture to this copious outpouring of dew upon the thirsty vegetation of Palestine, and its blessed and fructifying influence, are many and beautiful. It is called the "dew from the Lord," (Micah v. 7). In his blessing upon his son Esau, Isaac gave the *first* place to the "*dew* of heaven:" "God gave thee of the dew of heaven, and the fatness

* It is in reference to these extreme vicissitudes of the heat by day and the cold by night in Palestine, that Jacob, speaking of the hardships he endured whilst watching the sheep of Laban, says, "in the day the drought consumed me, and the cold by night" (Gen. xxxi. 40). In Bengal great numbers of persons are employed in the collection and preservation of ice formed by exposing thin surfaces of water to the night air; it is an article of *manufacture*. The process is this:—A space of ground, of convenient dimensions, being carefully levelled, is divided into plots of four or five feet square, round which the earth is raised three or four inches. Each of these compartments has its floor covered with a layer of straw, or dried sugar-cane, on which are placed open earthen vessels containing the water to be frozen. When the air of the night is calm, and the sky clear, ice forms itself in abundance. It is by the *direct radiation* that this depression of the temperature of the water is brought about. It is carried far lower than that of the surrounding air. A full account of the circumstances connected with this formation of ice will be found in a paper by Mr. Williams, in the *Phil. Trans.*, vol. lxxxiii. A manufactory of ice has recently been formed on this principle in the neighbourhood of Paris.

of the earth, and plenty of corn and wine" (Gen. xxxvii. 28). Jacob, too, in blessing his sons, gave to his *beloved* son Joseph "the blessings of *heaven above*" (Gen. xlix. 25); and in "the blessing wherewith Moses the man of God blessed the children of Israel before his death, he said of Joseph, Blessed of the Lord be his land, for the precious things of heaven, for the *dew*, and the deep that coucheth beneath" (Deut. xxxiii. 1, 13). The *goodness* of God is compared to the influence of the dew: "I will be as *dew* unto Israel," saith he; "he shall grow as a lily, and cast forth his roots as Lebanon" (Hos. xiv. 5). His *presence* is likened to "a dew in the heat of harvest" (Hos. xviii. 5); and his "*speech*" is said to "distil as the *dew*" (Deut. xxxii. 2).

Unity in the Church is compared by the Psalmist to the blessed influence of dew: "Behold how good and how pleasant it is," says he, "for brethren to dwell together in unity!..... It is as the *dew* of Hermon, and as the *dew* that descends on the mountains of Zion: for there the Lord commandeth the blessing, even life for evermore" (Ps. cxxxiii. 1-3).

These allusions of Scripture to the copious dews of Palestine can scarcely be understood in all their fulness and significance until we have compared them with testimonies, such as the following, of *travellers* in those countries. "We were instructed by experience," says Maundrell, travelling near Mount Hermon, "what the Psalmist means by the *dew of Hermon*, our tents being as wet with it as if it had rained all night." And Dr. E. Clarke thus writes of a journey from Aboukir to Rosetta: "We had a tent allotted to us for the night; it was double lined; yet so copious are the dews of Egypt" (the climate of which country is said to be similar to that of the Holy Land) "after sunset, that the water ran copiously down the tent-pole." * With the idea we thus arrive at of the *dews of these regions*, such passages as the following become intelligible: "His body was *wet* with the dew" (Dan. iv. 33). "My head is *filled* with dew and my locks with the drops of the night" (Cant. v. 2).

* See Horne's Introduction, vol. iii. p. 32.

THE CLOUDS.

"Sing unto the Lord with thanksgiving; sing praise upon the harp unto our God: who covereth the heavens with *clouds*, who prepareth *rain* for the earth, who makes grass to grow upon the mountains."—*Psalm* cxlvii. 7, 8.

THE same cause which accounts for the deposition of *dew* explains the formation of *clouds*. The lower strata of air becoming heated and expanded by contact with the earth's surface, and more or less saturated with its *moisture*, are buoyed up, and made to seek in higher regions of the atmosphere a density like their own. As they thus ascend, they find a continually *diminishing temperature*, and, under its influence, they diminish the velocity of their ascent, and contract their dimensions. At length, perhaps, a region is attained where the temperature of the ascending mass of air sinks to the *dew-point*. Its vapour then *condenses* into moisture, and a *cloud* is formed. Or, perhaps, its *ascent* is arrested before the elevation corresponding to this temperature is reached; but in the mean time it has entered one of those *currents* of the upper regions of the air which have a prevailing tendency from the tropics towards the poles, and, forming part of this current, it is borne along over regions of the earth successively colder than one another—descending as it advances—until at length it traverses some region where its temperature sinks to the dew-point, and it becomes a *cloud*. An elevated region, if such occur, will first present to it these conditions, and especially a mountain range. The current climbs its sides, until it attains, perhaps, a region elevated and cold enough to produce the vaporous condensation of its moisture.* The watery particles of the cloud thus formed, suspended in the air out of which they are condensed, are then borne along in the wind, like mountainous snow-flakes swept along in a flood of waters. Long columns of them are, by an optical deception, made to

* It has already been explained that the *depression* of the temperature of a mountain-peak or ridge by radiation during the night is very great, exceeding that of the plain beneath. Its surface must, then, become greatly colder than the surrounding air during the night, as, according to the experiment of Dr. Wells, the even surface of the ground does. This depression of its temperature will probably be greatest about an hour after sunrise, which explains the accumulation of clouds on the tops of mountains about that period of the day; the cold will, however, remain in a less degree until much later, and that especially as one-half of a mountain is, in our latitudes, always in the shadow. Hence arises the moisture of mountains in tropical regions, and consequently their fertility, so often alluded to in Scripture. We read in Isaiah, "Their pastures shall be in all high places. They shall not hunger nor thirst; neither shall the sun or heat smite them: for he that hath mercy on them shall lead them, even by the springs of water shall he guide them" (Is. xlix. 9, 10). And thus the "mountains and all hills" are said to "praise the Lord" (Ps. cxlviii. 9). And on the mountains of Gilboa the curse of God descended, that there should be "no dew upon them" (2 Sam. i. 21).

mould themselves, as it were, into the cavity of the sky; and, as they travel onwards in long lines, we seem to see thousands of them winding round us in segments of the great dome of the heavens.

It is somewhere about the 30th parallel of latitude that the temperature of the region in which the great permanent currents of the air prevail, appears to attain the dew-point. Here, then, commences what may be called emphatically the *region of clouds*, and the *temperate zone*. Here it is that God first "bindeth up the waters in his thick cloud" (Job xxvi. 8), and "it poureth down rain according to vapour" (Job xxxvi. 27).

THE RAIN.

"Nevertheless, he left not himself without a witness, in that he did good, and gave us *rain* from heaven, and fruitful seasons filling our hearts with food and gladness."—*Acts* xiv. 17.

THE condensation of vapour is attended by the extrication of heat. When, therefore, a mass of air passes into another of a temperature lower than the dew-point, and makes its first deposition of cloud, it may, in the *very instant of deposition*, elevate the temperature of the medium immediately around it slightly above the dew-point. In this case but a *thin* cloud will form. If, however, the difference of the temperature of the two media be great, or if the mass of heated air passes *on*, so as continually to change the medium which surrounds it, there will result a *continual* abstraction of heat, a *continual* depression below the dew-point, and a *continual* accumulation of vapour and *thickening* of the cloud. In the act of condensing, the moisture will have a continual tendency to accumulate on the particles already formed, until at length, becoming too heavy to be longer suspended, they will *fall*, and adding to their mass the moisture that lies in their path and that surrounds it, they will at length reach the earth in large drops under the form of RAIN.

Here, then, is that second provision of God for watering the earth yet more abundantly than by the dew. "Thou, O God, didst send a plentiful rain upon thine inheritance" (Ps. lxviii. 9), "the great rain of thy strength ..... to satisfy the desolate and waste grounds, and to cause the bud of the tender herb to spring forth" (Job xxxvii. 6, 27).

As *elevated* regions cause the formation of cloud, so do they favour the descent of RAIN—a fact with which every one who has lived in a mountainous district is sufficiently conversant.* Obstructing the currents of the lower air, mountain ranges cause them to climb their sides, and, under the powerful contraction of the cold that reigns at their summits (especially during the night), *compel* them to give out their vapour, in clouds and rain. Thus *the irrigation of the earth is effected by the mountains.* It is in the rains upon the mountains that all the great rivers of the world have their origin, and hence that they are continually fed. Here, too, replenish themselves those mighty *tanks*, which, embowelled in mountain regions, by a thousand secret channels disseminate their waters under the surface of the soil, cherish the deep roots of trees, and feed the thirsty herbage, or gush out in the green places of the earth into springs, and fountains, and brooks.

> "these
> The mountain cisterns fill, those ample stores
> Of water, scoop'd among the hollow rocks;
> Whence gush the streams, the ceaseless fountains play,
> And their unfailing wealth the rivers draw."
>
> *Seasons—Autumn.*

For *this cause*—as well as that He might infinitely multiply over the same narrow region the forms of

* More than TWICE as much rain falls at Kendal, in Westmoreland, as in London.

vegetable nature by accumulating there all the varieties of climate—we may conceive the mountains to have been *established*, and to have been "weighed in scales, and the hills in a balance" (Is. xl. 12).

When we behold the ranges of the Himalaya and Taurus stretching their mighty barrier almost due east and west,* just without the tropic of Cancer, five thousand miles across the southern breadth of Asia, it is scarcely possible not to believe that they were there placed to lift their heads into that current of the higher air, which, bearing with it the evaporation of the torrid zone, sets from the tropic of Cancer continually to the north; to gather its waters, and *return* them, to the fertile plains of Hindostan, by the vast river-system of the Ganges and the Indus, and to Persia and Syria, by the Euphrates and the Tigris.

Let us *follow* this belt of mountains westward, and we shall find it *continued* by a double system; one branch of which, commencing at the Straits of Constantinople, and terminating at Cape la Roca in Portugal, skirts the Mediterranean, and forms the southern boundary of Europe; and the other, commencing with Lebanon, traverses Palestine on this side Jordan—"a land of brooks of water, of fountains and depths that spring out of the valleys and hills" (Deut. viii. 7)—and passes by Arabia Petræa into that mountainous district which, with the interval of a narrow fringe of low and level land on the shores of the Mediterranean, appears to form the northern boundary of Africa, and terminate in the regions of Atlas.

* The true direction of the parallel ranges of the Himalaya and Taurus is E.S.E. and W.N.W.

But the continent of Africa, stretching completely across the tropics, and far into the southern hemisphere, requires *other* sources of irrigation than are to be found on its northern frontier. Further south, across a central region, then, south of Sahara, and between the coast of Guinea and the Red Sea, rises, as we have reason to believe, a vast mountain-district, in which are the sources of the Bahr el Abiud—the parent of the Nile—on the east, and the mighty Quorra (the Niger) on the west; and on the *extreme* south we find the elevated table-lands of the *Cape*.

If, now, we pass to the new world, whose vast length reaches from one pole almost to the other; for the irrigation of that far-stretched region, a mountain-range presents itself, which is made to run along its entire length, from the Tierra del Fuego to the Frozen Ocean.

Of this mountain-chain the southern division is the Andes, "the longest unbroken range of lofty summits on the globe." It is continued into the northern continent by that mountain district which, rising in the Isthmus of Panama, and spreading itself into the table-lands of Mexico, merges in the Rocky Mountains of the United States, then becomes the Chippewayan range of the north-west country, and terminates west of Mackenzie's River in the Frozen Sea,—having traversed a space of not less than 8,700 miles; skirted (with a considerable interval towards the north) the western shore of both continents and the Pacific; given birth, by its eastern slope, to the greatest rivers on the globe—the Parana, the Maranon (the La Plata and the River of the Amazons), and the Mississippi;

called into existence the widest known varieties of climate; fertilized a vast track, under an infinite variety of forms; and fostered every where a luxuriant and a *giant* vegetation.

To the long and narrow continent of *South* America an abundant irrigation is supplied by the range of the Andes, with the *tributary* ranges of Venezuela, of Guiana, and Brazil, which cross it in its widest part. The wide expanse of the *northern* continent requires, however, other fountains of water than those of the Rocky Mountains and the Chippewayan range on its western skirts. To meet this exigency, eastward of the valley of the Mississippi rises the system of the Appalachians, and stretches to the banks of the St. Lawrence.

Such are the mountain-ranges of the earth. These, however, are but a *part* in the great system of its high places; these but give *rise* to the rivers, whose course is afterwards controlled, and whose waters are replenished by more gradual variations in the level of the land.

All the great continental masses would seem gradually, and to the eye imperceptibly, to *lift* their surfaces from their shores towards their central regions; and it is upon these central elevated platforms that the great characteristic mountain-systems are, for the most part, builded up. Who will believe that they were not thus placed, in order that the waters which fall upon them, compelled from the clouds, should not lie accumulated and stagnant around their bases, but be directed by the gradual and various descent of the land in a devious course, and with a far-spreading influence to the sea? For this reason it is that Asia rises from the level plains of Hindostan and of Arabia, and from the steppes of Tartary and Siberia, by a series of gradual slopes and terraces, to those vast systems of table-land known as the plateaus of Thibet and Iran, whose elevation varies from four thousand to ten thousand feet; which comprises an area of not less than nine millions of square miles, or two-fifths of all Asia; and on the skirts of which rise, like mountain-entrenchments, the ranges of Himalaya, of Taurus, and of Caucasus.

Thus Africa too, as far as we know it, appears to be "a land of terraces, rising from the coast into the interior by successive steps, which are spread out into widely extended plains,—in some places known by observation to exist, as in the Cape colony, and on the shores of the Mediterranean; in others indicated by a regular series of falls in the beds of great rivers."

And thus America elevates itself, in its *northern* continent, from the shores of the Atlantic and the Pacific, by a series of gradual elevations, to the platform which carries the Appalachians on the east, and to that which supports the Rocky Mountains on the west. And thus along its *southern* continent runs the ridge of the Andes, like the mighty spine of a vast living animal, towards whose base its surface elevates itself from the Atlantic on one side, *gradually*, and from the Pacific on the other, more *abruptly*. It is a region than which no other in the world presents a more striking contrast of far-stretched plains, rising step by step into elevated table-lands, and crowned by mountain masses; so that no other has the same contrasts of climate, or so abundant an irrigation, or such interminable varieties of vegetation or forms of animal life.

To this law of the gradual *elevation* of continental masses towards their centres, Europe—comparatively a small continent—appears to present an exception. Her two great mountain systems are placed on her northern and southern *boundaries*. That on her southern limit includes the Pyrenees, the mountains of southern France, the Alps, the Carpathians, and the Balkan. The northern system is that of Scandinavia. Within these mountain-systems central Europe extends in one vast plain, occupying nearly two-thirds of its surface, increasing its width towards its eastern boundary, and reaching to the Frozen Sea, the Ural Mountains, and the Caucasus.

Now, why does this distribution of the elevated regions of the small continent of Europe differ so essentially from that of the other great continents? *This*, at any rate, we may see, that by reason of the small extent of its surface, the same provision for the divergence of ample streams from its central regions towards its shores is not required; and that its mountain-groups are so placed by Him, who "understandeth the spreadings of the clouds, and can number them in his wisdom" (Job xxxvi. 29, xxxviii. 37), as to *water* it every where abundantly; moreover that it owes largely to the peculiar features of their distribution that *mildness* of climate which *is its great characteristic*, and, in respect to its position on the earth's surface, an *anomaly*. Were its mountain-districts placed in its centre, like those of the greater continents, instead of under the mild influence of its shores;* or were its central regions lifted into table-lands, as are those of the corresponding latitudes of Asia; a temperature would reign there like that under which vegetation perishes in equal latitudes of Tartary, or the desert of Gobi, or on the more southern plateau of Thibet, or of the Tartaric region of Himalaya.

Such are the high places and the mountain-regions of the earth; and such evidence have we that "the Lord possessed *wisdom* in the beginning, before the *mountains* were brought forth, or ever he had formed the earth;" that in very deed "he hath weighed them in scales, and the hills in a balance;" that "in his hand are all the corners of the earth, and the strength of the hills is his also;" and that "by his *knowledge* the depths are broken up, and the clouds drop dew," and "the land drinks water of the rain of heaven."

* The great southern mountain-system of Europe receives the warm southern currents of the *upper* air; and its *base* is washed by the waters of the Mediterranean, whose temperature is 3° or 4° above that of the Atlantic.

THE TROPICAL RAINS.

"Let us now fear the Lord our God that giveth RAIN, both the former and the latter, in his season: he reserveth unto us the appointed weeks of the harvest."—*Jeremiah* v. 24.

IF, by any powerful rarefaction, a mass of air were *rapidly* carried up from any point in the earth's surface to a *great elevation* in the atmosphere immediately above that point, that elevation, being accompanied by the requisite degree of cold, would immediately cause the condensation of vapour and the abundant formation of clouds, and, possibly, the plentiful descent of rain. This is precisely that which occurs continually over that region which is at any instant the region of *direct sunlight*—the region where the sun's rays are at any instant falling *perpendicularly*, and which coincides with the *bright* spot on the artificer's globe. The earth, heated under that burning radiation, so elevates the temperature of the incumbent air, that, replenished by the surrounding medium, it rushes up in a perpetual stream towards colder regions—deposits, as it ascends, cloudy vapour—spreading a veil between the earth and the sun—and at length attains a region so cold, that its moisture accumulates in drops, and it descends under the form of a continual rain.

That surely is a most beautiful provision of the goodness of God, by which it is so ordered that over the spot where the direct rays of the sun would otherwise fall with an unendurable heat, there should always be spread a covering of vapour, and that this spot should always be drenched in rain.

A perpetual shower traverses the torrid zone, deluging, in succession, every region of it; accompanying the point of direct sunlight, and thus completing its journey with the year.

Although the *most abundant* descent of the rain thus takes place at that time of the year when the direct sunlight is actually traversing any spot, yet do the rains *begin* to descend long before that time. The column of descending rain is of considerable width, and spreads over a large area; and although the flood of waters descends most abundantly in its *centre,* yet are there plentiful showers round its circumference, and upon its skirts; and these descend upon regions far remote from the spot where the sun is vertical. Thus, when the point of direct sunlight is traversing either tropic—that is, when the sun is said to be *in* that tropic—the column of descending rain covers an area extending far beyond that tropic, and *there* too are felt the tropical rains.

Twice in the year the point of direct sunlight, and its accompanying deluge of rain thus passes over every point within the tropics; once when it is approaching the nearest tropic, and once when it is receding from it. Thus, every year there would be every where within the tropics *two* rainy seasons, were it not that by reason of the great dimensions of the column it appears never wholly to desert a belt of the earth extending four or five degrees on either side of the equator; throughout this region there are said to be few days in the year without rain. Beyond it from the lat. 5° to the nearest tropic, extends a region which is every year wholly deserted by the column of rain, as it passes to the more distant tropic; here then the wet and dry seasons are distinctly marked. From the fifth to the tenth parallel is a belt which the sun passes over with remarkable rapidity, going and returning from the tropic, and bringing with it two seasons of *excessive* rain. Beyond this belt the sun *lingers* over the region immediately about the tropic, and the rain of the rainy season is there continuous.

It is a great mistake, however, to suppose that these rains continue at any place *incessantly*. The rotation of the earth sweeps a belt of its surface underneath the column of rain every twenty-four hours; but it is only during a certain *portion* of the twenty-four hours that any place in that belt can actually be passing through the column. This period is immediately about the time of noon at each place; that place *then* passing nearest to the point of direct sunlight, and to the centre of the column. "A day in which the rains fall without interruption from morning to evening, is of much rarer occurrence between the tropics than with us: the sun usually *rises* in a cloudless sky; two hours before noon the clouds begin to appear; and at noon the rains set in. They then frequently pour down in torrents for four or five hours; but towards sunset they cease, the clouds suddenly disappear, and not a drop of rain descends during the night."

The point (or rather the *ray*) of *direct* sunlight has been spoken of as the centre of the column of descending rain. This is not, however, strictly the case. The cause of the tropical rains has been explained to be, in the first place, the extraordinary heating of the earth's surface under the direct rays of the sun; and, secondly, the heating of the immediately incumbent air by contact with it; which air, rising rapidly to *higher* and colder regions of the atmosphere, becomes condensed, and gives out its vapours. Now this heat of any point of the earth's surface is *not* greatest *at the instant* when the direct ray is in the act of passing over it, or at *the* time when it is *receiving its greatest heat.* It *continues* to receive *more* heat than it *radiates*, and therefore to *accumulate heat* for some time after the direct ray has passed; so that the greatest heat, as we know by experience, is no where attained until noon has for some time *passed.* The greatest heating of the earth's surface is thus not immediately under the *direct* ray; and the greatest rarefaction of the air, and point of the most abundant production of rain—that is, the centre of the *column* of rain—are, for the same reason, not under the direct ray, but some distance behind it. It is thus explained why the rain of every day of the rainy season does not *commence* until noon, or terminate until some hours afterwards.

The following is the description given by Humboldt of the phenomena which attend the approach of the greater rainy season, as observed by him in South America in latitude from 4° to 10°:—

" Nothing can surpass the clearness of the atmosphere from the month of December to that of January (when the point of direct sunlight is at its greatest distance). The sky is then constantly without clouds; and if one should appear, it is sufficient to excite the whole attention of the inhabitants. The breeze from the east and the east-north-east blows with violence. The immense plains (called *llanos*), which in the rainy season display a beautiful verdure, gradually assume the aspect of a desert; the grass is reduced to powder, and the earth cracks; and the alligator and the large serpents remain buried in the mud till the first showers of the year awaken them from their lethargy. About the end of February, and the beginning of March, the blue of the sky becomes less intense; the hygrometer indicates greater humidity; and the stars, veiled at times by a slight vapour, lose the steady and planetary light which before distinguished them.

"The breeze at this period becomes less strong and regular, and is often interrupted by dead calms. The clouds accumulate towards the south-south-east, appearing like distant mountains, with strongly marked outlines; and from time to time they detach themselves from the horizon, and traverse the vault of the sky with a rapidity that little corresponds with the feebleness of the winds below. At the end of March the southern region of the atmosphere is illuminated by gleams of lightning (the point of direct sunlight is now rapidly approaching); and the breeze then passes frequently, and for several hours together, to the west and south-west. This is a certain sign of the approach of the rainy season, which begins at Oroonoko about the end of April: the sky becomes obscured, the azure disappears, and a gray tint is spread uniformly over it; at the same time the heat progressively increases; and soon dense vapours cover the heavens from one end to the other. The plaintive cry of the howling monkeys begins to be heard before the rising sun. The atmosphere is at length convulsed by frequent thunder-storms; the rains descend in torrents; and the rivers, rising rapidly above their banks, overspread the plains with extensive inundations."*

The rainy season of these regions is their season of greatest heat; and it is this union of heat and moisture which is the secret of the marvellous luxuriance and abundance of their vegetation.

When a small depression of the temperature of the air causes it to deposit moisture (or brings it to the dew-point), it is said to be nearly saturated with moisture, and is *humid*. When, on the contrary, it bears a great depression of temperature without depositing moisture, it is *wanting in it*, and has a tendency to take it up wherever it is found—it is then parching and dry, and, as it were, *thirsty*.

The observations of Humboldt show that the vapour of the atmosphere between the tropics approaches much more nearly to the point of saturation than that in the temperature zone.† And we may thus under-

* This extract is made from the Treatise on Physical Geography, published by the Society for the Diffusion of Useful Knowledge, p. 41.

† As we ascend higher into the atmosphere there is a marked diminution in the humidity. This is said to be the cause of that beautiful deep blue colour of the sky which strikes us when we look at it from high mountain-summits. It is thus, too, explained why clouds rarely form round the tops of *very*

stand why it is, that in *this*, our region of the earth, which is emphatically the region of *clouds*, and where the fall of rain is distributed much more continually over the year, the annual quantity which falls is greatly less than within the tropics. * In the island of St. Domingo, there falls on an average a quantity of rain which would, if all collected together, be sufficient to cover the surface of the ground 120 inches thick; in Calcutta, 70 inches; in Rome, 36; in London, 23; at St. Petersburg, 16.

high mountains, but on their sides. Fleecy clouds are, nevertheless, sometimes seen floating on the tops of the Andes, at an elevation of 25,000 feet.

THE TEMPERATURE OF THE SOIL.

"O ye Fire and Heat bless ye the Lord: praise him and magnify him together."—*The Benedicite.*

It is not only by the properties in respect to heat of the ocean, or by those in respect to heat and vapour of the atmosphere, by marine currents, by the winds, by rains, and by the dew, that the processes of vegetation are influenced, and the geographical distribution of plants modified; another vivifying element not less important in its agency is *the native temperature of the soil.*

There is a heat proper to the mass of the earth, increasing from a short distance beneath its surface downwards at the rate of about one degree of Fahrenheit's thermometer for every fifteen yards. This central heat becomes sensible in excavations reaching anywhere beyond a certain depth, and in deep mines it is oppressive.

It is a constant heat. It does not by the slightest appreciable quantity vary from year to year, or season to season. Observations were made in 1671, by Cassini, on the temperature of the air in certain closed cellars beneath the Observatory of Paris; they were repeated in 1730 by La Hire, and during the last forty-five years thermometrical apparatus of great sensibility have been fixed in these cellars and constantly observed; the temperature thus observed through a period of 175 years has never varied by more than one quarter of a degree from 11°·82 of the centigrade thermometer, or 53°·37 of the thermometer of Fahrenheit.

There is, however, a temperature proper to the surface soil which is influenced at once by this constant subterranean heat and by the superficial absorption, and the radiation of the solar heat. This is a variable temperature. It extends in different localities to different depths, varying from 40 to 60 or 80 feet on the continent of Europe, but being bound in tropical regions at the depth of a single foot. If a surface be imagined to pass through all those points beneath the earth's surface, to which the surface heat is propagated, and to which, therefore, a variable temperature extends, it will be that called "*the surface of invariable temperature.*"

Theory and experiment agree in indicating the temperature of any point in this surface of invariable temperature to be the mean temperature of that point in the earth's surface which is immediately above it.*

It is not a regular or an even surface, but one having elevations and depressions dependent partly upon corresponding elevations and depressions of the earth's surface, and partly upon irregularities in the strata which constitute the earth's crust. Whilst beneath this surface there reigns an invariable temperature, a constant change is taking place above it, and that of a very remarkable kind.

* Thus the mean temperature of Paris is 10°·6 of the centigrade thermometer, which differs but one degree from the invariable temperature of the cellars under the Observatory. (See *ante.*)

From experiments made at Edinburgh, Zurich, and Strasburg, it appears that, during the winter months, January, February, and March, the temperature increases uniformly as we descend from the earth's surface to the surface of invariable temperature ;—that in the months of April and May there comes, with the spring, a sudden and remarkable elevation of the temperature*, extending to a depth of about two feet into the soil, but continually diminishing to that depth ; whilst beneath it, the earth retains the temperature of the two preceding months, continually increasing as we further descend, so that there is a depth (and a surface) of minimum temperature, situated between the surface of the earth and the surface of invariable temperature.

As the year advances, this surface of minimum temperature sinks continually deeper and deeper, until, in the month of August, it reaches the surface of invariable temperature and indentifies itself with it. In this month, however, the mean temperature at the surface has begun to diminish, and beneath the surface it is reduced, at different depths, more nearly to a state of uniformity, which state it actually attains in September, to the depth of 10 or 20 feet. It is in the month of October and November that this uniformity changes into an increasing temperature. And the

* In the experiments of Mr. Fergusson at Edinburgh, in 1817, the temperature at a depth of one foot, whose mean in February, was 37°·04, became in March 39°·4, and April 62°·96. No variation of the temperature of the surface soil comparable to this, as to its amount, and the shortness of the time in which it is brought about, occurs at any other season of the year.

temperature, which in the preceding months had increased from the depth of 15 or 20 feet to the surface of invariable temperature, now becomes throughout that space uniform.

Although the temperatures of the atmosphere and the soil are dependent for their variations on the same causes, yet in their amounts they are essentially different. During the day the temperature of the soil is much higher than that of the air*. At night it is sometimes from 14° to 18° below it. The relations by which these changes in the temperature of the soil are connected with atmospheric causes and the solar radiation, it is not easy to trace;—who can, however, doubt that when, in the months of March and April, the temperature of the soil so suddenly and so rapidly ascends, it is to meet the first efforts of vegetation—the bursting of the germ and the putting forth of the bud and blossom!

The black colour of the earth, favourable as it is to the absorption of heat, is one of the causes which contribute to give to the soil a temperature higher than that of the air above it; were some limit not indeed placed to the operation of this cause, the moisture of the soil might everywhere be transferred to the atmosphere. That limit is found in the fact, that, although black be the colour most favourable to the *absorption* of heat, it is also that most favourable to its radiation; and since, during the whole day, whilst the earth is in the act of receiving heat from the sun, it is also in the

* At Paris, the temperature of the soil is not unfrequently 112° F.; and, in the summer of 1824, it attained 149° F.

act of radiating it, in some degree unknown to us, into space, and since this process of radiation is going on also all night, it follows that the radiating properties of a body may have a greater influence to keep down its temperature than its absorbing properties have to raise it; and thus we may understand why vegetable mould which is commonly the darkest, is at the same time the most humid; and why the gardener whitewashes the wall against which his fruit-trees are nailed; not that reflecting the heat, it may be cooled, but that, radiating it ill, it may remain hot,—why regions of sand are parched with heat, and why the Almighty, in his wisdom and goodness, has given to the animals of cold regions a white covering, and one of a darker colour to those within the tropics; man himself being, in this respect, a memorable example.

Thus, too, that is obviously no visionary analogy which the covering of animals presents in arctic regions, to the covering of the earth's surface; in winter a white mantle of snow is thrown down upon it, and bodies of animals are enveloped in thick white furs. When summer comes, under the form of a single day, of from five to six months' duration, and the clothing of animals is made thinner and lighter, its colour also is changed, and the covering of snow is withdrawn from the earth.

"For are we not all His, without whose care
Vouchsafed, no sparrow falleth to the ground?
Who gives his Angels wings to speed through air,
And rolls the planets through the blue profound."

Wordsworth.

O eternal God, thy holiness and power, and excellent greatness are far above the praises of men and angels, and yet thou art pleased in the harmony and consent of a thankful heart, and a thanksgiving tongue. Touch our hearts with admirable apprehensions of thy divine perfections, that our songs of thy honour may be devout, and illuminate to the height of ecstasies, and the devotions of a seraphim; for nothing is proportionate to thy glories, but what is infinitely beyond our infirmities. Make us to sing thee and thy name while we have breath; and when we are breathless, let our hearts fill up the harmony, and think thy praises so cordially, till our souls being separated from the harsh sound of our bodily organs, we may praise thee when we are all spirit, in the state of separation, and in the re-union, when our bodies shall be made spiritual; singing to thee exalted praises for ever.

To thee, O blessed and glorious God, be praises and honour and glory ascribed, now and to all eternity. Amen, amen.

Bishop Jeremy Taylor.

A Varnham, 61, Strand.