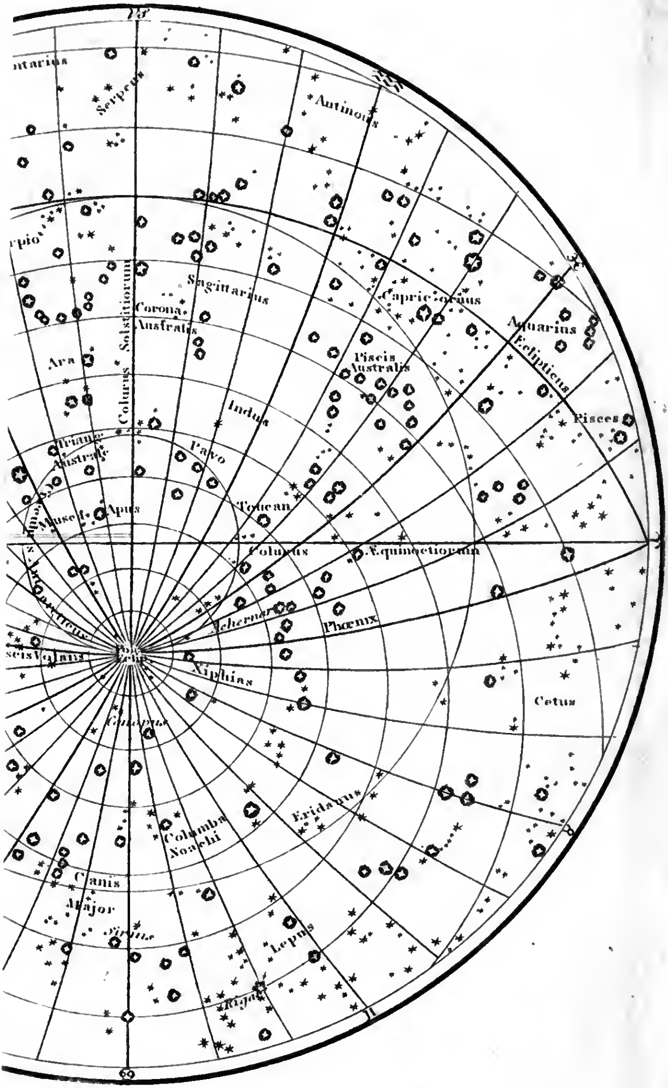
Edm. John Senkler
Caius Coll.
Camb—

E * I * Senkler

:RN CELESTIAL HEMISPHERE.



LESSONS,

ASTRONOMICAL AND PHILOSOPHICAL,

FOR THE

AMUSEMENT AND INSTRUCTION

OF

British Youth:

BEING

AN ATTEMPT TO EXPLAIN AND ACCOUNT FOR

THE MOST

USUAL APPEARANCES IN NATURE

IN A FAMILIAR MANNER,

FROM ESTABLISHED PRINCIPLES.

The Whole interspersed with

MORAL REFLECTIONS.

BY OLINTHUS GREGORY, LL.D.

OF THE ROYAL MILITARY ACADEMY, WOOLWICH.

————The glittering stars,
By the deep ear of Meditation heard,
Still in their midnight watches sing of HIM.
He nods a calm; the tempests blow His wrath;
The thunder is His voice; and the red flash
His speedy sword of justice. At His touch
The mountains flame. He shakes the solid earth,
And rocks the nations. Nor in these alone,
In *every common instance* GOD is seen. THOMSON.

THE FIFTH EDITION,

MUCH ENLARGED AND IMPROVED.

LONDON:

PRINTED FOR JOSIAH CONDER, 18, ST. PAUL'S CHURCH-YARD LONGMAN, HURST, REES, ORME, AND BROWN, PATERNOSTER ROW; DARTON, HARVEY, AND DARTON, GRACECHURCH STREET; SHERWOOD, NEELY, AND JONES, PATERNOSTER ROW; AND LAW AND WHITAKER, AVE MARIA LANE.

1815.

Ellerton and Henderson, Printers,
Johnson's Court, London.

TO THE

RIGHT HON. JOHN JOSHUA PROBY,

EARL CARYSFORT,

EVER ZEALOUS IN THE PROMOTION AND ENCOURAGEMENT
OF GOOD WORKS;

UNDER WHOSE PATRONAGE

THE FORMER EDITIONS OF THIS PERFORMANCE

MET WITH

SO FAVOURABLE A RECEPTION;

THE PRESENT IMPROVED EDITION

IS RESPECTFULLY DEDICATED

BY

HIS LORDSHIP'S

MOST OBEDIENT, AND MOST OBLIGED,

HUMBLE SERVANT,

OLINTHUS GREGORY.

PREFACE.

IT has been for a considerable time allowed by the majority of intelligent persons, that amongst a variety of studies there are none of greater utility, or that afford more real pleasure to a rational mind, than those on Philosophical Subjects. On mature deliberation it may be concluded, that this does not so much arise from any intrinsic value of *Natural Philosophy*, solely considered; as from the peculiar use to which it may be applied, and without which it hardly merits the name it has obtained: and this is no other, than regulating by it our observations upon the numerous objects of the creation, whereby we may correct any erroneous notions which we may have hitherto encouraged, either concerning them, or the

OMNIPOTENT BEING by whose *Will* they were formed.

When it is considered how liable all our senses are to deception, and what wrong ideas are generally formed of the different parts of the universe from mere cursory observation, the absolute necessity of the dissemination of true philosophical principles will the more obviously appear. And if the rudeness and imbecility of the human mind in an uncultivated state of nature be taken into the consideration, it will be the more readily admitted, that every attempt to extend the sphere of human knowledge is laudable in its nature; and, if it be found to answer the intention, is deserving of encouragement.

Being duly impressed with the force of these reflections, and also recollecting that it is the indispensable duty of every member of society, to render himself as serviceable to his fellow-creatures as his abilities will allow, I was induced to apply my leisure hours to the execution of a performance which might in some measure tend to the

instruction

instruction of the *Youth of Great Britain*. And as my principal design was to lay before them some pages of the Volume of Nature, I judged that if this could be performed in such a manner as to be also a source of amusement, it would probably meet with a more welcome reception, and consequently have the better effect.

I have likewise been cautious in checking any inclination to scepticism during the study of Natural Philosophy: and in guarding against a mischievous misapplication of the word *Nature*. I uniformly wish this word to be considered as an abridged form of expressing, sometimes the results of the laws to which the mechanism of the universe is subjected by the Supreme Being; sometimes the collection of beings created by him. Nature viewed thus, in its true light, is no longer a subject of cold unproductive speculation, with regard to morality. The study of its productions and its phænomena not only enlightens the mind, but *warms the heart*, by exciting feelings of reverence and admiration, at the sight of so many wonders,

bearing

bearing such striking characters of unlimited power and matchless wisdom.

Pursuant to these ideas I have divided the following work into easy lessons of various lengths, as the nature of the respective subjects would admit; and have interspersed them with moral reflections, in prose and verse, in order to alleviate the mind of the student, and to lead him, by imperceptible degrees, to reflect seriously on the several objects around him. To the honour of our British Poets, it must be acknowledged, I was seldom at a loss for an Extract suitable to my purpose; and if my acquaintance with their works had been more extensive, I believe there would have been no occasion for those two or three little original pieces, which make so dim an appearance in such brilliant company.

These Lessons may with propriety be introduced into Schools to be read before the master in greater or less proportions, as may be thought most proper: in which case they will answer a double purpose,—improving the Pupil in the Art of Reading, while they enlarge

enlarge the bounds of his understanding. That they might be as much as possibly subservient to the former, without raising an impediment in the way of the latter, reflections, attendant on the several subjects, are the more frequently introduced.

To some persons it may perhaps appear necessary, that I should have given an explanation of all the technical terms which are found in the following pages: for instance, such as *centre*, or *center*, *diaphanous*, *equinox*, *focus*, *glands*, *lacteal*, *peristaltic*, &c. Here I would observe, that I have not neglected such explanation where it could be given without leading me too circuitous a course; and even where it is otherwise, the omission will not afford an objection of great weight; for there is scarcely a dictionary in which the requisite information may not be met with. Perhaps in schools this may be productive of some advantage, as it may lead to inquiry; but that this may have the better effect, it may be remarked, that the preceptor does not properly acquit himself in his duty towards

his

his pupils, who does not indulge them in the liberty of asking every question, the solution of which may have a tendency to increase their fund of learning. Masters, by acting thus, would undoubtedly be able to judge in what respects their scholars were most deficient; and could, of course, supply those deficiencies from their own knowledge, or from those helps which it may naturally be supposed they have at hand.

In the composition of these Lessons, I have not scrupled to make a free use of the Works of several of the most esteemed Authors on Astronomy and Philosophy; and if I have not always acknowledged where the obligation lay, I may observe that such alterations were made, or the extracts taken in so detached a manner, as rendered it nearly, if not absolutely, impossible. When we remember that the improvements in these sciences were gradual and not effected by one man, or by one age; it must be allowed that every production (except those which boast of new inventions and discoveries) must be principally a compilation; and the chief

merit

merit to which the person who undertakes it can aspire, is that of arranging the materials before him in a manner more suitable to his purpose, and making such reflections as may be best adapted to the subject.

I am conscious, that in the present undertaking many imperfections will be met with: however, such as it is, I present it with cheerfulness to the public view; and if it meet with a favourable reception from the candid and ingenuous, I shall have but little to fear from the severe critic. Literary fame I want not to acquire: zeal for the welfare of the British Youth was the only motive which urged me to this performance; and if it prove to be of service to them, I shall think myself amply rewarded. As to the numerous defects, I must sue for indulgence by observing, that I am yet but a young man; and am willing to hope that if health and leisure should permit, I may at some future period produce something more worthy of public favour. Yet, as I am desirous to make this Work as correct and useful as possible, I cannot but add, that those who will be so

obliging

obliging as to furnish me with hints for its improvement, will confer a lasting obligation upon me, and shall receive my grateful acknowledgments.

O. G. GREGORY.

Yaxley,
May 20th 1793.

ADVER-

ADVERTISEMENT.

GRATITUDE for the favourable reception which the first Edition of these LESSONS *has experienced, has induced the Author to give them a careful revisal, in order that this New Edition may be found less unworthy of public favour. In this revisal, he has been assisted by the polite suggestions of some of the Reviewers, (for whose testimonials in favour of his performance he feels peculiarly obliged), and by many useful hints which have been communicated to him in letters from several of his literary friends; to whom he cannot but acknowledge his obligations, and whose names would reflect honour upon his work, if he were permitted to mention them. He is in a particular manner indebted to a Nobleman of distinguished worth and abilities, for condescending to point out several alterations and emendations; all of which were of so much importance, that his Lordship will find they have been universally attended to. The Author has taken care to incorporate into this Edition, all those improvements and discoveries that have been made since the first Edition was published, and that appeared to have any connection with the subjects on*

which

which he has treated. Besides the numerous alterations which are to be met with in almost every Lesson, he has added three New Lessons,—one on Electricity, *one on* Fountains *or* Springs, *and one on* Plants *and* Vegetation. *He humbly hopes that these corrections and additions will ensure to him a continuation of that encouragement with which he has been already honoured by an indulgent Public.*

Cambridge,
May 20th, 1799.

Should any, who possess extensive philosophical knowledge, honour this work with a perusal, they will perceive that it is a juvenile production; being, indeed, written originally before the author was 20 years of age: but, as its success has shewn its fitness for juvenile minds, the Author should not think himself justifiable in making any alterations in the plan; but simply thinks himself bound to correct it as much as possible, and to supply omissions by notes of reference, while the plan remains the same. The principal additions and changes in the fourth edition, were in the 15*th*, 20*th*, 24*th*, 28*th*, 29*th*, *and* 38*th Lessons. Several minor corrections are made in the fith edition.*

Royal Military Academy,
Aug. 20th, 1815.

CONTENTS.

LESSON I.

INTRODUCTION.

——— Every object of Creation
Can furnish hints to contemplation. GAY.

AS you, my dear young friends, have now arrived at a period of life, in which the mental faculties are rapidly expanding and increasing in vigour, you will perceive an inquisitive curiosity, which has long remained dormant in your minds, hastily bursting forth: it will be of the utmost importance to your happiness, both present and future, that you be careful in directing this active principle into its proper course.

Ever since you have been able to exercise the power of reasoning, you cannot but have observed, with wonder and admiration, the sun shining with astonishing splendour, dispensing light and heat around;—the moon, with majesty serene, gliding along the arched heavens, scattering her gentle rays, in the absence of the glittering luminary of day;—and the spacious canopy bespangled with numerous stars, like twinkling flames, adding to the beauty of the scene. You must have observed, with awful astonishment, the forked lightning in vivid motion glancing through the wide expanse; and have heard, with fear and anxiety, the tremendous thunder, shaking the firmest buildings with its pealing crash. When you reflect upon these and other appearances in nature, what impressions do you feel? You who have considered these things attentively will ingeniously confess, that you are thereby led to conceive that there must be some *First Cause* which produced, governs, and regulates the whole. The most cursory observation will have induced you to entertain a high opinion of the wisdom, power, and goodness of the ALMIGHTY DESIGNER; but I can assure you, my young friends, that the more you reflect upon the universe, in the display of its wonders and beauties, and the better you are acquainted with it, so much the more will be increased your reverence and love of the *Governor of all.*

> Nature is but a name for an effect
> Whose cause is God. COWPER.

Natural Philosophy is subservient to purposes of a high and noble kind, and is chiefly to be valued, as it lays a sure foundation for natural religion and moral philosophy; by leading us, in a satisfactory manner, to the knowledge of the Author and Governor of the universe. To study nature is to search into his workmanship: every new discovery opens to us a new part of his scheme. And while we still meet, in our inquiries, with hints of greater things yet undiscovered, the mind

is

is kept in a pleasing expectation of making a further progress; acquiring, at the same time, higher conceptions of that great Being, whose works are so various, and hard to be comprehended.

It is a melancholy consideration, that too many young persons, instead of being zealous of acquiring real and useful knowledge, suffer a kind of torpor to dwell upon their minds, and give way to such supineness as may, if they be not quickly roused from their lethargy, be attended with fatal consequences. If any such persons should peruse these Lessons, let me exhort them to shake off their carelessness, and endeavour to furnish their minds, ere it be too late, with a true knowledge of the works and wonders of the creation: let them be assured that such conduct will produce the happiest effects; for philosophical contemplations will form the safest bulwark against the insidious attacks of Atheists: because the principal intention of such inquiries is, from a consideration of the effects produced, to correct our ideas with respect to the Great First Cause; or, as the poet has expressed it,

To look through Nature up to NATURE'S GOD. POPE.

In these Lessons it shall therefore be my province to explain to you, in a concise and familiar manner, some of the wonders of the universe: I will first lead you to take a survey of the heavenly bodies; and afterwards consider some of those objects and some of those appearances of nature which relate to the earth we inhabit: thus shall we

——— See through this vast extended theatre
Of skill divine, what shining marks appear!
Creating power is all around exprest,
The God discover'd, and his care confest:
Nature's high birth her heav'nly beauties shew:
By every feature we the parent know.
Th' expanded spheres, amazing to the sight,
Magnificent with stars, and globes of light;
The glorious orbs which heav'n's bright host compose;
Th' imprison'd sea, resistless ebbs and flows;
The fluctuating fields of liquid air,
With all the curious meteors hov'ring there,
And the wide regions of the land proclaim,
The POW'R DIVINE that rais'd the mighty frame.

BLACKMORE.

LESSON

LESSON II.

VIEW OF THE HEAVENS.

Heaven
Is as the book of GOD before thee set
Wherein to read his wond'rous works. MILTON.

The heav'ns declare the glory of GOD. DAVID.

AGREEABLY to my plan, I shall now endeavour, in the first place, to describe to you the nature, size, and motion of the principal heavenly bodies; the beauty and variety of which have no doubt often filled you with astonishment: following the advice of Ovid,

" We, though from heaven remote, to heaven will move
" With strength of mind, and tread th' abyss above;
" And penetrate with an interior light,
" Those upper depths which nature hid from sight.
" Pleas'd we will be to walk along the sphere
" Of shining stars, and travel through the year."

The science which teaches the knowledge of the celestial bodies, their magnitudes, motions, distances, periods, eclipses, order, &c. is called ASTRONOMY: the study of this has been pursued with avidity in all ages, and it is now arrived at a tolerable degree of accuracy. The hypotheses which have been invented by astronomers, at different times and in different countries, are numerous, and the greater part of them are too futile in their nature to deserve a particular account: the only one which agrees with all the phænomena is that which was first invented by *Pythagoras* (who was born 577 years before Christ), and taught in Greece and Italy; but this was soon buried in oblivion, and was set aside from the time of Ptolemy, until it was restored about the year 1507, by *Nicholas Copernicus*. The discoveries of Kepler and Galileo tended greatly to prove its truth; but it was much opposed, until at length the indefatigable researches of Sir ISAAC NEWTON fixed it upon too firm a basis to be easily overthrown. It is now generally adopted by Astronomers, and is, with a few modifications, now called the *Newtonian System;* an account of which I shall here proceed to lay before you.

When we take a view of the heavenly bodies, our attention is first attracted by the *sun* and *moon*, which are distinctively named *luminaries:* the other beautiful spangles in the glorious canopy are called *stars;* and of these a distinction is made into *planets* or *wandering stars*, and *fixed stars*. The planets, of which the earth we inhabit is one, move in regular and uninterrupted order around the sun; some of these planets have attendants, usually called *satellites*, moving around them. Sometimes there are other stars seen, with blazing tails issuing from them: these pursue very eccentric irregular courses, and are called *comets*. The planets* them-

* Correctly speaking, the Satellites are Planets, as well as those round which they revolve: for *planet* is a Greek word,

themselves are frequently called *primaries*, and their satellites *secondaries*. There are two methods of discovering which are planets, and which are fixed stars: every fixed star *twinkles*, but a planet does not; for the stars are to appearance only lucid points, and therefore any opaque particle floating in the air is sufficient to cause a momentary eclipse of them †; but the planets, though smaller, suffer very little apparent diminution. The proper criterion, however, is this: the planets are always in motion from one part of the heavens to the other, whereas the other stars keep constantly the same relative distance.

The names of the planets, beginning with that nearest the sun, are as follow: *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, *Saturn*, and *Georgium Sidus*, or *Herschel*. These are all that are yet discovered, though there very probably may be

signifying any thing that wanders. Agreeably to this acceptation, the Sun itself is a Planet; as it, like the others, has a two-fold motion. And indeed, to complete the similarity, Dr. Herschel has (in a paper which will be presently more largely spoken of) asserted, that his body is opaque, and that it is diversified with hills and valleys.

† Although the above is the generally adopted method of explaining the twinkling of the fixed stars, yet it is now thought to be inaccurate. Mr. *Michell* justly observes (in the "Philosophical Transactions,") that no object can hide a star from us, that is not large enough to exceed the apparent diameter of the star, by the diameter of the pupil of the eye; nay, it must be large enough to hide the star from both eyes at the same time.

Perhaps the principal cause of this twinkling, is the unequal refraction of light, in consequence of inequalities and undulations in the atmosphere.

 more:

more*: after describing to you the sun, I shall proceed to the rest in their order.

* Since the commencement of the present century, *four* other Planets have been discovered.

The first of these was discovered on the 1st of January, 1801, by M. Piazzi, of Palermo: its mean distance from the sun is not quite three times that of the earth (2.768): its revolution is performed in four years, seven months, and ten days; and its orbit is inclined to the ecliptic in an angle of about 10½ degrees. This planet is much less in size than our moon: its discoverer has given it the name of *Ceres*, but most astronomers call it by the name of *Piazzi*.

The second was discovered on the 20th of March 1802, by Dr. Olbers, of Bremen. Its distance from the sun, time of revolution, and magnitude, are nearly the same as Piazzi's planet; and the orbits of the two intersect each other; the latter being inclined to the ecliptic in an angle of about 34½ degrees. It is called by the names *Pallas*, and *Olbers*.

The third was discovered on the 1st of September 1804, by M. Harding, of Lilienthal. Its mean distance from the sun is rather greater than that of the two former; and its size nearly equal to that of Ceres. Its inclination is 13 degrees. It appears like a star of the eighth magnitude. Harding has given to this planet the name of *Juno*.

The fourth was discovered by Dr. Olbers, early in 1807. It is nearer to Mars than either of the other newly discovered planets, its mean distance being rather more than 2⅓ times that of the earth; and the revolution through its orbit is performed in 1136 of our days. The inclination of that orbit to the ecliptic is 7 and 1-7th degrees, being rather more than that of Mercury. The size of this planet is not known. Astronomers have given it the name of *Vesta*.

LESSON

LESSON III.

ON THE SUN.

——Hail sacred source of inexhausted light!
Prodigious instance of creating might!
His distance man's imagination foils;
Numbers will scarce avail to count the miles.
His globous body how immensely great!
How fierce his burnings! how intense his heat!
As swift as thought he darts his radiance round
To distant worlds his system's utmost bound:
Of all the planets the directing soul,
That heightens and invigorates the whole. BROWN.

OFTEN as you have beheld the mid-day sun shining in all his grandeur, disseminating his refulgent beams around; and often as you have felt the efficacy of his all-genial heat, you may never have entertained an idea of his vast size. When you are informed of the dimensions of this grand dispenser of light and heat, and when you come to be acquainted with some of the laws by which he is governed, you will consider it as one of the many irrefragable proofs, that the universe could not (as atheists assert) be jumbled together by chance; but that the whole must have been formed by an all-wise, all-powerful, and adorable Creator!

The sun is a body very nearly in the form of that solid which is by mathematicians called a sphere or globe, and the observations of astronomers have proved beyond a doubt, that its axis is nearly 883,210 miles, its circumference 2,774,692 miles, and its solidity in cubic miles 360,737,732, 256,524,299: viz. three hundred and sixty thousand seven hundred and thirty-seven billions, seven hundred and thirty-two thousand two hundred and fifty-six millions, five hundred and twenty-four thousand two hundred and ninety-nine; a number almost surpassing the powers of imagination!

From a cursory observation you would perhaps be led to imagine that the sun moves round the earth once in twenty-four hours; but this is not the case. The sun has two motions: the one is a periodical motion, in an elliptical or very nearly a circular direction, round the common centre of all the planetary motions. As this common centre is found to be always exceedingly near the sun, and most commonly within it, I shall henceforward suppose this luminary to be the centre of the planetary system, for in such a supposition we shall not fall into any material error. The other motion is a revolution upon its axis, which is completed in about twenty-five days, as appears obviously by paying attention to the *maculæ* and *faculæ*, or spots upon his surface.

The sun was supposed, by many of the ancients, to be the clearest image of his Maker, "without "spot, or wrinkle, or any such thing." To such a degree had this prejudice arisen, that when *Galileo* discovered several dark spots on the surface of

the

the sun, and mentioned his discovery to another philosopher, he was told that the thing was utterly impossible, and that there must be some defect either in his glasses or his eyes: it was added also, as another proof of the assertor's candour and penetration, that as such a circumstance was not noticed by Aristotle, the pretended discovery could be nothing less than presumption or deception. However, that there are spots on the sun, has since been indisputably confirmed, and is now universally admitted. Of these spots, the dark ones are called *maculæ*, to distinguish them from the others, which are of a brighter appearance than the rest of the sun's surface, and which have obtained the name of *faculæ*.

Concerning the nature of these spots, there have been various opinions entertained by different persons. Some have supposed maculæ to be large portions of opaque matter moving up and down in the fiery fluid, of which the sun was thought to be composed or surrounded, revolving near its surface, and sometimes beyond it. Others have taken them for the smoke of volcanoes in the sun, or the scum floating upon a huge ocean of fluid matter. Faculæ, on the contrary, have been called clouds of light, and luminous vapours; and, because maculæ have been sometimes observed to change into faculæ, it has been conjectured, that the latter were the bright flames of volcanoes rapidly blazing out, after the dark smoky matter, which produced the maculæ, became dissipated by combustion. These are the opinions that have been commonly held

held on the subject; but it does not appear to have been considered with much attention until very lately. The discoveries and observations of Dr. *Herschel*, have in a great measure supplied the defect, and afforded ample materials for forming a rational and plausible theory to explain and elucidate the appearances we are now treating upon.

This ingenious astronomer has assigned very forcible reasons for concluding, that the opinion commonly received, that the sun is a body of real fire, is futile and erroneous. He susposes, on the contrary, that it is an opaque body, surrounded by an atmosphere of a phosphoric nature, composed of various transparent and elastic fluids, by the decomposition of which, light is produced, and lucid appearances formed of different degrees and intensity. The doctor even goes so far as to assert, with much probability, that the sun is in reality an inhabitable world; but this assertion has no connection with our present inquiry, which we must confine, for the present, to maculæ and faculæ. Admitting, therefore, the preceding remarks, we will endeavour to deduce from them a satisfactory hypothesis to account for these appearances. The sun, it has been said, is an opaque body, surrounded by a lucid atmosphere: you will easily conceive, then, that maculæ are those parts of his surface which happen to be free from luminous decompositions, or, in other words, which are but slightly, if at all, covered by the shining matter, and are for that reason exposed to our view. In most cases the real body of the sun is supposed to be visible

through

through its transparent atmosphere, where the lucid substance is not very intense, or where it is removed by some temporary cause. As some of the spots appear below, and others above the surface of the shining fluid, it is reasonable to conclude that the former are the lower parts of the sun's surface, and the latter his mountains, which project beyond the lucid part of his atmosphere. The former are found to vary in their situation, as they may be hidden or rendered visible by any cause which will accumulate or remove the shining matter: the latter are fixed, with respect to the sun's surface, and are those, by observations on which the sun's rotation upon his axis has been determined. From what has been here said, it is hoped you are tolerably well acquainted with the nature of maculæ: we will now proceed to the consideration of faculæ.

Faculæ, on this hypothesis, are those parts of the solar atmosphere which are brighter, and in general more elevated than the rest. These Dr. *Herschel* supposes to be "more copious mixtures "of such fluids as decompose each other;" or they may be called, larger collections of the luminous fluids which form the solar atmosphere, according to the quantity, brightness, and depth of which, the faculæ differ in magnitude and intensity. They are more frequently observed near the borders, than towards the middle of the sun's disc, because, as they are supposed to extend beyond the usual level of his atmosphere those which are near the middle of the disc become edgewise to our view, and are therefore

fore not so easily discernible as those which approach nearer its circumference.

If the hypothesis concerning the nature of the sun, which is recited in this lesson, be admitted, it will readily be acknowledged that that luminary differs but little in his nature from the planets; and perhaps we may be allowed to call the sun, in a popular way, the *central planet*, or the *grand planet*, to which all the others are intimately united, and from which, as from a copious fountain, flows all that is necessary to support, connect, and harmonize the various planets in the system: hence we may advert to the beautiful and instructive observation of the poet, and say,

> The planets of each system represent
> Kind neighbours: mutual amity prevails;
> Sweet interchange of rays, received, return'd:
> Enlight'ning and enlighten'd! All at once
> Attracting and attracted! Patriot like,
> None sins against the welfare of the whole:
> But their reciprocal, unselfish aid,
> Affords an emblem of millennial love.
> Nothing in nature, much less *conscious* being,
> Was e'er created solely for *itself*:
> Thus man his sov'reign duty learns in this
> *Material* picture of *benevolence*. YOUNG.

LESSON IV.

ON MERCURY.

First Mercury amidst full tides of light,
Rolls next the Sun, through his small circle bright.
All that dwell there must be refin'd and pure;
Bodies like ours, such ardour can't endure;
Our earth would blaze beneath so fierce a ray,
And all its marble mountains waste away. BAKER.

HOWEVER ignorant we are of the nature of qualities, and how much soever their mode of operation is concealed from us, if it be but admitted that they act in right lines, and that they are propagated from a point, or body, as from a center, then it may be demonstrated in a strictly geometrical manner, that their energy, or intensity, diminishes in a duplicate proportion of the distance from that center. Thus, for instance, suppose a person whom I will call Thomas, stands at ten feet distance from a fire, and another, whom I will call James, stands twenty feet from the fire; if they are similarly situated in all respects but that of distance, it may be demonstrated, that the fire will impart four times as much heat to Thomas as to James; that is, Thomas's heat is to James's, as the square of James's distance from the fire is to the square of Thomas's distance from it.

Considering the sun as the center from whence proceed those rays, or particles, which meeting with

with proper substances, produce light and heat at the planets, and calculating by the theorem above mentioned, it has been concluded, that if the earth were placed in the situation of Mercury, its medium of heat would be seven times more intense than the greatest heat of our torrid zone is in its present situation. And hence it has been asserted, that if the materials of which Mercury is composed were exactly of the same nature as those of the earth, they could not long remain without being either melted into a fluid, and dissipated into vapour, or vitrified. Have we not then, in the formation of this planet, another proof of infinite wisdom? For, if the world were formed by chance, or, as atheistical writers express it, by the fortuitous concourse of atoms, whence comes it, that Mercury and the Earth should have the materials of which they are composed, so adjusted and arranged as to make them so well adapted for their respective situations, as we have abundant reason to conclude they are?

It will be necessary to premise, that, though the motions of the planets are tolerably uniform and regular, yet they are not exactly so: nor are their orbits, or the tracks in which they describe their periodical motions, strictly circular, but rather elliptical; their bodies are not globes, but spheriods, being flatted at the ends of their axes, which are called poles, and more protuberant at their middle parts or equators: their orbits are not all in the same plane, but are variously inclined to each other. However, as it is foreign from my design

to

to treat upon them in so particular a manner, I shall content myself with referring you to places where you may find abundant information in these respects. (See the books recommended towards the end of these Lessons.)

Those planets which move in orbits within that of the earth, are called *inferior*, perhaps more properly *interior* planets: those whose orbits enclose the earth's are called *superior*, or more properly *exterior* planets.

Mercury is the smallest of the inferior planets, and the nearest to the sun, about which he is carried with a very rapid motion. Hence it was, that this planet was considered mythologically as the messenger of the gods: he was represented emblematically by the figure of a youth with wings at his head and feet, and his caduceus entwined by winged serpents. The character ☿ in present use for this planet is also derived from the mythological description. Though small, he has a bright appearance, with a light tinct of blue: he never departs 28° from the sun, and on that account is usually hid in the splendour of that luminary.

The mean distance of *Mercury* from the sun, is to that of the earth from the sun, as 387 to 1000: hence his distance is about 37 millions of miles. The sun's diameter will appear at Mercury nearly three times as large as at the earth: and the sun's light and heat received there, is, as before observed, about seven times those at the earth.

The

The diameter of this planet is nearly one-third of the diameter of the earth, or about 3000 miles. Hence the surface of Mercury is nearly 1-9th, and his magnitude or bulk 1-27th of that of the earth.

His period of revolution round the sun is 87 days, 23 hours, and 1-4th: hence you may find that he moves in his orbit about the sun at the amazing rate of more than 95,000 miles in an hour. His length of day, or time of rotation on his axis, inclination of axis to his orbit, &c. are yet unknown.

Mercury changes his phases in a manner similar to the moon, according as he is differently stationed, with regard to the earth and sun: though we may observe that he never appears quite full, because his bright side is only turned directly towards us, when he is so near the sun as to be lost from our sight in his beams. These different phases of his make it obvious that he does not shine by any light of his own; for if he did, he would always appear round.

As the orbit of this planet is between the earth's orbit and the sun, if it were in the same plane as the orbit of the earth, Mercury would frequently be seen to move across the face or disc of the sun. But as the planes of their orbits are not coincident, this appearance happens less commonly; it is denominated by astronomers, a *transit of Mercury over the sun's disc*, the planet then appearing like a black spot on the face of the sun. The last transit of Mercury happened in the year

year 1802: other transits will happen on the 12th of November in the present year 1815; November 5th, 1822; May 5th, 1832; November 7th, 1835; May 8th, 1845; May 9th, 1848; November 12th, 1861; November 5th, 1868; May 6th, 1878; November 8th, 1881; May 10th, 1891; and November 10th, 1894. These are all which will occur in the course of the present century.

LESSON V.

ON VENUS.

> Fair Venus next fulfils her larger round,
> With softer beams, and milder glory crown'd;
> Friend to mankind, she glitters from afar,
> Now the bright evening, now the morning star.
>
> BAKER.

VENUS, the second planet from the sun, is the next which comes under our consideration: the character by which she is denoted in astronomical performances is ♀, which is the same as that which the chemists make use of to denote copper.

The mean distance of this planet from the sun is about 69 millions of miles, and her magnitude is nearly the same as the earth's, her diameter being something more than 7,900 miles. Astronomers have discovered mountains on her surface; and some dark moveable spots, which have been observed on her disc, give us great reason to suppose she has an atmosphere. Her periodical course round the sun is completed in less than 225 days. The time of a complete rotation on her axis was by *Bianchini* assigned to be 24 days and 6 hours: but *Cassini*, with a much stronger appearance of probability, says the rotation is performed in about

23 hours; and this assertion is supported by some late observations accurately made by *Shroeter*, from which he has determined the time of one rotation to be nearly 24 hours. *Delambre* assigns it at 24 hours 5½ minutes.

Venus when viewed through a telescope, is rarely seen to shine with a full face; but has phases changing in like manner with the moon: being now gibbous, now horned; and her illumined part is constantly toward the sun. To the naked eye this planet is easily distinguishable, on account of her brightness and whiteness, which exceeds that of any other planet; nay, her lustre is so considerable, that when she is about 40 degrees removed from the sun, it is hardly equalled by that of the moon, which is frequently a dull light when compared with the vigour and brightness of the beams of the planet. In this state she has been often mistaken for a comet, and is frequently seen in the day time when the sun shines: a phænomenon which is taken notice of by some of our philosophical poets.

"No stars besides their radiance can display
"In *Phœbus'* presence, the dread lord of day:
"Ev'n *Cynthia's* self, though regent of the night,
"Is quite obscur'd by his emergent light:
"But *Venus* only, as if more divine,
"With *Phœbus* dares in partnership to shine."

This planet is a *morning star*, when she appears westward of the sun, for she then rises before him; at these times she is among poets called *Phosphorus*

Phosphorus or *Lucifer*; but when eastward of the sun, she shines in the evening after he sets, and then is called popularly the *evening star*; but poets then give her the name *Hesperus* or *Vesper*. She retains each of these names in its turn about 290 days.

Venus, as well as Mercury, is sometimes seen to transit the sun's disc, in form of a dark round spot. These *transits of Venus* happen but seldom. One was seen in England in 1639; and two in the last century, viz. the one in 1761, and the other in 1769: there will not happen another until December 9th, 1874; and after that, only one more, namely, on December 7th, 1882, before the close of the present century.

None of the wandering stars are more celebrated and admired among the ancients, than the one we are now reflecting upon: they had a prodigious veneration for her, making her their favourite goddess, paying her adoration, and all that Deity could claim; they even thought that her power supplied earth, air, and sea, and that clouds and tempests disappeared at her presence. But those who direct their contemplations into a proper channel will strip the planet of these imaginary honours, and place them where they are really due: we must consider her in all her varied and attendant beauties, as a part, a small part only, of the divine workmanship of HIM "who covers himself with light, as with a garment, and has stretched out the heavens like a curtain." By thus examining with attention the

the separate parts of his wonderful performances, we shall reflect with greater pleasure on the whole, and be induced to exclaim,

> These are thy glorious works, Parent of Good,
> Almighty; thine this universal frame,
> Thus wonderous fair! THYSELF how wond'rous then!
>
> MILTON.

LESSON

LESSON VI.

ON THE EARTH.

More distant still our earth comes rolling on,
And forms a wider circle round the sun;
With her the moon, companion ever dear!
Her course attending through the shining year.

BAKER.

IN the earliest ages of the world the generality of mankind entertained very strange notions concerning the form and dimensions of the earth we inhabit: and even in the present enlightened age it is not unusual to meet with persons whose ideas in this respect are very far from the truth. Those who have not been in the habit of considering this subject in an astronomical point of view, look upon the earth as a very extensive plane, here and there interspersed with hills and vales; they have also a confused notion of its being fixed firmly upon *something*; but upon what, or in what manner, it is impossible for them to tell.

But I would wish you, my young friends, to reflect upon the subject in a more correct manner. To you I must therefore observe, that the earth is in form nearly globular, and partakes of two constant motions; the one about its axis, and the other through its orbit round the sun, like the other planets. To this perhaps some of you may object,

ject, and you may advance several reasons for the objection, the principal of which will be like the following:—1. It is repugnant to our senses, which represent the earth to be flat and immoveable; and 2. It is contrary to the words of Scripture.

The first of these reasons may be obviated with ease, if the subject be considered with a proper attention. Thus, the roundness of the Earth is confirmed by recollecting that it has been frequently circumnavigated: that it is round is also proved by considering that its shadow, as projected upon the Moon in a lunar eclipse, always appears nearly circular, which would not happen if the Earth were not nearly spherical;—but the most manifest proof is derived from the considerations directly following. If we stand upon the sea shore and notice a ship sailing from us, we shall first lose sight of the hull or body of the vessel, then of the lower parts of the masts and rigging, and as she goes farther off, the upper parts of the masts disappear: so again, when a ship comes towards port, the steeples and highest buildings are first seen by the sailors; as the vessel comes nearer, they perceive the houses and lower buildings; and presently after the surface of the ground appears. Thus it is obvious that the earth is nearly spherical: and the diversifications of its surface with mountains and valleys have no sensible effect in destroying its sphericity; for the greatest hills, when compared with its magnitude, bear no greater proportion to the whole, than the little protuberances on the coat of an orange to the bulk thereof.

The argument alleged against the earth's motion, "that no such motion is evident to our senses," is too weak and frivolous to deserve a particular answer; for it is well known that we meet with deceptions in the sense of vision, in a variety of instances where the objects viewed are quite familiar to us; and when the fallacy is discovered, we have been surprised that we should be so easily deceived.

As to the second reason before advanced, those who oppose the astronomical principles concerning the shape and motion of the Earth, because they think them contrary to Revelation, would do well to consider for what purpose the holy Scriptures were written. Were they written as a measure of faith, or as a rule to regulate our philosophical opinions? *Gassendus* does not give a direct answer to the question; but he has made some very pertinent observations on the subject, with which I shall here present you. "There are," says he, "two sacred volumes; the one written, "called the *Bible*,—the other *Nature*, or the "*World;* God having manifested himself by two "lights, the one of revelation, and the other of "demonstration: accordingly the interpreters of "the former are divines, of the latter mathematicians. As to matters of natural knowledge, "the mathematicians are to be consulted,—and "as to objects of faith, the prophets; the former being no less interpreters, or apostles, from

"God

" God to men than the latter. And as the ma-
" thematician would be judged to wander out of
" his province, if he should pretend to controvert,
" or set aside any article of faith from principles
" of geometry; so it must be granted, the divines
" are no less out of their limits, when they ven-
" ture to pronounce on a point of natural know-
" ledge, beyond the reach of any not versed in
" geometry and optics, merely from holy Scrip-
" ture, which does not pretend to teach any thing
" of the matter."

I shall now proceed to exhibit to you the Earth in an astronomical point of view; for I am convinced, that the more attentively you consider it in this light, the more willingly you will throw aside the common prejudices, and place the true result of philosophical reasoning in their stead.

The earth, considered as an element, after the manner of Aristotle, is called *Terra:* but amongst astronomers it has obtained the name *Tellus*, and is denoted by the character ⊕; it is the third planet from the Sun, its mean distance from him being 95 millions of miles; and its diameter is found to be 7970 miles*. It is nearly 365¼ days in completing a revolution through its orbit, which is the length of our year: and a complete rotation upon its axis is performed in the compass of a na-

* Strictly speaking, the Earth, and indeed all the planets are spheroids formed by the rotation of ellipses of small ellipticity upon their minor axes; but their deviation from the spherical form is too minute to need any particular specification in a popular work like this.

tural day, or 24 hours. From mathematical principles it has been demonstrated that the length of the day is somewhat different at different parts of the year, but the difference is very inconsiderable; one day when the Sun is in the equinoctial being shorter by 40 seconds than when he is in the tropics. There is also another motion of the Earth, which occasions the precession of the equinoxes; but it is of too abstruse a nature to be explained to you in a satisfactory manner, until you have gained a better acquaintance with astronomy.

Here let us pause, and contemplate with humility, mingled with satisfaction, the abundant goodness of HIM "who hangeth the earth upon "nothing," to us his creatures. He compels the huge mass of inert matter on which we dwell, to travel with wonderful regularity through the abyss of space; and in its progress the various parts thereof are, by means of the diurnal rotation, made to feel the effects of the invigorating fountain of light and heat. Were it not for this we should sensibly feel the want of the returning seasons: no more should we see the valleys standing thick with corn; nor should we behold the beautiful verdure of the fertile meadow;—no more would the trees spread forth their foliage, nor would the plants be ornamented with flowers. Or as it is expressed in the language of inspiration, —"No longer would the fig-tree blossom, nor "fruit be in the vine: the labour of the olive "would fail, and the fields could yield no meat:

"the

"the flocks must be cut off from the fold, and "there would be no herd in the stalls."

Consider this, ye perverse mortals! who argue against conviction: consider, and tell us, if the above gloomy picture would not be realized, were the chance, which you so blindly extol, to preside over us. But thanks to the beneficence of the all-wise PROTECTOR of erring men, the evils which would be brought upon us under the dominion of chance, are averted: directed by an ALMIGHTY command, the earth is carried gradually along, and its motions are regulated in such a manner as are most conducive to the general design: the varied seasons of the year and the vicissitudes of day and night follow each other in pleasing gradations: the whole move on with astonishing harmony; and through every part of their progress, the omnipotent Conductor is administering to our wants, and bestowing upon us additional blessings. "Oh! that men would praise the Lord "for his goodness, and for his wonderful works "to the children of men *!"

The

* It has been customary, when speaking of the benefits we enjoy, to mention the convenient situation of the earth in the system, with respect to light and heat: and in particular, with regard to heat, it has been said that were we nearer the sun, the earth would be burnt; and were it farther off, we should be frozen. This method of reasoning might be applied with propriety, when it was thought that the sun was a globe of fire; but as modern discoveries have led philosophers to dispute the truth of such an opinion, it was thought better to omit the argument here hinted at. However, I have in some parts of these Lessons spoken of the degrees of light and heat,

The Earth is attended with a satellite, which adds greatly to our comforts and greatly to our pleasures: I dare say you will wish to be acquainted with its nature and size, when I tell you that this satellite is no other than the *Moon*, which with a

——— pleasing light
Shadowy sets off the face of things. MILTON.

But as this heavenly body is of such importance as to deserve a separate description, I shall gratify your curiosity in a future Lesson.

in a manner conformable to the most generally received opinion: I have also, in those places where I have spoken of the heat produced by the action of the Sun's rays, generally called it the *solar heat;* as it would not be right to alter the mode of expression most commonly used, until the premises upon which such alteration is grounded, are entirely acceded to.

LESSON

LESSON VII.

ON MARS.

In larger circuit rolls the orb of Mars,
Guiltless of stern debate, and wasteful wars,
As some have erring taught: he journeys on,
Impell'd and nourish'd by the attractive sun;
Like us, his seasons and his day he owes,
To the vast bounty which from Phœbus flows.

BROWN.

THE next planet which falls under our consideration, is called by the same name as *Mars*, the heathen god of war; and very probably, because he appears with a ruddy fiery countenance: among astronomers he is characterised by this mark ♂, which seems to be a rude sketch of a man holding a spear protended. Mars is the first of the four superior planets, his orbit being immediately above that of the earth: his mean distance from the sun is about 152 of those parts, of which the mean distance of the earth from that luminary is 100: hence his real distance is about 144 millions of miles. He performs his revolution round his orbit in about 687 of our days, or 667¼ of his own days, which is the length of his year. The light and heat at this planet (calculating after the manner described in the fourth Lesson) are in proportion to the light and heat at the earth, nearly as 43 to 100. His diameter or axis is nearly 4200 miles, from hence it may be shewn that his bulk is 7-24ths of the Earth's. Dr. Hooke, in the year 1665, observed several spots in Mars: observations on these spots and their motion, by the noted astronomers *Cassini* and *Herschel*, have at length determined the rotation of this planet on his axis to be performed in 24 hours ⅔ very nearly, which is the length of his day.

Mars, when observed through a telescope is seen to increase and decrease like the Moon, with this exception that he is never cornicular, or horned: from this we may infer that he shines not by his own light, and that his orbit includes that of the Earth.

This planet when viewed by the unassisted eye, appears smaller than Venus, and redder; having a ruddy troubled colour: whether this arises from the planet being of such a nature as to reflect the red rays of light best, or from a thick atmosphere attending it, is rather uncertain. But be this as it will, it appears pretty manifest that his sanguine complexion has obtained him a post of eminence among the pagan deities.

Virgil, and some other of the ancient poets, give us lively descriptions of him: they represent him as riding in a high chariot drawn by two horses, *Fear* and *Terror;* and, that the god may sit at his ease, his sister *Bellona* is employed in holding the reins and driving. However, though earthly poets have honoured him with these attendants,

tendants, it does nor appear likely that he has any in the heavens: for no satellites of his have yet been discovered; though he is the only one of the superior planets that travels through his annual round without attendance.

LESSON VIII.

ON JUPITER.

Next Jove, prodigious planet of the skies!
His orb presents, of huge amazing size,
In bulk none equals his enormous mass:
The whole joint system his contents surpass. BROWN.

THUS sang the poet: his assertion was strictly true, when the general opinion was that there were only six primary planets; but as there has a seventh lately been discovered, and that a large one, there now remains some doubt: however, as the diameters of each of the planets are given in these Lessons, my young readers may find if Mr. B—'s assertion will now hold good, when they have leisure to perform the necessary operations.

This planet has the same name as the grand heathen deity, viz. *Jupiter*, the character by which he is denoted is ♃, to represent the thunderbolts, as some people suppose; this mark is the same as that by which the chemists denote tin.

Jupiter is situated between Mars and Saturn and is the fifth primary planet, reckoning from the Sun: his mean distance from the Sun is 52 of those parts, of which the Earth's distance is 10: hence his real distance is about 490 millions of miles. His annual revolution about the Sun is performed

in

in about 4332 days and ½, being nearly 12 of our years; moving in his orbit at the rate of more than 25 thousand miles per hour. The light and heat received from the sun at *Jupiter*, are in proportion to those received at the earth, as 37 to 1000: hence, it is a very providential circumstance that he is attended by satellites; otherwise his inhabitants (I shall give reasons for supposing he has inhabitants, in another place) would be in a very dreary situation.

Jupiter's diameter or axis is more than 10 times that of the earth, and therefore his magnitude more than 1000 times the earth's: his diameter in English miles is 89,170; he performs his diurnal rotation on his axis in the short interval of 9 hours and 56 minutes, by which mean his equatoreal parts are carried round with about 25 times the velocity of the like parts of our Earth; being carried at the amazing rate of 26 thousand miles per hour. This quick succession of days will also be viewed by the attentive philosopher as another instance of Divine wisdom: for, as the poet observes,

> —In ample compass *Jove* conducts his sphere,
> And later finishes his tedious year;
> Yet swiftly on his axle turn'd regains,
> The frequent aid of day to warm his plains. BROWN.

But how will the hearts of all religious youths glow with admiration, when they are informed that the axis of Jupiter is so nearly perpendicular to his orbit, that he has no sensible change of seasons! can this be the work of chance? how wisely

wisely ordered! for if the axis of this planet were inclined any considerable number of degrees, so many degrees round each pole would be almost six years together in darkness. And as each degree of a great circle on this planet, contains more than 700 miles; it is natural to conceive, that vast tracts of land would be rendered uninhabitable, by any considerable inclination of his axis.

Jupiter, when viewed through a telescope, is found to be surrounded by faint substances called zones or belts. These belts are generally parallel to its equator, which is very nearly parallel to the ecliptic: they are subject to great variations, both in respect to their number and figure: sometimes eight have been seen at once, and sometimes only one; sometimes they continue for three months without any variation, and sometimes a new belt has been formed in less than two hours. From their being subject to such changes, it is very probable that they do not adhere to the body of Jupiter, but exist in his atmosphere. Dr. Smith in his Optics has given a curious account of these belts; and the greater part of the writers on astronomy have presented descriptions of them.

This planet, when viewed by the unassisted eye, is remarkable for its pure white brightness; indeed it is the brightest of all the planets, except sometimes Venus. This may appear singular when we remember his great distance from the sun; but when we also consider his enormous bulk, the wonder will cease.

In the year 1610, *Galileo* discovered that Jupiter

piter had four satellites, which he called *Medicean Stars*, in honour of the family of the *Medici*, his patrons. This was a discovery very important in its consequences, as it afforded a method of determining the longitude of places on the earth (by means of the eclipses of these satellites) with greater facility and accuracy than by any other method yet known. These eclipses also enabled M. *Roemer* to discover and ascertain the progressive motion of light; and hence Dr. *Bradley* was enabled to explain an apparent motion in the fixed stars, which could not otherwise have been accounted for, and which philosophers characterize by the term *aberration*.

LESSON

LESSON IX.

ON SATURN.

Still farther off, scarce warm'd by Phœbus' ray,
Through his wide orbit, Saturn wheels away.
How great the change, could we be wafted there,
How slow the seasons! and how long the year!

BAKER.

THE sixth planet has obtained the same name as *Saturn*, the supposed father of the heathen gods: amongst astronomers he is represented by the character ♄, to imitate an old man supporting himself upon a staff; the same character among the chemists denotes lead; and indeed there is some affinity between the colour of that metal, and the light, dusky colour of the planet.

Saturn's mean distance from the Sun is about 9½ times farther than the mean distance of the Earth from that luminary; being nearly 900 millions of miles: and of course the light and heat he derives from the Sun are about ninety times less than at the Earth.

This planet performs his annual revolution in about 10,759 of our days; being not far short of thirty years. His diameter or axis is more than 79,000 miles, and his magnitude is almost 1000 times that of the earth As it is agreeable to the

the nature of a planet to revolve on its axis, *Cassini* and others supposed that Saturn had a rotation of this kind, the time of which they endeavoured to determine, but without success. This point has, however, been at length ascertained by the observations of Dr. *Herschel,* from which he has found that Saturn revolves about his axis in ten hours and sixteen minutes.

Saturn has seven satellites or moons, attendant upon him; but the most surprizing thing observed about this planet is a kind of ring which encompasses his body: astronomers have noticed it very attentively, and some of them have determined it to be about twenty-one thousand miles distant from Saturn, and to be nearly thirty thousand miles in breadth. After paying a very minute attention to this ring, Dr. *Herschel* thinks himself authorised to say, that it is divided into two concentric rings, situated in one plane, which is not much inclined to the equator of the planet. M. *Laplace* extends this conjecture, and affirms that there are *several* concentric rings, adjusted nearly to one plane.

There are several conjectures with regard to the uses of this ring; and amongst them, the one which tends most to evince the wisdom of the Almighty I shall give you in the words of a poet, who has evinced an extensive acquaintance with philosophy, united with that rational devotion which is generally the result of an attentive contemplation of the works of nature.

Muse! raise thy voice, mysterious truth to sing,
How o'er the copious orb a lucid ring,
Opake and broad is seen its arch to spread
Round the big globe at stated periods led;
Perhaps (its use unknown) with gathered heat
To aid the regions of that gilded seat,
The want of nearer Phœbus to supply,
And warm with reflex beams his summer sky;
Else might the high-placed, world, exposed to frost,
Lie waste, in one eternal winter lost. BROWN.

Some persons, who object to this, observe, that the inhabitants of Saturn have *undoubtedly* constitutions suited to the globe they inhabit: but these objectors may be reminded, that the nature of Saturn's inhabitants may be so tempered as continually to require the aid of this ring to keep them sufficiently warm; it may also serve to remind them in what a deplorable state they would be, were it not for the continual superintendance and presence of the adorable Creator.

LESSON X.

ON GEORGIUM SIDUS, OR HERSCHEL.

Mathesis with uplifted eye,
Tracing the wonders of the sky,
Now shews the mariner to guide
His vessel through the trackless tide;
Now gazing on the blue profound,
Where whirl the stars in endless round,
Beholds new constellations rise,
New systems crown the argent skies;
Views with new lustre round the glowing pole,
Wide his stupendous orb the Georgian planet roll.

PYE.

IT was for ages supposed that there were only six planets in the *solar system:* and the ingenious *Kepler*, a very eminent astronomer, was so firmly persuaded there were no more, that he confesses, one of the three things which he anxiously sought to find the reason of, was,—why the planets were six in number?

It is to the indefatigable application of an astronomer, who has long resided in this country (and whom I have had frequent occasion to mention), Dr. *William Herschel,* that we are indebted, amongst other brilliant discoveries, for that of a planet, which is the fourth of the superior ones, and the farthest from the sun of any yet discovered.

vered. This new-found planet was discovered on the 13th of March, 1801, and is known by two titles: the one of *Georgium Sidus*, was bestowed upon it by the discoverer, in honour of our present Sovereign. The other of *Herschel* was long given it by the chief astronomers of all nations, as a proper testimony of respect to the assiduity and abilities of the person who discovered it. The name by which it is now designated by continental astronomers, is *Uranus*.

Georgium Sidus, or *Herschel*, is characterized by the mark ♅, being the initial of the discoverer's name, with a cross bar, intersecting the horizontal bar of the H, to represent a cross, and thereby to denote that the discovery of this planet was after the birth of Christ. Herschel's mean distance from the sun is about nineteen times that of the earth, viz. about 1800 millions of miles; he performs a revolution through his orbit in 30,689 days very nearly, being almost ninety of our years; the light and heat he derives from the sun are about the 362d part of those at the earth, calculating on the hypothesis before explained. This planet appears of a bluish white colour, and its brilliancy is between that of Venus and the Moon. With a telescope that magnifies about 300 times, he appears to have a very well defined visible disc. In a very fine clear night, when the moon is absent, he may be perceived by a good eye without a telescope.

The time of this planet's diurnal rotation is not yet discovered: his axis is found to be 35,865 English

English miles, and his solidity 24155283745628 cubic miles. How amazing must be the power that could hurl this and the other planets with such rapidity through the liquid ether! but let your admiration not yet cease, for "these are only part "of his ways." Our contemplations on the starry canopy are not yet completed;—

> Night opes the *noblest* scenes, and sheds an awe,
> Which gives those venerable scenes full weight,
> And deep reception in the entender'd heart. YOUNG.

Georgium Sidus has six satellites already discovered, which are probably of very great utility to his inhabitants. For it is very reasonable to conclude, that there is scarcely any part of this large planet, but what is constantly enlightened by one or other of these moons *.

* That the system which is described in the first eleven Lessons, claims a preference to all others, will, I think, appear obvious from the following considerations.

I. The planet *Venus* moves round the Sun, and not round the Earth. For through a telescope, it sometimes appears with a bright and round face like the full Moon, and sometimes horned like the new Moon; and when it appears full, it is seen near the body of the Sun, as well as when it appears horned: which could not be, did it move round the Earth alone, or round neither the Sun nor the Earth. For, if it moved round the Earth alone, or round both the Sun and the Earth, it must be seen sometimes in that part of the Heavens which is opposite to the Sun. If it moved round neither the Sun nor the Earth, it could not appear both horned and full when it is seen near the body of the Sun: it remains, therefore, that it revolves about the Sun, and not about the Earth. Hence its orbit includes the Sun, and is within the orbit of the Earth.

II. Applying

II. Applying a similar mode of reasoning, we may conclude, that *Mercury* moves round the Sun in a less orbit than that of *Venus;* because it puts on the same phases with Venus, and is never seen so far from the sun as that planet is.

III. The orbit of *Mars* includes both the Earth and the Sun; and the Earth is not in the centre thereof. For this planet is capable of appearing opposite to the Sun, or in any other situation with respect to that luminary; which could not be, unless it moved round the Earth: and it always appears full, or nearly so; which it could not do if it ever came between the Sun and the Earth; hence, it moves also round the Sun. And farther, when Mars is in the opposite part of the Heavens to the Sun, it appears about five times larger than when it is near the Sun; which shews that it is much nearer the Earth in one situation than in the other: the Earth, therefore, is not in the centre of its motion.

IV. The like being observable of *Jupiter*, *Saturn*, and *Herschel*, (though, on account of their greater distance from the Sun and us, the diversity in their apparent magnitudes in different parts of their orbits, is not so great as in *Mars*), it is reasonable to conclude, that these planets also have both the Earth and the Sun within their orbits, and that the Sun, rather than the Earth, is in the centre of the same.

V. Since then, the Earth is placed within the orbits of *Mars Jupiter*, *Saturn*, and *Herschel*, these planets cannot appear to us to stand still, or to go backward, as observations shew they sometimes do appear, unless the earth moves: and since, as has been shewn, *Venus* and *Mercury* revolve about the Sun, and not about the Earth; since also, the Earth is placed between the orbits of *Mars* and *Venus*, and the periodical time of the Earth, if it does move, is, in point of magnitude, between the periodical times of those two, it seems quite reasonable to suppose that the Earth revolves about the Sun in the same manner as the planets do: it is therefore reckoned in the number of them.

VI. But what very much confirms this conclusion is, that astonishing harmony, which, upon this supposition, runs through the whole *solar system*: for it is known that the motions of all the planets, both primary and secondary, are in conformity

to

to one and the same law; which is, that *the squares of the periodical times of the primary planets,* are *proportional to the cubes of their mean distances from the Sun;* and that *the squares of the periodical times of the secondaries of any primary, are to each other, as the cubes of their distances from their primary.* By no other hypothesis which has been yet invented, can the motions of the heavenly bodies be accounted for with such beauty and simplicity, as by this; nor is there any other system which exhibits the fabric of the universe, in that regularity and harmony, which is worthy the DIVINE ARCHITECT.

It may not be improper to mention in this note, that the planets differ in *density* as well as in *magnitude*, a circumstance which will make the ratio of their absolute masses different from that of their apparent bulk or volume: assuming that of the Earth as unity, the others will be expressed in integers and decimals in the following table.

	Volumes.	*Masses.*
Mercury	0.0565	0.1627
Venus	0.8828	0.9243
The Earth	1.0000	1.0000
Mars	0.1386	0.1294
Jupiter	1280.9	308.94
Saturn	974.78	93.271
Uranus	81.26	1.6904
Sun	1395324.	329630.
Moon	0.2035	0.0801

LESSON

LESSON XI.

ON THE MOON.

He smooth'd the rough-cast Moon's imperfect mold,
And comb'd her beamy locks with sacred gold:
Be thou, said he, Queen of the mournful night:
And as he spoke, she rose oer'clad with light,
With thousand stars attending on her train. COWLEY.

AMID the beauteous scenes which deck the face of nature, there are very few that have a more pleasing effect, than those which are viewed by the light of the Moon. Several of the poets have given noble descriptions of the delightful appearance and effect of a moon-light evening; one of which, by the ancient poet *Homer*, I shall here insert.

——So when the Moon, refulgent lamp of night,
O'er heaven's clear azure spreads her sacred light,
When not a breath disturbs the deep serene,
And not a cloud o'ercasts the solemn scene;
Around her throne the vivid planets roll,
And stars unnumber'd gild the glowing pole.
O'er the dark trees a yellower verdure shed,
And tip with silver every mountain's head:

Then

Then shine the vales; the rocks in prospect rise;
A flood of glory bursts from all the skies;
The conscious swains, rejoicing in the sight,
Eye the blue vault, and bless the useful light.

POPE'S HOMER.

Mr. Pope observes that these lines exhibit, in the original, the finest night-piece in poetry: the reader may judge that in the translation they do not appear disadvantageously.

This beautiful luminary, whose gentle beams render the summer evenings more agreeable, and the winter nights less unpleasant, is a secondary planet; being a satellite to the Earth we inhabit, about which she revolves in an elliptical orbit from one new Moon to another in twenty-nine days twelve hours forty-four minutes very nearly. Her mean distance from the earth is 240,000 miles, and she moves in her orbit at the rate of about 2290 miles in an hour: her diameter is about 2180 miles; and her rotation on her axis is performed in the same time as her revolution through her orbit; hence it appears that her day and night taken together are just as long as our lunar month.

You have without doubt, very frequently taken notice of the various changes the Moon undergoes, and you very probably are anxious to see them accounted for: I shall here endeavour to satisfy your curiosity. The Moon is a dark, or opake body, shining principally with the light she receives from the Sun; hence, only that half which is turned towards him at any time can be illuminated,

nated, the opposite half remaining dark: then, as the face of the Moon visible on the Earth, is that part of her body turned towards us, we shall, according to the different positions of the Moon, with regard to the Sun and Earth, perceive different degrees of illumination. Hence the Moon appears sometimes increasing sometimes waning; sometimes horned, then half round; sometimes gibbous, then full and round. At the time of new Moon, the Moon is between the Earth and Sun; and at the time of full Moon, the Earth is between the Moon and Sun.

This may be familiarly illustrated by means of an ivory ball, which, being held before a candle in various positions, will present a greater or less portion of its illumined hemisphere to the view of the observer. The Earth presents the same phases to a spectator on the Moon, as she does to us, only in a contrary order, the one being full when the other changes, &c. and in a greater degree, the Earth giving thirteen times as much light as the Moon.

The face of the Moon, as you may have often observed, appears to have shades of different colours: when viewed through a telescope these shades are found to be the diversifications of hills and valleys; the same are also shewn by the border of the Moon appearing indented or jagged, especially about the edge of the illumined part when the Moon is either horned or gibbous. Dr. *Herschel* has measured the heights of several of the lunar prominences with greater precision than

than any of the former astronomers: he has determined that very few of them exceed half a mile in their perpendicular elevation. He has also observed several volcanoes on the Moon, emitting fire, as those on the Earth do: and indeed there seems no reason to doubt, that, to complete the similarity between her and the Earth, she has also seas, rivers, and an atmosphere.

Christianus Huygens, in his excellent Conjectures concerning the Planetary World, says, "'Tis "certain that the Moon has no atmosphere surrounding her." He then proceeds to give his reasons for such an assertion. But he has in this instance fallen far short of his usual sagacity; for the existence of a lunar atmosphere has been frequently proved, by later writers, from the most manifest considerations.

If the Moon shone by a light of her own, we should feel a sensible warmth from her rays: but it is a light reflected from the Sun with which she shines, and is so exceedingly weak and languid, that the most powerful burning glass will not collect enough to make any sensible degree of heat. This has been accounted for; and those who have gone through the computation assert, that the light of the full Moon is ninety thousand times less than day-light. How wonderfully is infinite goodness and wisdom displayed in this instance! For if the Moon's reflected rays produced heat, as the air of the night would then have a continual warmth, it is obvious that it would be prejudicial to the health of mankind.

The effect of moonlight in diversifying the scenery of nature, and the changes which that luminary herself undergoes, have furnished the poets with some of their most beautiful and touching images. The following describes, with great felicity, the separation of the spirit from the body of a pious young female :—

——But she was waning to the tomb;
The worm of death was in her bloom :
Yet as the mortal frame declin'd,
Strong through the ruins rose the mind ;
As the dim Moon, when night ascends,
Slow in the east the darkness rends,
Through melting clouds, by gradual gleams,
Pours the mild splendour of her beams,
Then bursts in triumph o'er the pole,
Free as a disembodied soul!
Thus while the veil of flesh decay'd,
Her beauties brighten'd through the shade;
Charms which her lowly heart conceal'd;
In Nature's weakness were reveal'd!
And still the unrobing spirit cast
Diviner glories to the last ;
Dissolv'd its bonds, and clear'd its flight,
Emerging into perfect light. MONTGOMERY.

LESSON XII.

ON COMETS.

At his command, affrighting human kind,
Comets drag on their blazing lengths behind;
Nor, as we think, do they at random rove,
But in determin'd times, through long ellipses move;
And though sometimes they near approach the Sun,
Sometimes beyond our system's orbit run,
Throughout their race they act their Maker's will,
His power declare, his purposes fulfil. BAKER.

Hark! from the world's exploding centre driv'n,
With sounds that shook the firmament of heav'n,
Careers the fiery giant fast and far,
On bick'ring wheels and adamantine car:
From planet whirl'd, to planet more remote,
He visits realms beyond the reach of thought;
But wheeling homeward when his course is run,
Curbs the red yoke, and mingles with the sun!

CAMPBELL.

ANOTHER kind of wandering bodies is known by the name of *Comets*. These the common people call *blazing stars*, because they generally have long tails blazing or streaming from them. As these extraordinary bodies are but seldom seen, they are by many persons thought portentous, presaging some extraordinary event; some look upon them as bloody signs hung out by Divine resentment over a guilty world: some read in their appearance the fate of nations and the fall of monarchies; others imagine they foretel desolating plagues, famines, or wars. They must, however, be acquitted of all tendency of this kind.

Nor indeed is there any occasion for apprehension that they should at all injure the earth we inhabit. The probability is some millions to one against a cometary and a planetary body coming into contact: and even the tail of a comet cannot come near our atmosphere, unless the Comet be at its inferior conjunction very nearly at the time when it is in a node; circumstances *extremely* unlikely to happen together.

Among the various opinions which have been entertained concerning the nature of Comets, that of NEWTON was, till lately, most generally adopted. According to his hypothesis, Comets consist of a very compact, durable, and solid substance, capable of bearing most exceedingly great degrees of heat and cold without dissolution: they are of an opake nature, shining by reflection of the Sun's light, as the planets do. They move in stated periods in very long elliptical orbits, having the Sun in one of their Foci; in one part of their orbits they approach extremely near to the Sun, and in another part they are immensely distant from him; sometimes they come much nearer to the Sun than Mercury's orbit, at other times they are greatly farther from the Sun than *Georgium Sidus.*

Comets differ much in their magnitude, though most of those which have been observed are considerably less than the Moon; but their dimensions are not determined with accuracy; neither are their periods:—for as one person's life is seldom longer than a Comet's period, and very frequently not so long, there is but little probability of his again seeing a Comet, when it returns near the Sun after another

another revolution through its orbit; and, of course, their periods are not precisely ascertained.

The tail of a Comet, which is generally its most conspicuous part, is thought by NEWTON to be a prodigious quantity of fume and vapours, flying off from its body, as it becomes more and more heated in its approach to the Sun. These tails are sometimes exceedingly long, some having been computed to be 80 millions of miles in length: that they are vapours was thought evident from these considerations; first, the fixed stars are often seen through them; secondly, they appear broader on their upper part than near the head of the Comet; thirdly, the tails lie always towards those parts which the Comets have just left; and fourthly, they seem most splendid and large immediately after they return from the Sun;—all which is agreeable to the nature of smoke and vapour.

The hypothesis of NEWTON, as above recited, has been objected to by Dr. *Halley* and Dr. *Hamilton*, who think that the tail of a Comet is formed of matter which has not the power of refracting and reflecting the rays of light; but that it is a lucid, or self-shining substance: and from its similarity to the *aurora borealis*, they think it probable that it is produced by a similar cause, and is properly an electrical phenomenon.

A more recently advanced opinion is that of Dr. *Herschel*, who has affirmed, that, after a very diligent examination, he could not perceive the least appearance of any solid nucleus; Comets seeming to be mere collections of vapours condensed about the centre of each. He farther supposed that the orbits of Comets are not regular and determinate, as they have been generally imagined to be, because, he says, they are liable to be changed considerably by the perturbation of the planets. Perhaps, the non-appearance of some Comets, which were predicted to appear in these last few years, may serve to confirm this suggestion.

After all, it must be acknowledged, that the philosophy of Comets is, at present, very imperfect. The discoveries which have hitherto been made (owing to the long intervals which frequently precede the return of Comets, and their irregular motions), are not sufficiently important to afford any thing decisive. The prediction of *Seneca* remains yet to be accomplished, wherein he says, "The "time will come when the nature of Comets, and "their magnitudes, will be demonstrated, and the "routes they take, so different from the planets, "explained. Posterity will then wonder, that the "preceding ages should be ignorant of matters "so plain and easy to be known *."

* M. LAMBERT, in his Letters on *Cosmogony*, takes for granted the principle that the universe ought to be as populous as possible, and contain as many moving bodies as it can without confusion and disorder. "Hence," says he, "the most perfect plan of our system will be that into which enters the greatest number of orbits, all separated from one another, and which in no point intersect each other. If, then, we should be able to prove that the orbits of comets correspond to this end better than those of the planets, the reason of their superiority in point of number must be seen and admitted." This, in fact, he *does* prove, and thus shews that the very elliptic orbits of Comets, instead of being irreconcileable with the wisdom which is otherwise manifest in the works of creation, are additional proofs that the highest possible perfection obtains in the universe at large.

LESSON

LESSON XIII.

ON GRAVITY, WEIGHT, &c.

This problem let philosophers resolve,
What makes the globes from east to west revolve?
What is the strong impulsive cause declare,
That rolls the pond'rous orbs so swift in air.

BLACKMORE.

WHILST you are reflecting upon the planetary bodies, and considering the regularity of their returning periods, these inquiries will very naturally be suggested to your mind. As a research of this kind cannot be unpleasing, the present Lesson will be appropriated to it. Sir *Isaac Newton* has left us no room to doubt that the bodies in the *solar system* are

All combin'd
And rul'd unerring, by that simple power
Which draws the stone projected to the ground.

THOMSON.

The sagacious *Kepler* had determined from observations, that the planetary motions agree with this regular law, viz. The squares of their periodical times are as the cubes of their mean distances from the Sun or focus of their orbits; and this law has been since demonstrated by *Newton*, from the principles of attraction and projectile motion. If we carry back our researches to the creation of the

 world,

world, we might reason in a manner similar to the following: In the beginning the GRAND MOVER impressed such a degree of motion upon these bodies, as, if not controuled, would have whirled them onward in straight lines, and to endless lengths, till they would have been lost to imagination in the abyss of space. But the *gravitating* property (which acts in reciprocal proportion to the square of its distance from the attractive centre), being combined with the *projectile* force, determined their courses to an elliptical form, and obliged these bodies to perform their destined rounds. Were either of these causes to have its action suspended, the harmony of these motions would be disconcerted: were the projectile force suspended, the planets would be drawn by the attractive power till they fell upon the central body: and if the gravitating force were suspended, they would be rapidly hurled to an inconceivable distance, and perhaps would be dissipated into atoms.

How admirable, how extensive, and diversified is the efficacy of the single principle—*Gravity!* It is this which penetrates the minutest pores of all bodies, and diffuses itself to the remotest limits of the Mundane System: it is this which keeps the planetary orbs, already impressed with motion, equipoised upon their centres: it is this to which we may attribute the pressure of the atmosphere: it is this which causes the ocean to ebb and flow with such wonderful regularity, and yet confines it within proper bounds. These and other complicated effects

fects arise from one single cause. And what is Gravity? We know there is such a power, and we know how it acts; but that it is a primary quality essential to all bodies, is not universally admitted: those who inquire after the cause of Gravity must be informed that the true cause is the DEITY: for Gravity may not improperly be styled the "*Finger* of GOD; the constant impression of Divine power;"—in every other sense, the cause is likely to continue to be unexplored by mortals.

But if the cause of Gravity have never yet been discovered, shall Gravity itself for that reason be called an occult quality, and rejected from philosophy? Those who draw such a conclusion should take care lest they advance an absurdity, by which the foundations of all philosophy may be overturned. For causes usually proceed in a continued chain from compound to more simple; and when we have arrived at the most simple cause we can proceed no farther. No mechanical explication can be given of the most simple cause: for, if there could, the cause would not yet be the most simple. If these most simple causes, then, may be called occult, and rejected; for the same reason we may reject those causes which immediately depend upon them, and those also which depend upon these last; and so on until philosophy be entirely divested of all causes whatever.

By the method of Analysis it is that we must trace out the established laws of nature, or that order in which instrumental causes are used in producing natural effects. But, as we rise from effects to causes, the more general are those powers which we discover. Effects apparently contradictory are found to proceed from the same principle. The ascent of light bodies, as well as the descent of heavy ones, is the consequence of the universal gravitation of matter. Cohesion, dissolution, and various phænomena in chemistry, are derived from the attractions of minute particles at very small distances. And, wherever we turn our view, the whole course of nature evidently points out to us, that all the various appearances which we behold flow from a few very general and subordinate causes, which more immediately depend upon the ascendant power of the ONE SUPREME CAUSE, the Author and Governor of the Universe! whose existence and influence are manifested by every the most obvious effect; and of whose power, wisdom, and goodness we acquire higher and more enlarged conceptions in proportion as we obtain a more complete knowledge of his works.

The laws of nature being discovered, as abovementioned, by analysis, particular phænomena are explained synthetically, by shewing their conformity to these laws. Thus, to shew that the Moon is retained in its orbit by the force of gravity, is to shew the agreement between that force and the force by which a stone, or any heavy body, tends to the centre of the earth: that the Moon is continually bent from the tangent of its orbit, in the same manner as a body near the surface of the earth is turned from its rectilinear motion into a curve: that both these motions are directed to the

same

same point, and agree in quantity: that, if the Moon were to approach to the surface of the Earth, the force, by which it is retained in its orbit, would make it descend towards the centre of the Earth, through the same space which a heavy body, falling by its gravity, would descend through in the same time: and that if a stone or a bullet could be carried to the distance of the Moon, and there projected with a sufficient velocity, it would revolve round the Earth like a Moon, for the same reason by which it is bent into a curve, when projected near the surface of the earth. By pursuing these methods Sir *Isaac Newton* demonstrated the universal gravitation of matter; and it is now pretty generally allowed that the same principle of gravity, by which we see all bodies tend towards the centre of the Earth, is a general law of nature, extended to all distances, and to every body in the universe. Thus it is agreed, that the primary and secondary planets in our system, as also the Sun, are mutually attracted by each other. But since all attractions are mutual, it will follow, that if one or more bodies revolve about another, which is also attracted by them, that other body will not be at rest; but together with them will revolve round the common centre of gravity of the whole system. Hence, then, and from the proportions of the quantities of matter of the Sun and the planets, it is found that the common centre of gravity of the solar system is never far removed from the body of the Sun, and is generally within its surface. Round this point the Sun itself is continually

moved

moved in various directions, approaching or receding according to the different positions of the planets.

Since, then, all bodies, terrestrial and celestial, on which experiments or observations can be made, are found to gravitate towards each other, what has been before said of the universal extension of Gravity will be the more willingly acceded to: I hope, therefore, I may now quit this part of the subject, without giving any additional arguments in support of the opinion.

Before I conclude this Lesson, I cannot avoid adding a few words to explain the difference between *Gravity*, *Weight*, and *Heaviness*; which appear to me the more necessary, because I am aware that the notions commonly entertained are not very correct.

In order to form an exact idea of the weight of a body, it must be recollected, that Gravity impresses, or has a tendency to impress, on every particle of bodies, in an instant, a certain velocity, with which they would fall, if they were not supported; and that, abstracting the influence of the air, this velocity would be the same for each of the particles of bodies, whatever be their substance. This being observed, we must understand by the weight of a body, the effort necessary to prevent it from falling; and, it is evident, that in order to this, it is necessary to destroy the velocity which gravity has impressed on every particle. This effort must, therefore, be equal to the sum of the velocities of all the particles. Hence it may be naturally con-

concluded that bodies the most compact, and which consequently contain a greater number of particles in the same bulk, will weigh more than others; because the weight being the sum of the velocities impressed on all the particles, that sum must be so much the greater, as there are more material particles contained in the mass of the body.

From what is here said, I would observe with M. *de Condorcet,* that we may see "the necessity "of carefully distinguishing between the effect of "Gravity, and that of Weight: the former is the "power of transmitting, or a tendency to transmit, into every particle of matter a certain velocity which is absolutely independent on the "number of material particles; and the second is "the effort which must be exercised to prevent a "given mass from obeying the law of Gravity. "*Weight* accordingly *depends on the mass, but* "*Gravity has no dependence at all upon it.*"

Again, with respect to the difference between Heaviness and Weight, taken in their literal sense, *heaviness* is that quality in a body which we feel, and distinguish by itself: *weight* is the measure and degree of that quality which we cannot ascertain but by comparison. We say absolutely, and in an undetermined sense, that a thing is *heavy;* but relatively, and in a determined manner, that it is of such a *weight;* for example, of two, three, or four pounds. A thousand circumstances prove the *heaviness* of the air, for instance; but the mercury in the barometer determines its exact *weight.*

LESSON

LESSON XIV.

ON ECLIPSES OF THE SUN AND MOON.

> Give me the ways of wandering stars to know,
> The depths of heav'n above and earth below;
> Teach me the various labours of the Moon,
> And whence proceed th' eclipses of the Sun.
>
> VIRG. GEORG. II.

I DOUBT not but that several of you, my young friends, will heartily join in Virgil's petition above cited: and though you, perhaps, may never have either leisure or opportunity enough to acquire a very great astronomical knowledge; yet I can assure you it is no difficult matter to attain such an acquaintance with the science, as to understand the reason of *Eclipses* of the Sun and Moon.

You will observe, then, that an *Eclipse of the Moon* is a privation of the light of the Moon, occasioned by an interposition of the body of the Earth (as she revolves in her orbit) directly between the Sun and Moon; by which mean, the Sun's rays are so intercepted that they cannot illuminate the Moon: then

> ——The silver Moon is all o'er blood,
> A settling crimson stains her beauteous face. LEE.

It is at the time of full Moon that lunar eclipses happen;

happen; because it is only then that the Earth is between the Sun and Moon: neither do they happen every full Moon (as they would do if the orbits of the Earth and Moon were coincident) because of the obliquity of the Moon's path with respect to the Earth's; but only in such full Moons as happen at the intersections of those two paths, called the Moon's nodes; or at least on those full Moons which happen but a little distance from the nodes.

The chief circumstances in lunar eclipses, as they are given by Dr. *Hutton* in his Mathematical and Philosophical Dictionary, are as follow: —1. All lunar eclipses are universal, or visible in all parts of the earth which have the Moon above the horizon; and are every where of the same magnitude, with the same beginning and end.—2. In all lunar eclipses, the eastern side is what first immerges and emerges again; *i. e.* the left side of the Moon as we look toward her from the north; for the proper motion of the Moon being swifter than that of the Earth's shadow, the Moon approaches it from the west, overtakes it and passes through it with the Moon's east side foremost, leaving the shadow behind, or to the westward.—3. Total eclipses, and those of the longest duration, happen in the very nodes of the ecliptic; because the section of the Earth's shadow, then falling on the Moon, is considerably larger than her disc. There may, however, be total eclipses within a small distance of the nodes; but their duration is the less as they are farther

from

from them; till they become only partial ones, and at last not at all.—4. The Moon, even in the middle of an eclipse, has usually a faint appearance of light, resembling tarnished copper; which Gassendus, Ricciolus, and Kepler, attribute to the light of the Sun, refracted by the Earth's atmosphere, and so transmitted thither.—Lastly, she grows sensibly paler and dimmer before entering into the real shadow; owing to a penumbra which surrounds that shadow to some distance.

In addition to these circumstances, some astronomers observe, and it is here added, that no eclipse of the Moon can last above 5½ hours, from the Moon's first touching the Earth's penumbra, to its last leaving it: but an eclipse of the Moon, by the Earth's shadow, perhaps never lasts above 3¾ hours; nor when total, above 1¾ hours.

An *Eclipse of the Sun* is an occultation or hiding of the Sun's body from our sight, occasioned by an interposition of the Moon between the Earth and Sun.

> ———Shorn of his beams, the Sun
> In dim eclipse disastrous twilight sheds.
>
> MILTON.

It is by several considered and called an Eclipse of the Earth, since the light of the Sun is hid from the Earth by the Moon, whose shadow involves a part of the Earth. The manner of a solar eclipse may be conceived by imagining a small part near the vertex of the Moon's conical shadow, travelling over a part of the earth's surface, and making a coma complete eclipse to all the inhabitants residing within that track; but no where else; for in the large space around, within the limits of the fainter shade called the penumbra, the eclipse will only be partial.

It will not be difficult to understand that solar eclipses can only happen about the time of New Moon, when the Moon is in conjunction with the Sun. In the nodes, when the Moon has no visible latitude, the eclipses are total: out of the nodes, but near them, the eclipses are partial: the limits are about 17 degrees on each side the nodes:—but much also depends upon the Moon's latitude, for it must in these cases be always less than the apparent semi-diameters of the Sun and Moon added together.

Some circumstances of solar eclipses, as described by the very ingenious author before-mentioned in this Lesson, are, 1. That none of them are universal; that is, none of them are seen throughout the whole hemisphere which the Sun is then above: the Moon's disc being much too little, and much too near the Earth, to hide the Sun from the whole disc of the Earth. Commonly the Moon's dark shadow covers only a spot on the Earth's surface, about 180 miles broad, when the Sun's distance is greatest, and the Moon's least. But her partial shadow or penumbra, may then cover a circular space of 4900 miles in diameter, within which the Sun is more or less eclipsed as the places are nearer to or farther from the centre of the penumbra. In this case the axis of the shade

passe

passes through the centre of the Earth, or the New Moon happens exactly in the node, and then it is evident that the section of the shadow is circular; but in every other case the conical shadow is cut obliquely by the surface of the Earth, and the section will be an oval, and very nearly a true ellipsis. —2. Nor does the eclipse appear the same in all parts of the Earth, where it is seen; but when in one place it is total, in another it is only partial. Farther, when the Moon appears much less than the Sun, as is chiefly the case when she is in *Apoge* and he in *Perige* *; the vertex of the lunar shadow is then too short to reach the Earth, and though she be in a central conjunction with the Sun, is yet not large enough to cover his whole disc, but lets his ring appear as a lucid ring or bracelet, and so causes an *annular eclipse*.—3. A solar eclipse does not happen at the same time in all places where it is seen; but appears more early to the western parts, and later to the eastern; as the motion of the Moon, and consequently of her shadow, is from west to east.—4. In most solar eclipses the Moon's disc is covered with a faint light, which is attributed to the reflection of the light from the illuminated part of the Earth.—Lastly, in total eclipses of the Sun, the Moon's limb is seen surrounded by a pale circle of light; which some astronomers consider as an indication of an atmosphere of the Sun, because it has been

* *Apoge* is that place in which the Sun or a planet primary or secondary, is at its greatest distance from the Earth: *Perige* is when either of these is at its nearest possible distance from us.

observed

observed to move equally with the Sun, and not with the Moon.

In addition to these circumstances we may observe, that though a solar eclipse may last from beginning to end (at one place on the earth) more than two hours; yet the duration of total darkness can never, in the greatest eclipse be more than four minutes, and very commonly not more than two.

We may also observe, with regard to eclipses of both luminaries, that in general, as many eclipses happen of the Sun as of the Moon: but in any particular place there are more eclipses of the Moon than of the Sun. Again, that though in lunar eclipses the eastern side is first eclipsed, and the eclipse ends on the western side; yet in solar eclipses, the western side is first eclipsed, and ends on the eastern.

As to the number of eclipses both solar and lunar, it may be observed that there cannot in any year be less than two, nor more than seven: the most usual number is four, and it is very seldom that there are more than six.

The satellites of some of the superior planets frequently undergo eclipses and occultations; but as these are unobservable by the naked eye, it would not agree with my design to say more about them. Some of the fixed stars, Aldebaran for instance, is frequently hidden behind the Moon; Jupiter also experiences occultations of this kind: but of these the bare mention may suffice.

LESSON

LESSON XV.

ON THE FIXED STARS, WITH REFLECTIONS ON THE IMMENSITY OF THE UNIVERSE.

——Who turns his eye on Nature's midnight face
But must inquire—" 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 bowl'd them flaming through the dark profound,
" And set the bosom of old night on fire?"
Nature's Controuler, Author, Guide, and End!

YOUNG.

WHEN you, my young friends, consider the unwieldy size of those celestial bodies on which we have already descanted, and reflect upon the astonishing rapidity of some of their motions; surely you must entertain very high ideas of the GREAT POWER which first launched them in the illimitable void, and causes their motions to continue through the flux of so many thousand years; none having yet mistaken their way, or wandered from their destined paths:—on the contrary, their rotations still proceed in such exquisite regularity and harmony as is best adapted to the perfection of the whole. What awful power and adorable goodness is here displayed! But our reflections on the

the heavens must be carried infinitely farther than we have yet extended them.

The gems in the brilliant canopy which remain to be contemplated, are the *fixed stars;* which are chiefly distinguishable, as was suggested in the Second Lesson, from their never changing their relative situation with regard to each other.

The heavens are divided into three regions, called the Northern and Southern Hemispheres, and the Zodiac. The Fixed Stars were classed by the ancients under the outlines of certain figures of birds, beasts, fishes, and other animals; and these were called *Constellations.* The number of which is, in the Northern Hemisphere, 36; in the Southern, 32; and in the Zodiac, 12. Stars not comprehended in any of these ancient constellations, are called *Unformed Stars;* and others, of a cloudy appearance, are called *Nebulæ.* Of this number are the Magellanic clouds near the south pole, which resemble two whitish spots in the heavens, and are well known to sailors *.

The

* The Plate which is given as a Frontispiece, is a projection of the northern and southern CELESTIAL HEMISPHERES on the plane of the *Equator.* The centre of the first projection is the *North Pole* of the Equator, around which are described two circles; the smaller is the *Arctic circle*, the larger, the *Tropic of Cancer:* a little above the centre of the first projection is the *North Pole of the Ecliptic*, where all the *Circles of latitude* drawn through every tenth degree of each *Sign of the Zodiac*, meet and intersect each other. The centre of the second projection is the *South Pole* of the Equator; the first of the two circles, which are described about it, is the *Antarctic circle*, the other is the *Tropic of Capricorn:* a little below the

The last star in the tail of *Ursa Minor*, or the *Less Bear*, is called the *Polar Star*, and serves for a guide to mariners; because, on account of its nearness to the north pole, its apparent situation, with regard to the Earth, varies but very little throughout the period of the Earth's annual revolution. Two of the stars in the constellation of *Ursa Major*, or the *Greater Bear*, are called

the centre of the second projection is the *South pole of the Ecliptic*, where all the Circles of Latitude meet and intersect, as in the Southern Hemisphere. From the Poles of the Ecliptic as centres, the *Circles of Longitude* are drawn at every tenth degree: that circle which is described at 90° from each pole of the Ecliptic, is the *Ecliptic* itself; of this, half appears in the one projection, and half in the other; it interests the Equator in the first points of Aries (♈) and Libra (♎). The diameter of each projection which crosses it from top to bottom, is called the *Solstitial Colure*, because it passes through the solstitial points, *Cancer* (♋) and *Capricorn* (♑): the diameter that crosses each projection from right to left denotes the *Equinoctial Colure*, so called because it passes through the equinoctial points, *Aries* and *Librâ*. These four points of the Ecliptic which are crossed by the Colures are called *Cardinal Points;* and when the Sun enters one or other of these points, one of the four *Seasons* of the year commences.

The Stars are given in this plate as they appear on the surface of the *Celestial Globe*, with this difference, that the figures of the Constellations are omitted, as they would only tend to create confusion when the Hemispheres are projected on so small a scale. The Stars of different magnitudes are so distinguished, that with little difficulty they may be reckoned in many instances: Thus, in *Ursa Minor*, or the *Less Bear*, it is easy to reckon two stars of the second, one of the third, three of the fourth, one of the fifth, and three of the sixth magnitude. Again, in *Canicula*, or the *Little Dog*, you may discover ten stars, whereof one, called *Procyon*, is of the first magnitude.

the

the Pointers, because they always point very nearly to the polar star.

Those of the fixed stars which are nearest to us seem largest, and are therefore said to be of the first magnitude; those of the second magnitude, being at a greater distance, seem less; and thus they proceed by regular gradations unto the sixth magnitude, which includes all the rest of the fixed stars that are visible without a telescope. With regard to their number, a common observer might be led to suppose that even to the unassisted eye they are innumerable: but this arises from their being observed in a confused manner: for it may be proved, that when they are divided into proper classes, and reckoned up, those in the visible hemisphere, seen without a telescope, amount not to many more than a thousand.

Since the introduction of telescopes into astronomical observations, the number of fixed stars has been very justly considered as immense; for, to the greater perfection our glasses are carried, the more stars we discover. The astonishingly immense distance of the fixed stars from one another, and from the earth we inhabit, is one of the most proper considerations for elevating our ideas of the works of GOD. Astronomers have computed from indubitable principles, that the distance of Sirius or the Dog Star (which is the nearest fixed star) from us, is considerably more than two millions of millions of miles! A distance almost inconceivable! A cannon-ball flying from thence

at

at the rate of 400 miles in an hour, would not reach us in 570,000 years.

The stars being at such great distances from the sun, cannot possibly receive from him so strong a light as they shine with: hence, on mature reflection, it will appear that they shine with their own native lustre, in like manner with the sun; and since each star is confined to a particular portion of space, we must reasonably conclude that each fixed star is in reality a sun *.

It is not at all probable that the ALMIGHTY, whose actions all evince infinite wisdom; and who does nothing in vain, should create so many glorious suns for no other purpose than to add to our pleasure, and give us an additional glimmering of light. Those who are so fond of arrogating Divine favours to themselves have but a mean opinion of Infinite Wisdom; since, by a considerably

* "That stars are suns will scarcely admit of a doubt. Their immense distance would perfectly exclude them from our view, if the light they sent us were not of the solar kind. Besides the analogy may be traced much farther. The sun turns on its axis; so does the star Algol; so do the stars called β Lyræ, δ Cephei, η Antinoi, o Ceti, and many more; most probably all. From what other cause can we so probably account for their periodical changes? Again, our sun has spots on its surface; so has the star Algol; and so have the stars already named; and probably every star in the heavens. On our sun those spots are changeable; so they are on the star o Ceti; as evidently appears from the irregularity of its changeable lustre, which is often broken in upon by accidental changes, while the general period continues unaltered. The same little deviations have been observed in other periodical stars, and ought to be ascribed to the same cause."

HERSCHEL.

less

less degree of creating power, our earth would have received much more light from only one additional moon.

And canst thou think, poor worm, these orbs of light,
In size immense, in number infinite,
Were made for thee alone, to twinkle in thy sight?
Presumptuous mortal! can thy nerves descry,
How far from thee they roll, from thee how high?
With all thy boasted knowledge canst thou see
Their various beauty, order, harmony?
If not—then sure they were not made for thee.

BAKER.

Instead, then, of one sun and one world only in the universe, as the unscientific suppose, our contemplations induce us to acknowledge that there must be an inconceivable number of suns and of systems of planets revolving round them, dispersed through the infinitely wide expanse of boundless space; insomuch that were our sun, with all the planets about it, annihilated, they would be no more missed by an eye that could take in the whole creation, than a drop of water from the wide ocean.

——"Our single system is as nought in estimate
"When balanc'd with the heav'ns: greater the speck
"Which on the sun-beam dances, when compar'd
"With Taurus, or the Alps, or Caucasus;
"Or on the blade the dew-drop to the sea."

These reflections tend to excite a deep consciousness of our own inferiority. Who can help exclaiming with *David* after a similar contemplation—"Lord, what is man, that thou art mindful "of him?"

As there is a general analogy running through and connecting every part of the creation, into one grand whole: and as there is undoubtedly an absolute similarity between the earth we inhabit and the other planets in our system; can it be unreasonable to suppose that they and the planets of other systems have plants, and trees, herbs, fruits, &c. &c. as we have? Or is it repugnant to nature to imagine that they are inhabited by animals and rational creatures? Among numberless arguments which might be adduced, a very good one to shew the great probability of the planets being inhabited, is derived from the following consideration. There is no part of matter that we are acquainted with, which lies waste and useless: seas, lakes, and rivers, teem with living creatures; mountains and vallies; trees and herbs; grasses and the animals which feed upon them; nay, even the blood and humours of the animals themselves, all have their respective inhabitants. Surely, then, the most numerous and large bodies in the universe, are furnished with beings adapted to their several situations. What an august conception does this give of the works of the CREATOR! Almost more than the human imagination is able to conceive.

Millions of suns at immense distances from each other; attended by tens of millions of worlds moving round them, all in rapid motion, yet regular and calm: and these, we may safely infer, are

are inhabited by millions of millions of rational creatures formed for endless felicity;

> ——Hail! Source of being! universal Soul
> Of heaven and earth! essential Presence hail!
> To THEE I bend the knee, to THEE my thoughts
> Continual climb, who with a master-hand
> Hast the great whole into perfection touch'd!
>
> THOMSON.

When an innumerable multitude of bodies of enormous bulk, are all set in motion, and keep travelling through their extensive orbits with such beauteous regularity and order, by means of the attraction of the suns to which they respectively belong; without having their motions either destroyed or directed into other courses; how can we express our conceptions of the greatness, wisdom, and goodness of HIM who made and governs the whole?

"By the *word* of the LORD were the heavens "made, and all the host of them by the *breath* "of his mouth." *(David)* What an amazing instance of Omnipotence! How inconceivably great do these his marvellous works evince him to be: then

> Since the great Sovereign sends ten thousand worlds,
> To tell us he resides above them all,
> In glory's unapproachable recess: YOUNG.

how can we forbear venting our adoration in hymns of praise?—Previous to my closing this Lesson I shall therefore insert a hymn indited by

 inspiration.

inspiration, and translated into our language by no less a Christian and poet than Mr. *Addison*.

HYMN. PSALM XIX.

THE spacious firmament on high,
With all the blue etherial sky,
And spangled heavens, a shining frame,
Their great Original proclaim.
Th' unwearied sun from day to day
Does his Creator's power display,
And publishes to every land
The work of an Almighty hand.

Soon as the evening shades prevail,
The moon takes up the wondrous tale,
And nightly, to the listening earth,
Repeats the story of her birth;
While all the stars that round her burn,
And all the planets, in their turn,
Confirm the tidings as they roll,
And spread the truth from pole to pole.

What though in solemn silence all
Move round the dark terrestrial ball?
What though nor real voice, nor sound,
Amid their radiant orbs are found?
In reason's ear they all rejoice,
And utter forth a glorious voice;
For ever singing, as they shine,
The HAND *that made us is divine!*

END OF THE ASTRONOMICAL PART.

LESSON

LESSON XVI.

ON THE ATMOSPHERE.

Diffusing gently its enlivening pow'r,
The genial Air we all around us feel
Cheering—though unexplor'd by human sight.

AS we have now finished our survey of the heavenly bodies, our inquiries may naturally descend to the Earth we inhabit: and here the first thing which attracts our attention is, that thin, transparent, and fluid body, called *Air*, which surrounds this terraqueous globe, and covers it to a considerable height. Or, if we include in our definition the whole of the fluid mass, consisting of air, electric matter, aqueous and other vapours, which surrounds the Earth, and partakes of all its motions; we then make use of the word *Atmosphere*, as a term comprising the whole. Beside the different kinds of air, it is manifest that the whole mass of the atmosphere contains a considerable quantity of water, together with an heterogeneous collection of particles exhaled from all solid or fluid bodies on the surface of the Earth. These, however, are transformed into a fluid mass called *Atmospheric Air*, which is that transparent, colourless fluid which every where invests this globe, possessing permanent elasticity and gravity. It is composed of four gases, but principally of 78 parts of *nitrogen* and 22 of *oxygen* gas in bulk; and in

 weight

weight of about 74 *nitrogen*, and 26 *oxygen*; and is soluble in about 30 times its bulk of water: 100 cubic inches weigh 31 grains. On the surface of the earth it is compressed by the weight of the superincumbent atmosphere: its density, therefore, diminishes according to its height above the earth. It is dilatable by heat: at 60° of temperature, its bulk is increased about its 1-82d part. The constituent principles of atmospheric air are rendered evident by the following experiment: quicksilver being enclosed in a proper vessel of atmospheric air, on heat being applied the air will be diminished, and the quicksilver will lose its splendour, and gradually change to a reddish powder; acquiring, at the same time, an augmentation of weight. When neither the air nor the quicksilver suffers any farther change, the separation of the principles has taken place: the one, the gas remaining in the receivers, is now unfit for supporting flame, or maintaining respiration, and is nitrogen gas: the other is absorbed by the quicksilver, while reducing to the state of an oxide, and may be extricated from it on the application of heat; when the powder, to which the quicksilver is reduced, will be restored to its metallic state, but will have lost the weight it had gained during its oxidation; this deficiency being exactly equal to the weight of the evolved gas, which is oxygen gas. These separated gases, thus differing in their properties from each other, and, from atmospheric air being again mixed, form atmospheric air of the ordinary degree of purity.

The

The following is Mr. Dalton's table of the weights of the different gases constituting the atmosphere :—

	Inches of Mercury.
Azotic Gas	23.36
Oxygenous Gas	6.18
Aqueous Vapour	.44
Carbonic Acid Gas	.02
	30.00

Table of the proportional weights of the different gases in a given volume of atmospheric air, taken at the surface of the earth :—

	Per Cent.
Azotic Gas	**75.55**
Oxygenous Gas	**23.32**
Aqueous Vapour	**1.03** variable
Carbonic Acid Gas	**.10**
	100.00

The uses of the Atmosphere are so many and great, that it is absolutely necessary, not only to the comfort and convenience of mankind, but even to the existence of all animal and vegetable life. Experiments which have been frequently made with an instrument called an *air pump,* place it beyond doubt that without the air or atmosphere, no animal could exist, or even be produced: without its aid all vegetation would cease, neither would there be any great degree of either inflammation or combustion. Sound could not be produced without it, nor would there be either rains or dews to moisten the ground: in short, all our

 reflections

reflections on the atmosphere will tend more clearly to convince us that we continually stand in need of the superintendance of our allwise CREATOR.

Besides other innumerable conveniences which we receive from the atmosphere, one great advantage is, that while the Sun shines, it makes the face of the heavens appear lucid and bright: but, on the contrary, if there were no atmosphere surrounding the Earth, only that part of the sky would appear light in which the Sun was placed: if a person should turn his back to the Sun, he would directly perceive it as dark as night, and the least stars would be seen to shine, as in the clearest night. For in that case there would be no substance to reflect the rays of the sun to our eyes; and of course, those which did not fall upon the Earth would be thrown out into infinite space, and would never be reflected back to us. But since there is an atmosphere covering the Earth, which is strongly illuminated by the Sun, it, by its power of reflection, turns the light towards us, and makes the whole heavens to shine with such splendour as to render the light of the stars invisible in the day-time.

By means of the atmosphere it happens, that though after the Sun has set, we receive no direct light from the Sun, yet we enjoy its reflected and refracted light for some time; so that the darkness of the night does not come on suddenly (as it would otherwise do) but by degrees. For, after the Earth by revolving on its axis has withdrawn us from seeing the Sun; the atmosphere (whose reflecting part reaches to the height of about sixty miles) will still be illuminated by that luminary: so that for a while the whole heaven will have some of his light imparted to it. But as the Earth pursues its revolution, the Sun retires farther below the horizon; and so much the less is the atmosphere illustrated by him: until the Sun is about eighteen degrees below the horizon, when he no longer enlightens our atmosphere, and then all that part thereof which is over us becomes dark.

Likewise in the morning, as soon as the Sun comes within eighteen degrees of the horizon, he begins again to enlighten the atmosphere, and to diffuse his light over the sky: so that its brightness does still increase, till the Sun rises and makes full day. This kind of illumination between day and night, which is observed in the morning before the Sun's rising, and in the evening after his setting, is called *Crespusculum* or *Twilight*. It is longest in England, from May 24th to July 23d; during which period there is "no real night;" and shortest on March 2d and October 12th, when its duration at London is about 1 hour 55 minutes.

The terrestrial atmosphere also refracts those rays which fall upon it from the Sun and Stars, and changes their directions, by propagating the light in other lines, and thus making the apparent places of the celestial bodies different from their true places. This refraction causes the Sun to be visible before he has risen above the horizon, and to protract his stay with us after he is set in the evening. This is an admirable contrivance to shorten the long and dismal nights in the frigid zones, and thus to add to the comfort of the inhabitants of those forlorn regions. *Varenius* relates in his geography, that "to those Hollanders "who wintered in *Nova Zembla*, the Sun was "visible, in a clear sky, sixteen days before it ac"tually rose above the horizon, being yet four de"grees below it." And *Hook*, speaking of the same circumstance, says,—"The night in that "place shortened no less than a whole month; "which must needs be a very great comfort, to "all such people as live very far towards the "North and South poles, where length of night, "and want of seeing the Sun, cannot but be very "tedious and irksome."

Though it is rather foreign from the immediate subject of this Lesson, yet I shall here relate a few properties of refraction; as it will somewhat tend to elucidate what is above-mentioned with regard to the twilight. By numerous experiments we find that the rays of a luminous body or even of any visible object, when they fall upon a medium or diaphonous body of air or water of a different density from that from whence they first proceeded, do not afterwards go directly in the same straight lines, but are broken or bent, and proceed as though they had been propagated from another point. And if the medium on which they fall be denser than the first, they are bent towards a line perpendicular to the surface whereon they fall

at

at the point of incidence; but if it be a rarer medium, in their bending they recede from the perpendicular.

We observe in nature many effects of refraction: for instance—A staff, one part of which is immersed in water, and the other in air, appears broken; and that part which is in water appears higher than it really is. Again—Take a tub, whose sides are straight, and in the middle of the bottom lay a shilling, or any other visible object, fixed so that it cannot move, then go so far from the tub that you can but just see the object, and stand there till another person more than half fills the tub with water, and the shilling will then appear as though it were removed some distance farther from you: this experiment may be varied several ways.

Another remarkable instance of refraction is the following:—A person standing by the side of the river Thames at Greenwich, when it is high water there, may see the cattle grazing on the marshy meadow on the other side of the river called the *Isle of Dogs*; but when it is low water there, he cannot see any thing of them, they being hid from his view by the bank on the other side the river. This curious effect is probably owing to the moist and dense vapours just above the surface of the water, being raised higher or lifted up with the surface of the water at the time of high tide; the rays passing through these vapours are so much refracted as to render those

things

things visible, which are not to be seen at the time of low water.

But to return from this digression, and proceed with our account of the air and atmosphere: the science which treats of the weight, pressure, and elasticity of the air is called *Pneumatics.* And here it may be first observed, that the air is a fluid body which surrounds and gravitates upon all parts of the earth's surface. But it differs from all other fluids in the following particulars: 1. It can be compressed into a *much* less space than what it naturally possesses, which no other fluid can. 2. It cannot be congealed as other fluids can. 3. It is of a different density in every part upward from the earth's surface, decreasing in its weight, bulk for bulk, the higher it rises: and therefore must also decrease in density; and the law of diminution is such, that when the heights increase in arithmetical progression, the densities decrease in geometrical progression. 4. It is of an elastic or springy nature: and the law it observes in this respect is, that the force of the spring is equal to its weight, or the density is always proportional to the force by which it is compressed. We may also observe that heat increases and cold diminishes the elasticity of the air: or heat expands and cold condenses it.

The weight or pressure of the atmosphere upon any base at the surface of the earth, is equal to the weight of a column of quicksilver of the same base, and its height between twenty-eight and thirty-one inches:

inches: or equal to the weight of a column of water of the same base and height, between thirty-two and thirty-five feet. The first part of this is proved by observations on the *Barometer*, an instrument which measures the pressure of the air: for the limit of barometrical variation is between twenty-eight and thirty-one inches. And the latter part is proved by the sucking pump, which will never raise water higher than thirty-five feet, and sometimes not higher than thirty-two. This variation in the weight of the atmosphere depends in great measure on the different degrees of heat in the air near the surface of the earth; but, perhaps it depends in a much greater degree, on the commotions and changes in the atmosphere from wind, vapours, and other causes.

From the foregoing account of the weight of the atmosphere, it will not be difficult to infer, that, at a medium, there is a pressure equal to nearly fifteen pounds avoirdupois upon every square inch: this entirely arises from its weight and fluidity. By the combination of these two qualities, which bind down all bodies on the earth with such great force, many wonderful effects are produced: it is this which prevents the arterial vessels of animals and plants from being too much distended by the impetus of the circulating juices, or by the elastic force of the air so copiously abounding in them: it is this also which hinders the fluids from transpiring in too great a degree through the pores of their containing vessels, which would otherwise destroy the animal by a debility gradually brought on: to this are also owing many natural phænomena by far too numerous to be mentioned in this place.

Another property of air, and which indeed is its chief criterion, is its elasticity or springiness; it is by virtue of this quality that it dilates itself, after the removal of any pressure; or contracts itself into a less space when it has to sustain a greater pressure. A familiar instance of this quality you may often have observed; namely, by having a fresh bladder filled with air; for when squeezed in the hand the air makes a sensible resistance, but when the hand is taken away, the parts which were compressed, directly restore themselves to their former state.

I have before observed that the air presses on a square inch with the weight of 15lbs. on a medium. Now if we suppose the surface of a full-sized human body to be ten square feet, which is not too much, we shall find, (as it is the nature of the air to press equally in all directions,) that a man who probably supposes he bears no weight, sustains a pressure of no less than 21,600 lbs. When we consider that the greater part of us are surrounded with such an astonishing pressure, and that this pressure may in the course of a very few hours be either increased or diminished by more than a thousand pounds weight; are we never led to reflect upon that POWER who keeps us from utter destruction? Let the Atheist consider what

he

he has to expect, for his blasphemous denial of so wise and mighty a Being.

Another remarkable property of air, which ought to fill our hearts with thankfulness to the adorable CREATOR, is its transparency: let us recollect in what a dreary and disconsolate situation we should be if the air were visible. What would then be the use of that noble instrument the eye? Or how should we discern those diversified and variegated prospects of distant towns, green woods, flowery meadows, fields of corn, &c. which now so often give us pleasure? Alas! how dismal and gloomy would be the reverse! Surely our hearts must overflow with gratitude to the DIVINE AUTHOR of our existence, for such unbounded goodness to us his creatures.

Before we terminate this Lesson, we cannot forbear recurring to the use of the air in respiration; but shall point out one or two striking instances which it furnishes of exquisite contrivance for the most beneficent purposes.

Animal heat is preserved *entirely* by the inspiration of atmospheric air! The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body. Nothing can afford a more striking proof of creative wisdom, than this provision for the preservation of an equable animal temperature. By the decomposition of atmospheric air, caloric is evolved, and this caloric is taken up by the arterial blood, without its temperature being at all raised by the

addition.

addition. When it passes to the veins, its capacity for caloric is diminished, as much as it had been before increased in the lungs: the caloric, therefore, which had been absorbed, is again given out; and this slow and constant evolution of caloric in the extreme vessels over the whole body, is the source of that uniform temperature which we have so much occasion to admire. Dr. Crawford ascertained, that whenever an animal is placed in a medium, the temperature of which is considerably high, the usual change of arterial into venous blood does not go on; consequently, no evolution of caloric will take place, and the animal heat will not rise much above the natural standard. How pleasing it is to contemplate the arrangements which the Deity has made for the preservation and felicity of his creatures, and to observe that he has provided for every possible exigency!

Lavoisier has shewn, that in respiration there is a constant combination of the oxygen of the atmosphere with the hydrogen and carbon of the blood.

> Thus *life* discordant elements arrests,
> Rejects the *noxious* and the *pure* digests;
> Combines with heat the fluctuating mass,
> And gives a while solidity to gas. DARWIN.

A postulatum has been assumed by some atheists, that the organs of the body have been formed by what they call *appetency*, i. e. endeavours perpetuated, and imperceptibly working its effects through a long series of generations: but I would ask

ask any one, whether he would venture to assert that he believes this to be the way in which the lungs acquired the faculty of decomposing atmospheric air; and that he believes that this hypothesis is sufficient to account for *the composition of this air*, which so exactly suits the operation of these lungs, and which contains that exact portion of caloric which the animal œconomy requires! It is worthy of remark, that cold-blooded animals, which are not furnished with this breathing apparatus, are so constituted that their temperature changes with every change of the temperature of the surrounding medium. Frogs have been absolutely frozen so as to chip like ice, and then when carefully and gradually thawed, have been completely re-animated.

Lastly, it may be remarked, that the interval which there is between every inspiration seems to have been designed to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed.

During that *remarkable* interval that always occurs in breathing, there is sufficient time allowed for the noxious fluids to separate; the first to ascend, while the other preponderates, leaving a space for a fresh current of uncontaminated atmospheric air. Thus every thing is prepared by Divine Goodness, without any care or forethought of ours, for a new inspiration.

The air inhaled is not the gas
That from a thousand lungs reek back to thine,
Sated with exhalations rank and fell,
Which, drunk, would poison the balsamic blood,
And rouse the heart to ev'ry fever's rage—
But air that trembling floats from hill to hill,
From vale to mountain, with incessant change
Of purest element.
ARMSTRONG.

LESSON XVII.

ON WINDS.

Trade-winds, observing well their stated course,
To human good employ their powerful force:
The loaded ships across the ocean fann'd
By steady gales, spread commerce through the land.
These you observe—but have you no desire
The hidden Spring of such effects t'inquire?
Or, when contending winds around you blow,
Do you ne'er wish the cause of them to know?

HITHERTO our reflections have carried us no farther than to consider the air in a motionless state; but as this fluid mass is frequently in motion, and that too sometimes in a violent degree, it would be almost unpardonable to pass by such an obvious effect without paying some attention to it.

Air in a current-like motion is known by the name of *wind*. Though the winds in a temperate zone of the earth are very inconstant and changeable, yet this is not the case in every part of the terrestrial globe; for in the torrid zone and some other parts, the winds are generally very uniform and constant in their directions, as will appear from the following facts relative to them:—

1. Over the Atlantic and Pacific oceans, particularly between thirty degrees of North and thirty degrees of South latitude, the *Trade-winds*, as they are

are called, blow uniformly from east to west, all the year round, with a small variation in the different seasons.—2. When the sun is on the equator, the *Trade-winds* in sailing northward, veer more and more from the east towards the north; so that about their limit they become nearly north-east: and *vice versa* in sailing southward, they become at last nearly south-east.—3. When the sun is near the Tropic of Cancer, the *Trade-winds* north of the equator, become more nearly east than at other times, and those south of the equator more nearly south; and *vice versa*, when the sun is near the Tropic of Capricorn.—4. The *Trade-winds* are not due east upon the equator, but about four degrees to the north of it.

To account for these facts relative to the winds is a most curious and important, though mysterious inquiry; having employed the pens of several very eminent philosophers: but amongst all the explanations I have seen, there is none in my opinion more agreeable to nature than one given by Mr. *John Dalton*, of Manchester, in his "Meteorological Observations and Essays." The method of reasoning applied to the subject in that work, I shall here adopt.

The inequality of heat in the different climates and places, and the earth's rotation on its axis, appear to be the principal causes of all winds, regular and irregular. It may be observed, that whenever the heat is greatest, there the air will ascend, and a supply of colder air will be received

from

from the neighbouring parts: it will be willingly allowed that the heat is at all times greatest in the torrid zone, and decreases gradually in proceeding northward or southward; also that the poles may at all times be considered as the centres of cold. Hence it manifestly results, that, abstracting from accidental circumstances, there will be a constant ascent of air over the torrid zone, which air will afterwards fall northward and southward, whilst the colder air below is determined by a continual impulse towards the equator.

When the effects of the earth's rotation are taken into consideration, our reasoning must be as follows:—The air over any part of the earth's surface, when apparently at rest or calm, will have the same rotatory velocity as that part; but if a quantity of air in the northern hemisphere receive an impulse in the direction of the meridian, either northward or southward, its rotatory velocity will be greater in the former case, and less in the latter, than that of the air into which it moves; consequently, if it move northward, it will have a greater velocity eastward than the air, or surface of the earth over which it moves, and will therefore become a south-west wind, or a wind between the south and west. And *vice versa*, if it move southward, it becomes a north-east wind. From similar considerations it will appear, that in the southward hemisphere the winds will be north-west and south-east respectively.

The *Trade-winds* may therefore be explained thus: The two general masses of air proceeding from

from both hemispheres towards the equator, as they advance, are constantly deflected more and more towards the east, by reason of the earth's rotation; that from the southern hemisphere originally a south wind, is made to veer more and more towards the east: in like manner, that from the northern hemisphere is made to change its direction from the north towards the east. These two masses meeting near the equator, their velocities south and north destroy each other, and they proceed afterwards with their common velocity from east to west round the torrid zone, excepting the irregularities produced by the continents. The equator is not in reality the place of concourse, but the northern parallel of four degrees: because the centre of heat is thereabouts, the sun being no longer on the north side of the equator than on the south side. Moreover, when the sun is near one of the tropics, the centre of heat upon the earth's surface is then nearer that tropic than usual, and therefore the winds about the tropic are more nearly east at that time, and those about the other tropic more nearly north and south.

If all the terrestrial globe were covered with water, or, if the variations of the earth's surface in heat were regular and constant, so that the heat was the same in every part of the same parallel of latitude, the winds would then be very nearly regular also. But this is not the case: for we find the irregularities of heat, arising from the interspersion of land and sea, are such, that though all the parts of the atmosphere in some measure conspire to produce

produce regular winds about the torrid zone, yet very striking irregularities are often found to take place. A remarkable instance we have in *Monsoons*, which are winds that in the Indian ocean, &c. blow for six months together one way, and the next six months the contrary way: these with sea and land breezes do not seem easily accounted for on any other principle than that of rarefaction.

Perhaps some persons may be led to suppose that the winds in the northern temperate zone should be between the north and east towards the poles, and between the south and west nearer the equator, almost as regular as the Trade-winds: but when the changes of seasons, the different capacities of land and water for heat, the interference and opposition of the two general currents are considered, it might be concluded almost next to impossible that the winds in the temperate zone should exhibit any thing like regularity. However, notwithstanding this, observations sufficiently evince, that the winds therein are, for the most part, in the direction of one of the general currents: namely, somewhere between the south and west, or almost as commonly between the north and east; and that winds in other directions happen only as accidental varieties, chiefly in unsettled weather.

We may have frequently taken notice, that several winds, particularly stormy ones, are attended with a cloudy sky. To this it may be added, that we have more winds than usually occur in rather less latitudes, where the atmosphere is generally more serene: these considered make it exceedingly

ingly probable, that the aqueous vapours which are sustained by the air, from whence come clouds and rains may be one great cause of irregular winds. It has been determined, from very accurate experiments, that one inch of water when evaporated, will fill more than 2000 inches of space: from hence it appears that the water which falls in drops of rain, &c. possessed more than 2000 times the space when it floated in the atmosphere in vapours; the condensation thereof must therefore occasion vacuities of such a nature as will cause winds of different kind and degrees, according to the deficiency which is to be supplied.

The œconomy of winds, an illustration of which has been here attempted, is admirably adapted to the various purposes of nature, and to the general intercourse of mankind:—if the earth had been fixed, and the sun had revolved about it, the air over the torrid zone, and particularly about the equator would have been almost always stagnant: and in the other zones the winds would have had little variation either in direction or strength; in this case navigation would have been greatly impeded, and a communication between the two hemispheres by sea rendered impracticable. On the present system of things, however, the irregularity of winds is of the happiest consequence, by being subservient to navigation: and a general circulation of air constantly takes place between the eastern and western hemispheres, as well as between the polar and equatorial regions; by reason of which, that diffusion and intermixture of of the different aërial fluids, so necessary for the life, health, and prosperity of the animal and vegetable kingdoms, is accomplished :—such is the transcendant wisdom and providential care of the beneficent FATHER OF ALL!

LESSON XVIII.

ON SOUNDS AND ECHOES.

——— Sweet music breathe,
Above, about, or underneath,
Sent by some spirit to mortals good. MILTON.

ANOTHER peculiar motion of the air remains yet to be considered, which is, that by means of which *sounds* are rendered audible or sensible to us, under all their different affections and circumstances. Of the philosophy of sounds, *Music* is undoubtedly the essential and most refined part; and we find that persons in general are exceedingly fond of musical sounds, being thereby affected with the most agreeable and ravishing sensations. It is my province in this place to give no more of the science of *Music* than what relates to the production of musical sounds, and indeed of *sounds in general,* to which I shall now proceed *.

Experiments

* Though it be somewhat foreign to the subject immediately under discussion, yet I cannot pass by an opportunity of suggesting an obvious improvement in the practice of Music; the use of which has been frequently urged, though it be not yet generally acceded to. This improvement is no other than the substitution of proper characters to denote the different kinds and velocities of *musical time,* instead of those vague,

Experiments on the air-pump prove to us, that without the assistance of air, sounds cannot be produced: they also evince, that the nature of sounds depends entirely upon a certain motion of the aërial particles. This motion is a pulsive or vibratory one, carrying these particles forward and backward through the very same space: and it results from, or depends upon, the spring or elasticity of the air. It is by means of this power that, when any one particle is by any cause urged forward, it must necessarily propel the particle next before it: this second particle, in the same

vague, indefinite ones, which are now in use. What is the information we can obtain from casting our eyes upon the characters $\frac{2}{4}$, $\frac{3}{2}$, $\frac{3}{4}$, $\frac{6}{8}$, &c.? Why truly, no more than can be learned from reckoning up the Crotchets, Minims, Quavers, &c. in the first complete bar in the tune. The characters for the several rates of common time; and the terms Adagio, Largo, Allegro, Presto, &c. &c. are also of very little avail in ascertaining with precision the point the musician wishes to discover. Every composer of musical airs, &c. would be of real service to the practitioner, if he would point out the absolute rate at which his music is to be performed: this would be no difficult task; as he would only have to mention the length of a pendulum which would make one complete vibration in the time that part of a bar called a beat was performing. Thus, for instance, suppose I set a tune in triple time, and wish to have each bar performed in a second and a half, the character I must make use of is $\frac{3}{10}$; for from this it might be concluded that there were three beats in a bar, and each of these beats must be performed in the time a pendulum 10 inches long made one vibration.

To explain this method clearly, much more room is requisite; but the present would not be a proper place for it: however, those who understand what improvement is intended, from this short account, will, I hope, excuse me for exhorting them to use their best endeavours to make it general.

 manner,

manner, moves a third, and so on, successively: and by these means the motion is propagated in the several particles, through a certain space in a direction forward: but, on the other hand, when the force which was first imprest upon the elastic particles of air ceases to act, those particles return again, by the action of the air's elasticity, through the same space. It is evident, that if the producing force be continued on these elastic particles, there must necessarily be produced in them a mutual vibratory motion of each particle, so long as the repercussive force continues to act: and this motion of the aërial particles being continued until it reaches the *ear*, the different parts, nerves, &c. belonging to and contiguous to the organ of hearing, being exquisitely adapted to the purpose, convey the sensation to the *brain*, and so produce the idea or perception of sound.

The waves in water, and the pulses in air which produce sound, though brought about by two different causes, gravity and elasticity, are yet somewhat similar: if a stone be dropped into the water, it will cause waves to be propagated in a circular direction upon the water's surface all round the point where the stone was thrown in; in like manner, the motion of a sounding body is propagated around it in regular gradations: but the aqueous waves differ from the aërial pulses in this, that the former are circular, being generated on a plane *surface;* but the latter are of a spherical form, because they are produced in the *body* of an elastic fluid.

The

The kind of motion which produces sound must be understood to be that which is brought about by means of the elastic particles of which sonorous bodies consist; for without such an elastic disposition of parts they could not by any means be rendered sonorous, or capable of emitting sounds; because the stroke being made externally, affects the particles of such a body but with one single act: the particles of the body could therefore, in such a case, be moved only through a certain small space, and would there be made to stop by the resistance of the parts beyond: thus without an elastic force, the particles would remain at rest, after the percutient body was removed; and therefore, from a single stroke the parts of unelastic bodies could emit but a kind of blunt, short sound: in such cases, it is common to say *we hear the stroke*, as when we strike with a hammer on a piece of lead.

But when we consider the stroke impressed on bodies whose parts are in any considerable degree elastic, they not only yield to the stroke and go forward through a small space, but, after the striking body is removed, those elastic parts, by their renitent force, return again with a velocity equal to that by which they were displaced; and thus a vibratory motion being produced, will continue a perceptible time, and produce successive impulses on the contiguous air; hence, the air being thus agitated by the elastic particles of the body, transmits its impulses successively to the ear, and there produces a sensation of sound of some duration. Thus amongst sonorous bodies, we notice a wire when stretched and properly struck: also a bell and a glass, which are some of the fittest instruments for musical modulations. Much more might be said on the causes of sound in general; but for a general notion, what has been already mentioned may suffice.

To determine the nature and effect of different bodies in conducting sound, Mr. *George Saunders* made a variety of experiments: some of his conclusions and remarks are as follow:—

Earth may be supposed to have a two-fold property with respect to sound. Being very porous, it absorbs sound, which is counteracted by its property of conducting it, and occasions it to pass on a plane, in an equal proportion to its progress in air, unencumbered by any body. If a sound be sufficiently intense to impress the earth in its tremulous quality, it will be carried to a considerable distance, as when the earth is struck with any thing hard, as by horses' feet, or the motion of a carriage. Plaister is proportionally better than loose earth for conducting sound, as it is more compact.

Clothes of every kind, but particularly woollen ones, are very prejudicial to sound; their absorption of sound, may be compared to their absorption of water, which they greedily imbibe.

A number of people seated before others (as in the gallery of a chapel or theatre) considerably prevent the voice reaching those behind; and hence it is that we hear so much better in the front of the galleries,

galleries, than behind others. Our seats, rising so little above each other, occasion this defect; which would be remedied, could we have the seats to rise their whole height above each other, as in the ancient theatres.

Water has been little noticed with respect to its conducting of sound; but it has been lately found to conduct sound more than any other body whatever. A conversation delivered in no very loud tone, has been distinctly heard, on water, at the distance of a mile; and a whisper has been heard at the distance of more than two hundred yards.

Stone is sonorous, but gives a harsh disagreeable tone, unfavourable to music. Brick, in respect to sound, has nearly the same properties as stone.

Wood is sonorous, conductive, and vibrative. Of all materials, it produces a tone the most agreeable and melodious; and it is, therefore, the fittest for musical instruments, and for lining rooms and theatres.

Paint has been generally thought unfavourable to sound, from its being so to musical instruments, whose effects it entirely destroys. Musical instruments mostly depend on the vibrative or tremulous property of the material, which a body of colour hardened in oil must very much alter: but we should distinguish that this regards the *formation* of sound, which may not altogether be the case in the *progress* of it.

A remarkable circumstance in the nature of sounds, which well deserves the attention of my young readers, is, that every substance whatever, whose parts are so connected as to be capable of an uniform vibration, may have that vibration produced in it by the sounding of a certain musical note or tone, with which it is in unison. Thus *Kircher* speaks of a large stone that would tremble at the sound of one particular organ-pipe. Mr. *Boyle* states the fact of seats trembling at the sound of organs; he tells us also, that he has felt his hat to shake under his hand at certain notes, both of organs and other instruments; and he was told by an experienced builder, that any well-built vault will answer some determinate note. Even liquids, when so suspended as to be capable of vibration (for example, water in a glass), are observed, not only to vibrate when a particular note is struck or sounded, but actually sound themselves in concord. That water suspended in a glass becomes in reality a sonorous body, is proved by the mode of tuning a set of musical glasses, which become the graver in tone, the more water is poured into them; for, were it only the empty part of the glass that sounded, the sound would become more acute, as more water is poured in; but, as the contrary is the fact, it is thence evident that the water and glass together form one compound sonorous substance, of which the greater the quantity or volume, the deeper is its musical tone.

From what has been already stated, it will appear manifest, that when the producing cause of

any

any sound is at a distance, there must be an interval of time elapse before the sound itself can arrive at the ear; and, indeed, this may often have been manifested to us by our own observations. Thus, for instance, when a gun has been fired at a distance, we may have taken notice, that after we have seen the flash, some time has elapsed previous to our hearing the report: or again, when a woodman, remote from us, has been felling trees, we may have observed that an interval of time passes away after we have seen the action performed before we hear the stroke. The experiments which have been made to determine the velocity of sound, have neither been so numerous nor so accurate as could be wished; and on this account it is, that opinions differ concerning the nature of its progressive motion. Because the intensity of sound diminishes as the distance increases, some persons suppose that the velocity does also: they therefore imagine that the velocity is inversely as the distance, and consequently the time will be directly as the distance: but an opinion which meets with more advocates, and may now be regarded as confirmed, is, that sound moves uniformly in common, atmospheric air, at the rate of 1142 feet in one second of time, or about an English mile in $4\frac{2}{3}$ seconds; and this rate of motion being allowed, it will not be any way difficult to determine the time for the passage of sound, the distance being given, and *vice versa*, in a variety of cases.

A curious phænomenon with regard to sounds, is an *echo*, which is caused by the vibrating air being interrupted in its passage. For as the air undulates forward like a wave, it often meets with various objects, and by striking against them is reflected back to us, and causes new vibrations, which, if the object lie in a proper situation, return to us and repeat the same sound, tone, or word, as was first given : and this, it sometimes happens, not only once but several times.

From this short account of the nature of echoes, it will not be difficult to conceive that they also may be applied to the measuring of inaccessible distances : thus, Dr. Derham, standing upon the bank of the Thames opposite to Woolwich, observed that the echo of a single sound was reflected back from the houses on the opposite bank in 3 seconds ; consequently the sum of the direct and reflex rays must have been 1142 multiplied into 3, or 3426 feet, and the half of it, viz. 1713 feet, the breadth of the river in that place.

But to treat upon the nature of sounds in such a manner as the importance of the subject demands would fill a volume : I must therefore now desist. From what little has been here mentioned, the contemplative young reader will with pleasure draw this inference : that even in the nature and production of sounds the goodness of the CREATOR to his creatures is conspicuously shewn : for, if bodies had no degree of elasticity, or if the air were not so fluid as to be easily put in motion, there would be an end of all the melody and harmony which now so much delight us. What praise does that benevolent BEING require from us, us, who not only administers to us what is necessary for our welfare, but has contrived all around us in so admirable a manner as to be subservient to our pleasures!

"On the contrary, had God wished our misery, or even had he been *indifferent* to our happiness, he might have formed our senses to be so many pains and sores to us, as they now are instruments of gratification and enjoyment: or have placed us amidst objects so ill suited to our perceptions as to have continually offended us, instead of ministering to our refreshment and delight. He might have made, for example, every thing we tasted, bitter; every thing we saw, loathsome; every thing we touched, a sting; every smell, a stench; and every sound, a discord."

LESSON XIX.

ON EVAPORATION, RAIN, HAIL, SNOW, MISTS, AND DEW.

—— Th' effusive south
Warms the wide air, and o'er the void of heav'n
Breathes the big clouds with vernal show'rs distent.
At first a dusky wreath they seem to rise,
Scarce staining æther; but by swift degrees,
In heaps on heaps, the doubling vapour sails
Along the clouded sky. THOMSON.

OUR next business is to reflect upon the means by which the most usual meteors, as *Rain, Hail, Snow,* and the all-enlivening *Dew,* are produced: and in order to this, the first thing we are to consider is the process of *Evaporation.* To have a precise idea of *evaporation,* some persons distinguish it from *exhalation,* and say that the former is the act of dissipating the humidity of a body in fumes or vapour; while the latter, they say, is properly a dispersion of dry particles issuing from a body. Others say there is no need of any such distinction, *exhalation* (properly signifying a *breathing forth*) being applicable to all bodies capable of being respired, whether moist or dry. The term commonly used by chemists for the raising of the minute particles of bodies in a dry form,

form, is *sublimation*. *Evaporation* is by them generally applied to bodies in a state of humidity; and *precipitation* is the falling down of any body, dry or humid, which has been held in solution in any other body.

There are, indeed, few subjects of philosophical investigation that have occasioned a greater variety of opinions than the theory of Evaporation: as such a diversity of opinions yet exist, it is almost next to impossible to advance one, but what may be contradicted, and, in some respect, refuted: however, be this as it will, among the various theories I shall make use of the following.

Dr. *Hamilton*, late Professor of Philosophy in the University of Dublin, supposes that Evaporation is nothing more than a gradual solution of water in air produced and promoted by attraction, heat, and motion, just as other solutions are effected. To account for the ascent of aqueous vapours into the atmosphere, this ingenious author observes, that the lowest part of the air being pressed by the weight of the upper against the surface of the water, and continually rubbing upon it by its motion, attracts and dissolves those particles which it is in contact with, and separates them from the rest of the water. And since the cause of solution in this case is the stronger attraction of the particles of water towards the air, than towards each other, those that are already dissolved and taken up, will be still farther raised by the attraction of the dry air that lies over them, and thus will

will diffuse themselves, rising gradually higher and higher, and so leave the lowest air not so much saturated but that it will still be able to dissolve and take up fresh particles of water; which process is greatly promoted by the motion of the wind. When the vapours are thus raised and carried by the winds into the higher and colder regions of the atmosphere, some of them will coalesce into small particles, which slightly attracting each other, and being intermixed with air, will form *clouds;* and these clouds will float at different heights (varying from less than half a mile to somewhat more than two miles) according to the quantity of vapour borne up, and the degree of heat in the upper part of the atmosphere: and thus, clouds are generally higher in summer than in winter.

When the clouds are much increased by a continual addition of vapours, and their particles are driven close together, by winds, cold, and other causes, then will they run into drops heavy enough to fall down in *Rain:*

> —The clouds consign their treasures to the fields,
> And, softly shaking on the dimpled pool
> Prelusive drops, let all the moisture flow
> In large effusion o'er the freshen'd world.
>
> THOMSON.

In the winter, when the air is disposed for freezing, it is not unlikely that the atoms of vapour which are near the earth are congealed, whereby they become more opaque, and form those obscure fogs which constitute a hoar frost. At this time

time the clouds are probably frozen before their particles are gathered into drops: small pieces of them being condensed and made heavier by the cold, fall down in *Snow*:—

> Then from aërial treasures downward pours
> Sheets of unsullied snow in lucid showers;
> Flake after flake, through air, thick wav'ring flies,
> Till one vast shining waste all natnre lies.
> Then the proud hills a virgin whiteness shed
> A dazzling brightness glitters from the mead;
> The hoary trees reflect a silver show,
> And groves beneath the lovely burden bow.
>
> BROOME.

On a close examination, Snow is found to be composed of icy darts or stars united to each other, as crystals of water commonly are, whether they compose ice, snow, or hoar frost, at angles of 60 or 120 degrees. Its whiteness is owing to the small particles, into which it is divided, refracting and reflecting, instead of transmitting, all the rays of light that fall upon it. Ice, when pounded, becomes equally white.

If drops of rain in their falling pass through a region of cold air, they become congealed in their passage, and fall in *Hailstones*: but *Signior Beccaria* supposes that Hail is formed in the higher regions of the air, where the cold is intense, and where the electric matter is very copious.

In the months of October and November, *Fogs* or *Mists* are more frequent and thicker than at any other period of the year. If we consider the cause

of

of *Fogs*, the reason of this will appear evident. There is, besides the evaporation from the seas, lakes, and rivers, a constant and very large exhalation from the surface of the earth, at all seasons, of water in the form of vapour; and the warmer the ground the greater will be the evaporation. When the air is warmer, or even but a little colder than the earth, the ascent of vapour is not perceptible to the eye: but when the temperature of the air is considerably lower, the vapour as soon as it rises is deprived of part of its heat, the watery particles are brought more into union, and they become visible in the form of steam. It is also essential to the formation of Fog, that there should be little or no wind stirring, in order that the rising exhalations may have full opportunity to condense. The heat of the middle of the days in autumn is still sufficient to warm the earth and cause a large ascent of vapour, which the chilling frosty nights, which are also generally very calm, condense into Fogs.

When vapour is condensed into small drops upon the surface of bodies on the ground, it is called *Dew;* the most apparent difference between Dew and Rain is, that the condensation of vapour, in the one case, is made at or near the surface of the body receiving it, and in the other the drops fall a considerable space before they reach the earth: the cause is the same in both cases, namely, cold operating upon vapoury air. At first view, it will appear improbable that a condensation of vapour should take place in the air resting upon the earth's surface,

surface, which is generally supposed to be warmer than that above; but it is an incontestible fact, that after sun-set, and during the night, in serene weather, the air is coldest at the earth's surface, and grows warmer the higher we ascend, till a certain moderate height, commonly between 20 and 100 yards: accordingly we find, that *Dews* and *Hoar Frost* are more copious in valleys than in elevated situations. When we recollect that winds in great measure prevent the accumulation of Dew, it can scarcely be doubted but that it depends upon the above circumstance.

It would be nearly inexcusable to conclude this Lesson, without calling the attention of my young readers, for a moment, to the beneficent and wise laws established by the AUTHOR OF NATURE to provide for the various exigencies of the sublunary creation, and to make the several parts so dependant upon each other, as to form one well-regulated whole. In the torrid zone, and, it may be added, in the temperate and frigid zones also, in summer, the heat produced by the action of the solar rays would be insupportable, were not a large portion of it absorbed, in the process of Evaporation, into the atmosphere, without increasing its temperature. This heat is again given out in winter, when the vapour is condensed, and mitigates the severity of the cold. The dry spring months are favourable to agriculture, and the Evaporation, which then begins to be considerable, absorbs a portion of the heat imparted to the earth by the sun, and thus renders the transition from cold to heat

heat slow and gradual. In autumn, the sun's influence fails apace, but the condensation of vapour contributes to keep up the temperature and prevent too rapid a transition to winter.

Thus have you another page of the *volume of nature* opened to your view; and though descanted upon in a concise manner, I have no doubt but that it will be an additional incentive for you to increase in gratitude, reverence, and love for the adorable AUTHOR of all good.

LESSON XX.

ON FROST.

What art thou, Frost! and whence are thy keen stores
Deriv'd, thou secret, all-invading power,
Whom even th' illusive fluid cannot fly?

THOMSON.

HOW admirably wonderful and diversified are the operations of *Frost!* The thronging multitudes of the stars with peculiar brilliancy glitter through the fair expanse, while the Frost pours its subtle and penetrating influence all around; and sharp and intensely severe throughout the long night continues its rigid operations.

Loud rings the frozen earth, and hard reflects
A double noise: while at the evening watch
The village dog deters the nightly thief:
The heifer lows; the distant water-fall
Swells in the breeze; and with the hasty tread
Of traveller, the hollow sounding plain
Shakes from afar.

THOMSON.

When, late and slowly, the morning opens her pale eye, in what a curious and amusing disguise is nature dressed! The icicles, jagged and uneven, hang pendant from the eves, and a whitish film encrusts the windows, where mimic landscapes rise, and fancied figures swell. The once fruitful fields are hardened as iron, and the moistened mea-

dows

dows are firmly congealed. The limpid stream is arrested in its career, and its formerly flowing surface chained to the banks. The fluid paths become a solid road; and where the finny shoals were wont to rove, the sportive youths slide, or with rapid motion skate along the crystal pavement. When these and other wonders brought about by *freezing*, are considered, surely it is not unnatural to ask—how are they occasioned? This, perhaps, cannot be answered with the wished-for accuracy: however, though the following observations do not entirely determine the point under consideration, they may yet be somewhat amusing.

The fixing of a fluid body into a firm or solid mass by the action of cold, is called *freezing*, or *congelation*; in which sense the terms are applied to water when it freezes into *Ice*. By what mean it is that fluid bodies should thus be rendered solid by cold, the learned have not yet been able to discover. It would seem, however, that it arises from the air then abounding with nitrous and saline particles, which insinuate themselves into the pores of water, &c. by which mean they become hard. This is the more probable when it is considered that among *freezing mixtures*, all kinds of salts, whether alkaline or acid, are the principal ingredients.

The process of congelation is always attended with the emission of heat: it is also observed, that water loses of its weight by freezing, being found lighter after thawing again, than before it was frozen. And indeed it evaporates almost as fast when frozen, as when it is fluid: nay, it has been observed,

observed, that, in Frost, the greater the cold the greater the evaporation; and this, by the bye, furnishes us with a reason why there should generally be more rain fall in February than in any other month.

The manner in which congelation is effected, is now generally thus explained. When water is exposed to an atmosphere colder than itself, it parts with some of its free heat, and is reduced in temperature: but no part of it begins to freeze until the mass is reduced somewhat below the 32d degree of *Fahrenheit's thermometer* *: some of the water then becomes solid, which, by changing its state, sets at liberty a quantity of its combined heat, which restores the fluid in contact with it to the temperature of 32 degrees, or rather above it. The congelation is, therefore, rather at a stand, till this sensible heat is abstracted by the atmosphere, and the mass reduced somewhat below the 32d degree. Another portion of water then congeals, and the process is again stopped by the emission of heat. In this manner congelation proceeds, and is performed at intervals which are very observable when the phænomenon of freezing is accurately attended to.

Water which has been boiled freezes more readily than that which has not been boiled: it is also observed, that a slight disturbance of the fluid disposes it to freeze more speedily. Water having

* For a few remarks relative to this instrument, the Reader is referred to the Appendix.

its

its surface covered with oil of olives, does not freeze so readily as without it: and *nut-oil* absolutely preserves it under a strong frost, when olive oil would not. The surface of water in freezing, appears, as it were, wrinkled; the wrinkles being sometimes in parallel lines; but more commonly they make angles of about 60 degrees with each other; and sometimes they are like rays proceeding from a centre to the circumference.

Another circumstance relative to the congelation of water I cannot forbear mentioning, as it is very remarkable. When water is cooled to within eight or nine degrees of the freezing point, it not only ceases to be farther *condensed*, but is actually *expanded* by farther diminutions of its heat; and this expansion goes on as the heat is diminished, so long as the water can be kept fluid: and when it is converted into ice, it expands even still more, and the ice floats on the surface of the uncongealed part of the fluid. This is the more extraordinary, as it is an exception to one of the more general laws of nature with which we are acquainted. It is also worth while to remark, that though in temperatures above blood-heat, the expansion of water with heat is very considerable, yet in the neighbourhood of the freezing point, it is exceedingly small. Now it is evident, that when the specific gravity of a liquid is but little changed by any given change of temperature, the motions among the particles of the liquid occasioned by this change must be sluggish, and the communication of heat of course very slow, and hence, from the preceding account

account of congelation, its process must also be slow.

The late *Count Rumford* (whose reasonings on this point are very ingenious, and have been far extended) draws from the circumstance an observation which I cannot forbear presenting to my young readers. "Suppose," says he, "that in "the general arrangements of things it had been "necessary to contrive matters so that water "should not freeze in winter,—or that it should "not freeze *but with the greatest difficulty*, "very slowly, *and in the smallest quantity possible*;—how could this have been most readily "effected?

"Those who are acquainted with the law of the "condensation of water, on parting with its heat, "have already anticipated me in these speculations; and it does not appear to me that there "is any thing which human sagacity can fathom, "within the wide-extended bounds of the visible "creation, which affords a more striking or more "palpable proof of the wisdom of the CREATOR, "and of the special care he has taken in the general arrangement of the universe to preserve animal life, than this wonderful contrivance: for "though the extensiveness and immutability of "the general laws of Nature impress our minds "with awe and reverence for the Creator of the "universe, yet *exceptions to those laws*, or particular modifications of them, from which we are "able to trace effects evidently *salutary* or advantageous to ourselves and our fellow-creatures,

"afford

" afford still more striking proofs of contrivance, " and ought certainly to awaken in us the most " lively sentiments of admiration, love, and gra- " titude."

Though we cannot speak with confidence and certainty as to the secondary causes by which many of the wondrous effects of congelation are brought about, we cannot surely be at a loss to ascribe these and every other effect which takes place in the different seasons, to the great First Cause. With regard to the attendants of winter, they ought, though cold and dreary, to warm our hearts with the fire of *Charity*. Ye that sit easy and joyous in your commodious apartments, solacing yourselves in the diffusive warmth of your fire; O! remember, that many of your fellow-creatures, amidst all the rigour of the inclement skies, are emaciated with sickness, benumbed with age, and pining with hunger. Think! for Heaven's sake, think

——How many drink the cup
Of baleful grief, or eat the bitter bread
Of misery! Sore pierced by wintry winds,
How many shrink into the sordid hut
Of cheerless poverty! Thomson.

while a few faint and dying embers on the squalid hearth, rather mock their wishes than warm their limbs. Methinks every piercing wind that blows, and every addition to the severity of the frost, pleads for the poor indigents: may they breathe pity into your breasts, and may you be thereby induced

duced to succour them in their distresses, relieve them from their calamities, clothe their naked bodies, and mitigate the severities of their wants: thus shall you obtain their prayers, and bring peace and comfort to your own souls !*

* As the following sentences have an affinity to the persuasives above given, I hope an apology for inserting them here is wholly unnecessary.

"When the fatherless calls upon thee, when the widow's heart is sunk, and she imploreth thy assistance with tears of sorrow; O pity her affliction, and extend thy hand to those who have none to help them.

"When thou seest the naked wanderer of the street shivering with cold, and destitute of habitation, let bounty open thine heart; let the wings of Charity shelter him from death that thine own soul may live.

"Whilst the poor man groaneth on the bed of sickness, whilst the unfortunate languish in the horrors of a dungeon, or the hoary head of age lifts up a feeble eye to thee for pity; O how canst thou riot in superfluous enjoyments, regardless of their wants, unfeeling of their woes!"

ECONOMY OF HUMAN LIFE.

LESSON XXI.

ON ELECTRICITY.

Electricity possesses much of what is admirably adapted to discipline the mind ········ Let your resolutions then be formed to study it, as a science in all its tendencies favourable to the general interest of knowledge, and to your own particular improvement. MORGAN.

BEFORE I attempt to explain to you the nature of Thunder-storms, which will be the business of the next Lesson, it may be advantageous to appropriate a few pages to the subject of *Electricity*, as it will tend to elucidate what may be said relative o these phænomena.

Electricity (derived from the Greek name for amber) is that power or property, which was first observed in amber, and which sealing-wax, glass, and a variety of other substances, called Electrics, are known to possess, of attracting light bodies, such as chaff, fine thread, and bits of straw, when excited by heat or friction: and which is also capable of being communicated in particular circumstances to other bodies. The term is also, often, more extensively applied to all other similar powers or properties, and their various effects, in whatever

whatever bodies they reside, or to whatever bodies they may be communicated.

If a tube of glass, an inch and an half in diameter and about three feet long, be rubbed, by repeatedly drawing the hand, or a piece of leather, from one end to the other, it will become electric; so that small flashes of divergent flame, ramified somewhat like trees bare of leaves, will dart into the air; from many parts of the surface of the tube, to the distance of six or eight inches, attended with a crackling noise; and sometimes sparks will fly along the tube to the rubber at more than a foot distant. This luminous matter is called the *Electric Matter* or *Fluid*, and all bodies that we are acquainted with have more or less of it in them; though it seems to lie dormant till it be put in action by rubbing, and then (in a dark room) it appears like fire.

Some bodies freely admit this fluid, and let it pass through their pores; others do not. The former of these are called, *Non-electrics*, or *Conductors:* of this sort are all metals, living-creatures, water, and moist wood; but metals are found to be the best conductors. The latter, which do not allow the Electric Fluid to pass through their pores, are called *Electrics*, or *Non-conductors:* of this kind are glass, wax, rosin, dry glue, baked wood, and silk. But if either of these be wetted with water, the water that adheres to it will render it a conductor; consequently, when any body is to be used as a non-conductor, it should be well wiped with a dry warm cloth, to clear it of damps, which it may have contracted in a variety of ways. The quantity of Electric Matter which every body has lying dormant in it, is called its natural quantity; and this would always remain motionless and invisible if nothing disturbed it. But when any more is forced into it, as suppose at one end, the whole is instantly put into motion thereby, and begins to be driven out at the other end, if it can find a passage.

The earth is the grand source of the Electric Fluid, and no additional quantity can be forced into any body but from the earth. If the body be a free conductor, and have a communication with the earth by means of any other conducting substance, as metal, or by a table, to the floor and walls of a room, and from thence to the earth, the Electric Fluid will run as fast from the conductor to the earth, as it is by any means driven into the conductor. But if the communication between the earth and the conducting body be cut off by means of any non-conductor, some of the Electric Matter may be forced into the conductor, by which means it will have more than its natural quantity; and the earth, from which that additional quantity comes, will have so much less: which could never be, if the Electric Fluid were not of an elastic nature, or could not be compressed.

When any body has more than its natural quantity of this fluid, it is said to be electrified positive-

ly,

ly, or *plus;* and when it has less than its natural quantity, it is said to be electrified negatively, or *minus.* When bodies are electrified either of these ways, they repel each other; but if some be electrified *plus,* and others *minus,* they mutually attract; or if one body be electrified *plus,* and the other no way at all, they also attract each other.

The following experiments will tend to shew the reality of Electrical Attraction and Repulsion. Cut two bits of cork into the shape and size of a common pea. With a needle draw a thread through each of the corks, so that they may be made to hang at the ends of the threads with a knot below them. Let the other ends of the threads be inserted in the notch of a small piece of wood, about a foot long, an inch broad, and the thickness of a common match. Lay the piece of wood over the mouths of two wine glasses, a few inches asunder, so that the end of it, in which the threads are, may project over the edge of the glass nearest it, and the corks may be in contact with one another. Take another wine glass; and having rubbed it heartily with a piece of flannel, or upon the skirt, or sleeve, of a woollen coat, hold its mouth to within about an inch of the corks, and they will suddenly start asunder and continue so for some time.

Again, lay a pocket watch upon an horizontal table, and take a common tobacco-pipe, and place it on the face of the watch so that it may rest thereon in *equilibrio:* then, after rubbing a wine glass (as described in the former experiment),

 bring

bring it to within an inch of the smaller end of the tobacco pipe, and by moving the glass gently round in an horizontal circular track, you will cause the pipe to turn round on the watch-glass as the needle turns on its centre in a mariner's compass.

A great many experiments may be performed with the help of an Electrical Machine; which may be bought, with the necessary apparatus, at the shop of any philosophical-instrument maker in London: but, as it is probable that several persons may wish to try Electrical Experiments, who cannot well afford to purchase a more complete apparatus, I shall here give a description of a very simple machine, and one that may be made at but little expense. It consists of two plates of a circular form; the under plate may be of wood, glass, or brass, five inches in diameter and covered on the upper side with an even coat of melted sealing-wax of the second quality. The upper plate may be made of wood, coated entirely with tin-foil, having a handle of baked wood, or glass, fixed in the centre of its upper surface. Or it may be made of tin, wired and soldered round the edges on the upper side, with a small socket in the centre for fixing the handle. The socket and handle may be coated with melted sealing-wax dissolved in spirit of wine. If the under plate be made of wood, glass, or sulphur, it may be coated on the under side with tin-foil, fixed on with stiff paste.

To use this machine: First, with a dry, warm piece

piece of flannel, rub briskly that side of the under plate which is covered with sealing-wax, place it on a table with the excited side upward; set the upper plate exactly on the lower, touch the upper plate with the finger, then raise the upper plate by the handle, and it will give a spark of Electric Fire to any conducting substance. By repeating the operation, another spark may be obtained, and so on. If the upper plate be not touched with the finger, or some conducting substance, no spark can be obtained. If the sparks be given to the ball of a coated* phial, it will become charged, and the Electric Shock may be given.

Having said thus much concerning an Electrical Machine, I will proceed to describe a few more experiments.——If one body, as suppose a piece of metal, be kept for some time in an electrified state, by means of the machine, and an unelectrified light body, as suppose the down of a feather, be brought near the metal, the feather will be attracted to it, and thence electrified: on which it will be immediately repelled from it, and will not return to it again, till after it has touched some un-

* Bottles may be easily coated in the following manner:—Take bismuth *two* parts, lead and tin of each *one* part, melt them together and carefully skim off the dross; remove the mixture from the fire, and, before it grows cold add *ten* parts of hot mercury; stir the whole together, and the amalgam when cold, is fit for use. Let the bottle, to be coated, be quite new and clean; put into it a sufficient quantity of the amalgam, incline the bottle, and gently turn it round that the composition may adhere to every part, pour out the superfluous amalgam, and the bottle will be beautifully coated.

electrified body that is of the conducting kind, and deposited its fluid into it, and then if the distance be but small, as about two or three inches, it will return to the electrified metal as before, and be repelled from it again.

If a round piece of metal be electrified, and any pointed piece of metal be held near it, the point will draw off the fire from the electrified metal, if that which has the point be supported by any conducting substance.

If the middle of a wire, that is pointed at both ends, be fixed to a stick of wax, and either of the points be held near the metal which is kept in an electrified state by the machine, that point will draw off the fire from the metal, and the fire will run off from the other point into the air. From this we learn, what is very remarkable, that metallic points throw off, as well as attract Electric Fire. Should this experiment be made in a dark room, the Electric Matter drawn from the metal would appear like a round spark on the point that attracts, and would be seen going off in the form of a cone from the other point.

If a large globe of metal be electrified positively, it will retain the Electric Fire for some considerable time. For the surrounding air prevents the accumulated fire from issuing so fast from the globe as it otherwise would . . . . . If two globes of metal be hung by silk lines, or placed on wax, at about two feet from each other, and one globe be then electrified, and the other be hung, or placed, rather nearer it; the former will soon lose part of the

Electric

Electric Matter, which will be drawn off by the latter; but the point of a needle would draw it off much sooner.

Writers on Electricity give accounts of a variety of experiments in this entertaining science, from which some of the properties of the Electric Matter may be deduced; but as to its real nature philosophers have entertained very different sentiments. Some have supposed that it is the same with the ether of Sir Isaac Newton, to which the attraction and repulsion are ascribed; whilst the light, smell, and other sensible qualities of the fluid, are referred to the grosser particles of bodies driven from them by the forcible action of this ether: and other appearances are explained by means of a subtile medium diffused over the surfaces of all bodies, and resisting the exit and entrance of the ether; which medium, it is supposed, is the same with the Electric Fluid, and is more rare on the surfaces of conductors, and more dense and resisting on those of Electrics. But Dr. Priestley (whose abilities and penetration, as a philosopher, are two well known to need any encomium from me,) objects, in some measure, to the hypothesis above recited, and gives it as his opinion, founded on experiments, that the Electric Matter either is phlogiston, or contains it; since he found that both produced similar effects. Mr. Henley also apprehends, that the Electric Fluid is a modification of that element, which, in its quiescent state, is called phlogiston; in its first active state, Electricity; and, when violently agitated, Fire.

This Electric Fluid, it is supposed, moves with great ease in those bodies that are called conductors, but with extreme difficulty and slowness in the pores of Electrics; whence it comes to pass, that all Electrics are impermeable to it. It is farther supposed, that Electrics contain always an equal quantity of this fluid, so that there can be no surcharge or increase on one side, without a proportionable decrease or loss on the other, and *vice versa*; and as the Electric does not admit the passage of the fluid through its pores, there will be an accumulation on one side, and corresponding deficiency on the other. Then when both sides are connected together by proper conductors, the equilibrium will be restored by the rushing of the redundant fluid from the overcharged surface to the exhausted one. Thus also, if an Electric be rubbed by a conducting substance, the Electricity is only conveyed from one to the other, the one giving what the other receives; and, if one be electrified positively, the other will be electrified negatively, unless the loss be supplied by other bodies connected with it. This theory serves likewise to illustrate the various phænomena and operations in the science of Electricity: thus, bodies differently electrified will naturally attract each other, till they mutually give and receive an equal quantity of the Electric Fluid, and the equilibrium is restored between them. Beccaria supposes that this effect is produced by the Electric Matter making a vacuum in its passage, and the contiguous air afterwards collapsing, and so pushing the bodies together.

It

It is natural to imagine, that a power of such efficacy as that of Electricity, might be applied with advantage to medicinal purposes; especially since it has been found invariably to increase the sensible perspiration, to quicken the circulation of the blood, and to promote the glandular secretion: accordingly, many instances occur in the history of this science, in which it has been applied with considerable advantage and success. In most disorders in which it has been used with perseverance, it has given at least a temporary and partial relief, and in many it has effected a total cure. Electrical shocks, properly applied, have frequently cured the ague, tooth-ach, head-ach, rheumatism, pain in the stomach, sore throat, and sometimes the gout: deafness of several years' continuance has been removed; and in one case, a person who had been deaf from his birth, was cured by Electricity: it has cured chilblains, and removed hard swellings in various parts of the body; it has been successfully applied in bad spasmodic and paralytic cases; it has cured the St. Vitus's dance; and it has in one case, if not more, restored sight to the blind.

Since the science of Electricity has been applied to the desirable purpose of restoring health to the sick, the emaciated, and infirm, often with considerable success, even by gentlemen who are not physicians, and consequently cannot be supposed to distinguish always between cases where it may, and where it may not, be advantageously applied; it is much to be lamented, that medical gentlemen of skill and judgment do not, more generally than

they

they have hitherto done, give directions for the use of the Electrical Machine, and point out in what cases we may have recourse to it with benefit and safety, and in what cases it would be prejudicial. For I am convinced, that were such directions laid down and properly disseminated, many benevolent persons in different parts of the kingdom would, with alacrity, embrace the many opportunities which would be then afforded them, of removing the infirmities, and allaying the excruciating pains of their indigent neighbours; thus alleviating distress, and restoring comfort and joy to those who may have been long pressed down with affliction.

From perusing the imperfect account which I have here given of the science of Electricity, I hope you will be induced to labour after a more familiar acquaintance with it. Be assured that it possesses every property which can make knowledge interesting to the human mind: the power whose laws, whose relations, and whose effects it investigates, has been proved to be one of the most extensive in nature: there is scarcely any science, the light of which may not be increased by it: many are the arts in social life to which it will communicate new powers, and many are the mysterious circumstances in the history of nature and mankind, which by it may properly be developed and explained.

It must be acknowledged, however, that this science is, as yet, in its infantine state: the language by which it is taught is imperfect and obscure: and though various laudable attempts have been

been made by philosophers of eminence and celebrity, to gain a respectable place among its sister sciences, it is rarely made an object of eager and complete attention, or of that persevering activity, by which alone it can rise to its proper consequence and maturity.

Before I conclude this lesson I must briefly notice *Galvanism* or Voltaism, which embraces the phænomena which result from different conductors of Electricity being placed under different circumstances of contact. The conductors must be either perfect or imperfect conductors of Electricity: and the Galvanic Phænomena may be produced by two conductors of one of these classes placed in contact with each other, in one or more points, and in other distinct points with a conductor of the other class: thus gold and zinc may be made to touch each other, in some points, and may be connected in other points, by a portion of common water.

To produce the Galvanic phænomena with any considerable effect, several series of conductors, thus disposed, should be employed. Then, not only may an acid taste, a flash of light, the contractions of muscles just detached from a living body, the oxidizement of metals, and the decomposition of acids and of water, be produced; but shocks on the human body analogous to the electric shock, and brilliant sparks, with the deflagration of even silver and gold, may also be occasioned by this fluid, under certain circumstances. *Fabroni*, in *Nicholson*'s Journal for 1800, noticing the

the oxidizement of metals while under Voltaic influence, concluded it to be a chemical phænomenon merely. In this year, *Volta* announced his discovery of the Galvanic pile, formed by plates of two different metals, as zinc and silver, disposed alternately with moistened pasteboard between them. By connecting the ends of the pile by the hands, he obtained a strong shock, and produced many curious experiments. Mr. *Nicholson*, in the same year, employed much of his ingenuity in examining these phænomena, and devoted a considerable portion of his Journal to their investigation. By making a tube of water form part of the line connecting the two ends of the pile, he found, from the wire passing into the water from the silver end, hydrogen separated; whilst the other, if an oxidable metal, became oxidized, but, if platina, he found oxygen was evolved. Thus was ascertained its *chemical action, and its powers of decomposing water.*

But the most important discoveries in Voltaism have been made by Sir Humphrey Davy. They, however, would of themselves fill a volume, and therefore cannot be here detailed.

LESSON XXII.

ON THUNDER AND LIGHTNING.

—By conflicting winds together dash'd,
The Thunder holds his black tremendous throne;
From cloud to cloud the rending Lightnings rage:
'Till, in the furious elemental war
Dissolv'd, the whole precipitated mass
Unbroken floods and solid torrents pours.

THOMSON.

AMONG the numerous phænomena which you have observed, it is scarcely probable that there are any which should more tend to raise in your mind serious reflections, than that which we are now about to consider. The more than usual gloominess of the sky,—the uncommon heat of the air,—the astonishingly rapid descent of the rain or hail, which generally attend the *Thunder's* tremendous clap, and the *Lightning's* forked flash, undoubtedly all contribute to raise ideas of wonder and awe. But when we reflect upon the terrible effects which Thunder Storms sometimes produce,—buildings set on fire,—huge trees split into shivers,—steeples rent,—animals and men destroyed,—and metals melted like wax;—what emotions do we feel? The guilty soul will in a manner shrink into itself with terror: but the truly religious and philosophic mind, whilst filled with admiration of the

POWER

POWER which produces such stupendous effects, will be naturally led to inquire by what natural means they are occasioned.

An opinion very prevalent among philosophers until late years, was, that this awful class of phænomena is produced by a variety of *acetous, bituminous, spirituous, nitrous,* and *sulphureous* particles, exhaled from various bodies, and raised into the air; and there being driven to and fro by the wind and other causes, are at length violently agitated, and furiously striking against each other force themselves through the clouds, attended with an explosion which we call *Thunder,* and a flame or flash which is called *Lightning:* the bituminous and sulphureous particles causing the flash, and the nitrous particles occasioning the explosion.

But it is now universally allowed, that Thunder-storms are produced by electricity: the proof of this was reserved for Dr. *Franklin,* who is so justly celebrated for his many discoveries, particularly in that branch of natural philosophy which was the subject of the preceding Lesson. This philosopher traced out with much accuracy several particulars in which Lightning and the Electric Spark agree: a few of these I shall here mention.

Flashes of Lightning are generally seen crooked and waving in the air: this is also the case with the Electric Spark, when it is drawn from an irregular body at some distance. Lightning strikes the highest and most pointed objects in its way, preferably to others: in like manner, all pointed con-

ductors

ductors receive or throw off the electric fluid more readily than such as are terminated by flat surfaces. Lightning takes the readiest and best conductor: so does the electrical fluid. Lightning burns: so does electricity. Lightning sometimes dissolves metals: so does electricity. Lightning has been often known to strike people blind: and pigeons and other small birds have been struck blind by electricity. Lightning sometimes destroys animal life: animals have likewise been killed by electricity.

But what demonstrates in the clearest manner possible the identity of electrical fire with the matter of Lightning, is, that the Doctor, astonishing as it must have appeared, contrived actually to bring Lightning from the heavens by means of an electrical kite, which he raised when a storm of thunder was coming on. The same experiment has been frequently repeated by other philosophers; and it is to be lamented, that it was once attended with fatal consequences: for the *Abbé Richman* was killed by a flash of Lightning which he drew down from the clouds, in an experiment he was making at Petersburgh.

To know that Lightning and electric matter are the same, is a great step in natural philosophy; but so long as our acquaintance with the properties of electricity continues so very imperfect as it yet is, we must necessarily remain ignorant of the causes of many of the appearances which accompany Thunder-storms. However, we will now proceed to give such an explanation of the phænomena, as the

the present state of knowledge will permit. Many observations and experiments tend to prove that some clouds are in a positive, and some in a negative state of electricity; and from other experiments it has been inferred that the quantity of electric matter in a common Thunder-storm, is inconceivably great, considering how many pointed bodies, as steeples and trees, are continually drawing it off, and what a prodigious quantity is repeatedly discharged to or from the earth. This matter is in such abundance, that it is thought impossible for any number of clouds to contain it all, so as either to receive or discharge it. During the progress and increase of a storm, it has been observed, that though the Lightning frequently struck to the earth, the same clouds were ready the next moment to make a still greater discharge: whence it is concluded, that the clouds serve as conductors to convey the electric fluid from those parts of the earth that are overloaded with it, to those that are exhausted of it. The same cause by which a cloud is first raised, from vapours in the atmosphere, draws to it those which are already formed, and still continues to form new ones, till the whole collected mass extends sufficiently far to reach a part of the earth where there is a deficiency of the electric fluid, at which place the electric matter will discharge itself on the earth. A channel of communication being thus formed, a fresh supply of electric matter is raised from the overloaded part, which continues to be conveyed by the medium of the clouds, till the equilibrium of the fluid is re-

stored

stored between the two places of the earth. The Lightning throws before it the parts of conducting bodies, and distributes them along the resisting medium through which it must force its passage; the longest flashes seem to be made, by forcing in the way of the electric matter, part of the vapours of the air.

The claps of Thunder which accompany the flashes of Lightning, seem to be occasioned by the filling of the vast vacuum made by the passage of the electric matter: for, although the air collapses the moment after the matter has passed, and the vibration on which the sound depends commences at the same moment: yet when the flash is directed towards the person who hears the report, the vibrations excited at the nearer end of the track will reach his ear much sooner than those from the remote end; and the sound will, without any echo or repercussion, continue, till all the vibrations have successively reached him.

It must be confessed, however, that the question, how it happens that particular parts of the earth or the clouds come into the opposite states of positive and negative electricity, is not absolutely determined: among the numerous conjectures, the one which supposes the electric matter then in the clouds to be generated by the fermentation of sulphureous vapours with mineral or acid ones, seems to have a great share of probability, especially when it is recollected that Thunder-storms generally happen when the air is in a sultry state.

With

With regard to the degree of danger in storms of Thunder and Lightning, it is not easy to speak with precision: though it may be noticed, that it seems to depend chiefly on the distance from the track of the electric fluid: which distance is greater or less in proportion as a greater or less interval of time elapses, between seeing the flash and hearing the explosion. If a person can count five pulsations between the flash and the succeeding clap of Thunder, he may infer that the cloud is a mile distant. For ten pulsations the distance is two miles, and so on.

As to places of safety from the danger of these storms, the general opinion is that the open fields are more safe than under cover of a house: those who are in the fields at such times, would do well to place themselves within 50 yards of a tree, but by no means quite near it. It is generally thought safer to have one's clothes wet than dry, as the Lightning might then in a great measure be transmitted to the ground, by the water on the outside of the body.—Under cover, people are advised to sit near the middle of a room on one chair, and lay the feet on another, observing that no metals, as candlesticks, iron chains, &c. are near. A still better method is, to place the chairs upon mattresses or feather-beds: a safer way yet is, to be in a hammock hung on silken cords at an equal distance from all the sides of the room. But the place of greatest safety must be in a deep cellar, and especially the middle of it; for when

when a person is lower than the surface of the earth, the Lightning must strike it and spend itself, having a great probability of not reaching him.

A building may be secured, to a considerable degree, from the dreadful effects which Lightning sometimes produces; and this by fixing a pointed iron rod higher than any parts of the building, and joining to the lower end of it a wire which must communicate with the earth, or, rather, the nearest water. This rod the Lightning will seize upon, sooner than any part of the building: it will therefore descend along it, and the annexed wire, till it reaches the earth or water, when it will be dissipated without doing any harm. It would be advisable to have that part of the wire which is within five or six feet of the ground, surrounded by an open frame, of such a kind as will prevent men or animals from coming so near the wire, as to be injured by the Lightning, which it is designed to convey to the earth.

Several of the British poets have given us sublime descriptions of Thunder-storms, with admirable reflections suggested by them: as a specimen, my young readers are requested to peruse the following.

In gloomy pomp, whilst awful midnight reigns,
  And wide o'er earth her mournful mantle spreads,
  Whilst deep-voic'd Thunders threaten guilty heads,
And rushing torrents drown the frighted plains,
  And quick-glanc'd Lightnings, to my dazzled sight,
  Betray the double horrors of the night.

A solemn

A solemn stillness creeps upon my soul,
And all its powers in deep attention die;
My heart forgets to beat; my stedfast eye
Catches the flying gleam; the distant roll,
Advancing gradual, swells upon my ear
With louder peals, more dreadful as more near.

Awake, my soul, from thy forgetful trance!
The storm calls loud, and meditation wakes;
How at the sound pale superstition shakes,
Whilst all her train of frantic fears advance!
Children of darkness, hence! fly far from me!
And dwell with guilt and infidelity!

But come, with look compos'd and sober pace,
Calm contemplation, come! and hither lead
Devotion, that on earth disdains to tread;
Her inward flame illumes her glowing face,
Her upcast eye, and spreading wings, prepare
Her flight for heav'n, to find her treasure there.

She sees, enraptur'd, through the thickest gloom,
Celestial beauty beam, and 'midst the howl
Of warring winds, sweet music charms her soul;
She sees, while rifted oaks in flames consume,
A FATHER GOD, that o'er the storm presides,
Threatens, to save,—and loves, when most he chides.

MRS. CHAPONE.

LESSON

LESSON XXIII.

ON THE IGNIS FATUUS.

——————A wand'ring fire
Compact of unctuous vapour, which the night
Condenses, and the cold environs round,
Kindled through agitation to a flame,
(Which oft, they say, some evil spirit attends,)
Hovering, and blazing with delusive light,
Misleads th' amaz'd night-wanderer from his way
Through bogs and mire. MILTON.

TOO numerous by far are the stories of ghosts and apparitions, hobgoblins and spectres, which are handed down from one generation to another, by the great weakness and folly of some parents and nurses, whose whole intention, one would imagine, is to make their children chiefly susceptible of the impressions of fear. When we consider how difficult it is to eradicate prejudices which were imbibed in childhood, we shall not be greatly surprized at the avidity with which tales of the mischievous feats performed by *Jack o' Lanterns*, and *Will with a Wisps*, are swallowed, even by up-grown people, of mature judgment in other concerns. For instance, a child may have been told by his father, that once, when he was going over a piece of marshy land in a dark night, he was suddenly

denly startled with the appearance of a spirit wrapped up in fire, which kept dancing round him, and dazzled his eyes to such a degree, that he became dismally frightened, and so the fiery spirit led him out of his road, and then left him. This misfortune of the father would be remembered by the child when he arrived at years of maturity, when he would, perhaps, hear several similar tales from other persons, which the credulous youth would look upon as so many corroborating testimonies of the reality of such ghostly appearances; and, of course, the prejudice would be the more rooted in his mind.

Should any persons who have been thus miserably misinformed, peruse these Lessons, I hope they will be quickly convinced that these horrible *Jack o' Lanterns* are far from having any thing supernatural about them: on the contrary, their cause, and the effects they produce, may be accounted for in a very natural and easy manner.

The meteor vulgarly known by the names before mentioned, is among philosophers called *Ignis Fatuus*: it is chiefly seen about marshes, meadows, and other moist places, also in burying grounds that lie flat and low, and sometimes near dunghills. The appearances of it usually observed, sufficiently evince that it is an ignited vapour: for inflammable air has been found to be the most common of all the factitious airs in nature; and as it is known to be frequently produced from the putrefaction and decomposition of vegetable substances in water, with which marshes, bogs, &c. abound, it it may be reasonably inferred that when this inflammable air arises, it will be speedily kindled, and, being wafted about near the surface of the earth, will cause the appearances which create so much unnecessary alarm.

Dr. *Shaw* has described a singular Ignis Fatuus which he saw in the Holy Land, when the atmosphere had been thick and hazy, insomuch that the dew on the horses' bridles was remarkably clammy and unctuous. This meteor was sometimes globular, then in the form of a flame of a candle; presently afterwards it spread itself so much as to involve the whole company in a pale harmless light, and then it would contract itself and suddenly disappear. But in less than a minute it would become visible as before, or, running along from one place to another, with a swift, progressive motion, would expand itself at certain intervals over more than two or three acres of the adjacent mountains.

In the plains in the territory of Bologna, these meteors are very often seen: sometimes they vary in figure and situation in a very uncertain manner; but commonly they are very large, and give light equal to a torch.

Even in England they are frequently seen in different numbers, from two or three to upwards of twenty together in one field, running here and there with great rapidity; sometimes mixed together and crossing each other's paths, as though they were dancing; then all at once several of them disappear, which may, perhaps, be occasioned by their striking against each other, or some contiguous object. In many places, one may be almost sure of seeing them every dark night.

That persons should be led out of the way by these meteors is more to be attributed to their own unreasonable fears, raised by prejudices instilled into their minds in their infantile years, than any other cause. For when the Ignis Fatuus happens to overtake or approach them, they are struck with fear and surprize at so shining a light, and dismal a spectre, as they imagine it to be; whence they, in their fright, immediately run out of the direct pathway, and by such deviation very probably lose their road entirely: more especially, if (as will most frequently be the case) the meteor be attracted after them in their flight.

From a consideration of what has been here advanced, the great importance of being educated without having any superstitious or childish prejudices engrafted in the mind, is exceedingly obvious: to the elder part of my readers I would therefore take the liberty of recommending a peculiar attention that no idle trash be insinuated into the minds of their children; for in this, as well as other cases,

> Children, like tender osiers, take the bow,
> And as they first are fashion'd always grow.
>
> DRYDEN.

To those who have, unfortunately, been badly educated in this respect, a friendly act would be, to endeavour with sound reasoning to convince them of their error, and dissuade them from giving heed, in future, to idle, superstitious, or inconsistent stories

stories of any kind; advising them to furnish themselves with such knowledge, as may have a tendency to produce true pleasure and happiness through life, and which when dying they can reflect upon without uneasiness*.

* "The natural offspring of prevailing superstition is infidelity. Of the truth of this, the present times afford us a lamentable example. Where ignorance and fear once ruled supreme, there has rash philosophy but too successfully planted presumption and atheism. 'Tis the diffusion of pure and solid knowledge, which alone can preserve us from the dominion of these opposite tyrants. How should this consideration increase our zeal and stimulate our endeavours! The immediate sphere of our action may be circumscribed, but our exertions will not on that account be entirely lost. In that circumscribed sphere let us labour to root out every superstitious lying vanity, and plant pure religion and unsophisticated truth in its stead.

"How charming, how enlivening to the soul, to gaze upon the dawning beams of opening light, to behold them irradiate that dismal gloom of intellectual darkness which long overwhelmed the millions of mankind! How supremely pleasing, to view them wider and wider spreading their invigorating influence! How rapturously transporting, to contemplate the splendescent prospect of pure and perfect day!

"Power supreme!
"O everlasting King! to thee we kneel,
"To thee we lift our voice;".

"O spread thy benign, thy vivifying light over the dwellings of the sons of men; dispel the yet impending mists of ignorance and superstition: and, O preserve us from the dismal gulph of infidelity and atheism; let thy truth run and prevail gloriously; let pure, celestial wisdom overspread the earth as the waters cover the sea!—Then shall millions kneel before thee with grateful and enraptured hearts; then shall they rejoice to sing the praises of thee, their Benefactor, their Father, and their God: then shall this vale of tears be filled with the mansions of joy and gladness, and become a blissful foretaste of those regions, where the saints, crowned with unfading glory and felicity, surround thy throne with never-ceasing hallelujahs!"

See Sermons on "*The Inanity and Mischief of Vulgar Superstitions*," by the Rev. *M. J. Naylor*.

LESSON

LESSON XXIV.

ON THE AURORA BOREALIS.

——Silent from the north,
A blaze of meteors shoots: ensweeping first
The lower skies, they all at once converge
High to the crown of heav'n, and all at once
Relapsing quick, as quickly reascend,
And mix and thwart, extinguish and renew,
All æther coursing in a maze of light. THOMSON.

THERE are, perhaps, but few appearances in nature which are more curious than those known by the appellations, *Aurora Borealis, Northern-lights,* or *Streamers.* The radiant streams, like legions rushing to the engagement, meet and mingle, insomuch that the air seems to be conflicting fire;—presently they start from one another, and, like armies in precipitate flight, each marching a different way, they are thrown into a quivering motion:—the whole horizon is illuminated with the glancing flames; and, with an aspect partly awful, and partly ludicrous, they represent extravagant and antic vagaries.

The villagers, assembled together, gaze at the spectacle, first with astonishment, then with horror,

From look to look, contagious through the crowd
The panic runs, and into wondrous shapes
Th' appearance throws; armies in meet array,
Throng'd with aërial spears and steeds of fire,
Till the long lines of full-extended war,
In bleeding fight commixt, the sanguine flood
Rolls a broad slaughter o'er the plains of heav'n.
As thus they scan the visionary scene,
On all sides swell the superstitious din,
Incontinent; and busy frenzy talks
Of blood and battle, cities overturn'd,
And late at night in swallowing earthquakes sunk,
Or hideous wrapt in fierce ascending flame;
Of sallow famine, inundation, storm;
Of pestilence, and very great distress;
Empires subvers'd, when ruling fate has struck
Th' unalterable hour: ev'n Nature's self
Is deem'd to totter on the brink of time.

THOMSON.

Though this waving brightness, which plays so innocently over our heads, causes such astonishment in the gazing throng, it has a very different effect upon the philosopher: he feels stimulated to inquire how so curious, and in great measure pleasing, an appearance may be occasioned. In order to arrive at the result of such inquiry, it will be necessary to consider with attention the various phænomena of this meteor, as they have been accurately observed.

It may be remarked, then, that the appearances of the *Aurora* come under four different descriptions:—First, a *horizontal light,* like the morning Aurora, or break of day; which horizontal light tends to the magnetic east and west, and is bisected by the magnetic meridian.—Secondly, fine, splendid,

did, luminous *beams*, well defined, and of dense light; these continue $\frac{1}{4}$, $\frac{1}{2}$, or 1 minute, sometimes apparently at rest, but more frequently with a quick lateral motion. These *beams* appear at all places alike, to be arches of great circles of the sphere, with the eye in the centre; and these arches, if prolonged upwards, would all meet in one point. This converging point is the same as that to which the south pole of the *dipping needle* points, at the place where the observation is made.—Thirdly, *flashes* pointing upward, or in the same direction as the beams, which they always succeed. These are only momentary, and have no lateral motion, but they are generally repeated many times in a minute: they appear much broader, more diffuse, and of a weaker light than the beams: they become gradually fainter till they disappear; but they sometimes continue for hours, flashing at intervals.—Fourthly, *arches* nearly in the form of rainbows. These, when complete, go quite across the heavens, tending to the magnetic east and west, and crossing the magnetic meridian at right angles.

When an *Aurora* takes place, the appearances above described generally succeed one another in the following order:—first, the faint, rainbow-like arches; second, the beams; third, the flashes. As for the horizontal light, it is found to consist of an abundance of flashes or beams, blended together, owing to the situation of the observer relative to them.

These phænomena have been accounted for on various suppositions. 1. It has been supposed to be a flame arising from a chemical effervescence of combustible exhalations from the earth. 2. It has been thought to be inflammable air, fired by electricity. 3. It has been imagined to be occasioned by the zodiacal light. 4. It has been conjectured, that it is caused by the reflection of the sun's beams on large bodies of ice floating near the polar regions. But all these suppositions will admit of objections, being utterly inadequate to account for the appearances. Lastly, it has been supposed *electric light* itself; and this opinion has met with many advocates since the identity of lightning and the electric matter has been determined: for we know that discharges of the electric fluid in the atmosphere do exhibit light; and for this, and other reasons which might be advanced, it is considered almost beyond a doubt, that the light of the *Aurora Borealis* as well as that of *falling stars,* and the *large meteors,* is *electric light* solely, and that there is nothing of combustion in any of these phænomena.

M. Libes has lately proposed a new theory of the Aurora Borealis, which has already been adopted by most of the northern philosophers, and may be concisely stated thus: the production of hydrogenous gas is next to nothing at the poles; therefore, so often as the electricity is put into an equilibrated state in the atmosphere, the spark, instead of passing through a mixture of hydrogenous and oxygenous gas, as in our climates, passes through a mixture of oxygenous and azotic gas: it must therefore cause a production of nitrous gas, nitrous acid,

acid, and nitric acid, which give birth to ruddy vapours, whose red colour will vary according to the quantity and proportion of those different substances, which are generated. These vapours are carried towards the south, where the air is most dilated, so that they approach more and more towards the spectator; and it is probable their motion may be assisted by a north wind. Sometimes they rise as if to the zenith of the spectator, and then descend again towards the south; and a great number of causes may carry the vapour towards the different points of the heavens, whence originate the different motions taken by the Aurora Borealis, or its several parts. Lastly, the slight detonations which are sometimes heard, depend upon the small quantity of hydrogenous gas, which is found in the upper regions of the atmosphere, and which combines with the oxygen to form water.

These principles, at the same time that they account in M. Libes's estimation, for all the phænomena accompanying the Aurora Borealis, explain also why it is so common towards the poles, and so rare in the temperate regions; while thunder, which is frequent in the torrid zone, is scarcely ever heard in the polar regions. The disengagement of hydrogenous gas is considerable near the equator, and very little towards the poles: and when we excite the electric spark in a mixture of hydrogen, oxygen, and azote, it combines in preference the bases of the two former gases; the electric spark ought, therefore, to occasion thunder solely in hot countries, and to produce Aurora Boreales alone in cold countries.

This theory, though plausible, is not, however, entirely free from objections. Mr John Dalton, whose name I mentioned in the Seventeenth Lesson, has advanced a new theory of the Aurora Borealis, in which he has endeavoured to shew, that the luminous beams of this phænomenon are cylindrical, and parallel to each other at least over a moderate extent of country,—that these cylindrical beams are all magnetic, and parallel to the dipping-needle at the places over which they appear,—that the distance of these beams from the earth is nearly equal to their length,—that the rainbow-like arches are about 150 English miles above the earth's surface,—and that the Aurora Borealis is a *magnetic phænomenon whose beams are governed by the earth's magnetism.*

LESSON XXV.

ON LIGHT AND COLOURS.

Behold the Light emitted from the sun;
What more familiar, and what more unknown?
While by its spreading radiance it reveals
All nature's face, it still itself conceals.

BLACKMORE.

God said,—Let there be Light:—and there was Light.

MOSES.

THE famous *Longinus*, in his treatise on the Sublime in Writing, produces the above passage of the inspired historian, as one of the most striking he had ever met with. Its chief sublimity seems to consist in a forcible declaration of the almighty power of GOD. From this passage alone we might infer, that to will, to speak, and to accomplish, is all one with the DEITY; being an essential part of his attributes, without which he would be imperfect. In the *sacred record* it is next said, that "GOD saw the *Light* that it was good:" and indeed *we* have the greatest reasons for thinking so. How good must that Light be, which enables us to behold the heavens beautified with stars; and by means of which we can look around us, and trace the numerous wonders of the earth we inhabit,

inhabit, raising in our minds the most exalted ideas of the Divine perfections! We may also here observe, that the all-wise CREATOR has so divided our time into day and night, light and darkness, that we may never forget that all things in human life are mixtures of good and evil. Heaven is said to be all light, and hell is as frequently represented to be utter darkness: wherever the favour of GOD shines, there is light;

> ——"His presence gives eternal day,
> And makes eternal rest;"

but his absence and anger create darkness.

By *Light*, I would wish to have understood, that principle by which objects are made perceptible to our sense of seeing; or the sensation occasioned in the mind by the view of luminous objects. The nature of Light has very long been a subject of philosophical speculation: the earliest philosophers doubted whether objects became visible by means of any thing proceeding from them, or from the eye of the spectator. On this subject, opinions are still afloat. It is thought by some, that Light may be a fluid *(per se)* equally diffused through the universe; the action of the solar, or other rays, is necessary, according to this hypothesis, to give it motion, and make its effects perceptible. Others are of opinion, that Light is a *quality*, which cannot exist independently of matter, and which requires the assistance of the solar and other rays, to bring it into action. But as the hypothesis of *Newton* is the most generally received, what I shall say

on

on the subject will be agreeable thereto; though it must be allowed that some rather formidable objections have been advanced against it.

The Newtonians maintain, that Light consists of a great number of exceedingly small particles, thrown off from the luminous body by a repulsive power with an immense velocity, and in all directions; hence, Light is produced from motion: but then as all motion will not produce Light, therefore much manifestly depends on the quality of certain bodies which are of themselves luminous, and have the constant and invariable property of emitting or sending forth these very minute particles: such is the property of the sun, a star, a candle alighted, and all sorts of flame, &c. The velocity of the particles of Light is truly astonishing, amounting to near two hundred thousand miles in a second of time, which is almost a million times greater than the velocity of a cannon-ball. This may be easily proved by observations on the eclipses of Jupiter's satellites; for when the earth is between the sun and this planet those eclipses will happen about 8¼ minutes sooner, than according to the tables; but when the earth is in the contrary position, the eclipses happen about 8¼ minutes later than they are predicted by the tables. Hence, therefore, light takes up about 8¼ minutes in passing from the sun to the earth, a distance of 95 millions of miles: whence what was mentioned just above may be deduced.

Since Light diffuses itself every way with such incredible velocity, it is evident that if its particles

were

were not surprisingly small, it would strike against bodies with great force: this would be very injurious to those tender organs the eyes, and would probably soon cause blindness: but it is found that these particles are small, almost beyond conception; for it has been computed that there fly out of the end of a flame of a burning candle in a second of time, ten thousand millions of times more such particles than there are visible grains of sand in the whole earth: if they were not inconceivably small, it is certain, therefore, that the flame would be entirely dissipated and lost.

It is also asserted, that the particles of Light are emitted in right lines: preserving their rectilinear motion till they are turned out of their path by some of the following causes, viz. either by the attraction of some other body near which they pass, which is called *inflection;* or, by passing obliquely through a body of different density, which is called *refraction;* or, by being turned aside by the opposition of some intervening body, which is called *reflection*; or, lastly, by being totally stopped by some body into which they penetrate, and this is called their *extinction.* A succession of these particles following one another, in an exact right line, is called a *ray of Light;* and this ray, in whatever manner its direction may be changed, whether by reflection, refraction, or inflection, always preserves a rectilinear course, till it be again changed. It is to be observed, that bodies, as they respect the rays of light, are divided into three kinds: 1. Those which *emit* the rays of Light; as the sun and fixed

stars:

stars: 2. Those which *transmit* the rays, as the air, and glass: and 3. Those which *reflect* them, as the moon, the earth, polished iron, &c. The first are called *luminous*, the second *pellucid*, and the third *opaque* bodies. It is also to be observed, that the rays of Light themselves are not seen; but by their means we see the luminous bodies, from which they originally came, and the opaque bodies, from which they are reflected thus, for instance, when the moon shines. we cannot see the rays which pass from the sun to the moon; but, by their means, we see the moon, from whence they are reflected. If the eye be placed directly in the medium, through which the rays pass to it, the medium is not seen; thus, we never see the air through which the rays come to our eyes. But if a pellucid body, through which the rays are to pass, be placed at a distance from our eyes, that body will be seen, as well as those bodies from whence the rays come which pass through it to our eyes. For instance, he who looks through a pair of spectacles, not only sees bodies through them, but also sees the spectacle glasses; because the glass, being a solid body, reflects some rays of light from its surface; and being placed at a convenient distance from the eye, may be seen by those reflected rays, at the same time that bodies at a greater distance are rendered visible by the transmitted rays.

The properties of reflection and refraction produce several curious effects, some of which have been noticed in the Sixteenth Lesson; and others will be spoken of as we proceed.

Amongst

Amongst them we must not pass by the phænomenon of the variety of *Colours*, which are observable all over the face of nature, seeming peculiarly adapted to increase the pleasure of mankind. *Colours* are nothing else than different sensations excited in us by the variously refracted rays of light being carried to our eyes in a different manner, according to the different size, or shape, or situation of the particles of which the surfaces of bodies are composed. Colours, then, are not inherent in the bodies which appear to wear them; but they seem to arise from a capability or disposition in those bodies to reflect back particular rays, and these rays possessing different degrees of refrangibility produce the effect: thus it is found that the least refrangible rays produce the idea of a *red* Colour; and as the refrangibility increases, the ideas of the intermediate Colours are excited, till at length we arrive at the opposite extreme of refrangibility, and then the sensation of a *violet* Colour is produced. The primary Colours are, according to NEWTON, seven in number, of these I here present you with a poetical account:

——— First the flaming *red*
Sprung vivid forth; the tawny *orange* next;
And next delicious *yellow*; by whose side
Fell the kind beams of all-refreshing *green*;
Then the pure *blue*, that swells autumnal skies.
Etherial play'd; and then, of sadder hue,
Emerg'd the deepen'd *indico*, as when
The heavy-skirted evening droops with frost;
While the last gleanings of refracted Light
Dy'd in the fainting *violet* away. THOMSON.

Thus

Thus you have the regular gradations from one Colour to another laid before you, agreeably to the hypothesis which supposes the number of primary Colours to be seven: but it is yet a matter of dispute whether there are *seven* primary Colours, or whether their number is greater or less than seven. Many persons assert that there are but *three primary* Colours; but it is very evident that they affix an idea to the term totally different from that which is derived from *Newton*'s definition. He calls the Light whose rays are all alike refrangible, *simple, homogeneal,* and *primary;* and he shews that *Colours may be produced by composition, which shall be light to the Colours of homogeneal Light, as to the appearance of Colour, but not as to the immutability of Colour and constitution of Light.* But the new opinion of the theorists above spoken of is, that the primary Colours are *red, yellow,* and *blue,* because, of proper mixtures of these three Colours, all others may be formed. It would be a needless multiplication of words to shew, that Newton and they considered the subject in different points of view.

To have a familiar notion of the production of Colours, let the following experiment be tried: any time when the sun shines, standing in the open air, let the bowl of a tobacco pipe be filled with a lather of soap and water; then, gently blowing at the other end, a large bubble will arise, which let remain suspended at the top of the bowl: then let two or three persons carefully observe the different

different Colours, as they arise in the bubble; and they will perceive first *red*, then perhaps *blue*, or *orange*, *green*, *indigo*, *violet*, and in short, here and there, all manner of Colours; even *white* and perhaps at last a sort of *black**.

It

* The following curious and useful remarks on the different degrees of heat imbibed from the sun's rays, &c. by cloths of different Colours, were extracted from "Experiments and Observations" by that famous American philosopher and politician, *Dr. B. Franklin*.

"First, let me mention an experiment you may easily make yourself. Walk but a quarter of an hour in your garden when the sun shines, with a part of your dress white, and a part black; then apply your hand to them alternately, and you will find a very great difference in their warmth. The black will be quite hot to the touch, the white still cool.

"Another. Try to fire paper with a burning glass. If it be white, you will not easily burn it;—but if you bring the focus to a black spot, or upon letters written or printed, the paper will immediately be on fire under the letters.

"Thus Fullers and Dyers find black cloths of equal thickness with white ones, and hung out equally wet, dry in the sun much sooner than the white, being more readily heated by the sun's rays. It is the same before a fire; the heat of which sooner penetrates black stockings than white ones, and is so apt sooner to burn a man's shins. Also beer much sooner warms in a black mug set before the fire, than in a white one, or in a bright silver tankard.

"My experiment was this: I took a number of little square pieces of broad cloth from a tailor's pattern card, of various colours. There were black, deep blue, lighter blue, green, purple, red, yellow, white, and other Colours, or shades of Colours. I laid them all out upon the snow in a bright sunshiny morning. In a few hours (I cannot now be exact as to the time) the black, being warmed most by the sun, was sunk so low as to be below the stroke of the sun's rays; the dark blue almost as low, the lighter blue not quite so low as the dark; the

It may be observed, that *black* and *white* are never reckoned among the primary Colours; for

the other colours less as they were lighter; and the quite white remained on the surface of the snow, not having entered it at all.

"What signifies philosophy that does not apply to some use? May we not learn from hence, that black clothes are not so fit to wear in a hot sunny climate, or season, as white ones; because, in such clothes the body is more heated by the sun when we walk abroad, and are at the same time heated by the exercise, which double heat is apt to bring on putrid dangerous fevers? That soldiers and seamen who must march and labour in the sun, should, in the East or West Indies, have an uniform of white? That summer hats for men or women, should be white, as repelling that heat which gives head-achs to many, and to some the fatal stroke that the French call the *Coup de Soleil?* That the ladies' summer hats, however, should be lined with black, as not reverberating on their faces those rays which are reflected upwards from the earth or water? That the putting a white cap of paper or linen, within the crown of a black hat, as some do, will not keep out the heat, though it would if placed without? That fruit walls being blacked may receive so much heat from the sun in the day time, as to continue warm, in some degree, through the night, and thereby preserve the fruit from frosts, or forward its growth? With sundry other particulars of less or greater importance, that will occur from time to time to attentive minds?"

Many other properties of bodies of different Colours may be found in various parts of *Sir Isaac Newton's* Optics.

The subject of Light and Colours has been lately considered with much acuteness and attention by *Mr. Delavel*. From a variety of well-conducted experiments this gentleman concludes, that Colours are exhibited, not by reflected, but by transmitted Light. For an ample investigation of this curious and interesting subject, the reader must be referred to the *Memoirs of the Manchester Society*, Vol. II.

black

black cannot with propriety be called a Colour, it being a deprivation of all Light, because the substance stifles all the rays: but *white*, on the contrary, is comprehended of all the primary Colours in one, as may be proved experimentally, by taking a small wheel with a broad rim, which let be divided into 360 equal parts; then let 45 of these parts be painted *red*; 37, *orange*; 48, *yellow*; 50, *green*; 60, *blue*; 40, *indico*; and 80 of *violet*; making in all 360: if this wheel be whirled swiftly round, the rim will appear as though it were painted of the purest *white*. It is pretty generally admitted, that the whiteness of the sun's Light is owing to a mixture of all the original Colours in a due proportion; and hence it is naturally concluded, that whiteness in other bodies is a disposition to reflect all the rays of Light in the same proportion and order as they come from the sun.

My young readers will, I doubt not, after attending to what has been advanced in this Lesson, readily unite with me in acknowledging, with gratitude and joy, the great utility and benefit of Light. For by the help of this admirable, this first-made creature of the *Deity*, we are enabled (as before suggested) to behold many other of his glorious works: we can view with admiration and pleasure the beauties of the flowery fields, the gay attire of the feathered tribes, the exquisite and well-adapted proportions of many insects, quadrupeds, and other creatures; we can dwell with rapture in the contemplation of extensive landscapes

scapes and diversified prospects; we can trace enough to be convinced of the great harmony and beauty of the lower part of creation; and we can extend our views to the heavens, and thus survey God's wonderful skill and contrivance, so clearly manifested in every region of his glorious works.

LESSON XXVI.

ON THE RAINBOW.

—— Refracted from yon eastern cloud,
Bestriding earth the grand etheriel bow
Shoots up immense, and every hue unfolds,
In fair proportion running from the red,
To where the violet fades into the sky.

THOMSON.

DOUBTLESS you have frequently beheld that beautiful appearance known by the appellation of the *Rainbow*, or *Iris*, bending gracefully and majestically across the sky, painting the arched vault with a pleasing variety of beautiful colours: when this is viewed by the philosophic eye, it immediately excites an inclination to explore the cause of so curious and pleasing a phænomenon.

—— Not so the playful boy;
He wondering views the bright enchantment bend,
Delightful, o'er the radiant fields, and runs
To catch the falling glory; but, amazed,
Behold th' amusive arch before him fly,
Then vanish quite away. THOMSON.

By a perusal of holy writ you will discover, that the *Rainbow* was first placed, and is still at times seen

seen in the clouds, as a pledge of inviolable fidelity and infinite mercy; assuring us, that, "while the "earth remaineth, seed-time and harvest, and "cold and heat, and summer and winter, and day "and night, shall not cease." How gracious and benevolent that BEING, who so often renews a covenant of kindness and mercy to his creatures; and that too, in such a manner as to raise pleasing sensations in every heart, and charm every beholder!

To account for the production of the *Rainbow*, we are in the first place to consider, that it is never seen but in the time of rain, or near it, and when the sun shines. You will understand, then, that when a ray from the sun falls upon a drop of rain in a cloud, if it enter the upper part of the drop in a proper situation, it will, by refraction, be thrown upon the inner surface of the back part of the drop; from thence it will be reflected to the lower part of the drop, at which place undergoing a second refraction, it will be bent towards the earth: and thus rays of the sun, after one reflection, and two refractions, may come to the eye of a spectator, whose back is towards the sun, and his face towards the drop. When rays which are effectual, emerge from the drop after one reflection and two refractions, those which are most refrangible, will, at their emersion, make angles with the incident rays, different from those which are least refrangible; by which means the rays that produce the sensations of different colours

will

will be separated from one another. Hence it may be easily perceived, that some of the falling globules may be in that position which will cause the rays that produce a red colour to fall upon the eye,—others next to them below will send forth orange-making rays,—the drops next to them will cast the yellow-making rays,—and those successively in order below them, will refract the blue, indico, and violet-making rays to the eye;—and thus, in a certain space in the cloud, all the colours will appear; and since, under the same angles, the same phænomena will be produced, therefore an arch of this various-coloured light must necessarily be produced in the clouds.

The different sizes of the Rainbows depend entirely upon the height of the sun at the time: for when the sun is in the meridian, or at his highest altitude, the bow will then be least to our sight, being but a small segment of a circle; but as the sun gets lower and lower, the bow will increase in height; and when the sun is in the horizon, or just setting, a bow at that time is as large as it can be, being very nearly semi-circular. It may also be observed that at all those places and times when the altitude of the sun is more than 42° no primary *Rainbow* can appear; and when his altitude exceeds $54\frac{1}{2}°$ no secondary bow can appear.

With regard to the part of the sky in which a Rainbow appears, when I say that it is *always opposite to the sun*, I present you with an invariable rule where to find it; and this is an additional reason for

for concluding, that the appearance is occasioned by the rays of the sun shining upon the falling drops of rain.

There is also often seen a fainter coloured bow, commonly called a *water-gall*, above the Rainbow; and here it will be found, that the colours are in a contrary position to what they are in the bow itself: hence it is evident that this is a kind of reflection from the Rainbow, or a double reflection from the drops of rain; and as a considerable quantity of light is lost at each reflection, it is plain that the colours in the superior bow will be more dilute and faint than those in the lower.

The nature of the Rainbow, as here explained, may be illustrated and confirmed by experiment in several different ways. Thus, for example, hang up a glass globe, full of water, in the sun-shine, and view it in such a posture, that the rays which come from the globe to the eye may make an angle of about 42° with the sun's direct rays, and you will see a full red colour in that side of the globe opposite to the sun: and by varying the position so as to make that angle gradually less, the other colours, yellow, green, and blue, will appear very distinctly, in succession, on the same side of the globe. But if, by raising the globe, the angle be made about 50°, there will appear a red colour in that side of the globe which is toward the sun, though somewhat faint; and if, by raising the globe still higher, the angle be made greater,

 this

this red will change successively to the other colours, yellow, green, and blue.

Or, the appearances of the Rainbow may be exhibited, in a very natural and beautiful manner, any day when the sun shines, with the assistance of an *artificial fountain*, or *jet d'eau*, which is an instrument expressly intended to throw up streams of water to a great height. These streams, spreading very wide in their upper part, when falling, form a delightful shower of artificial rain. When the fountain is playing, move between it and the sun, at a proper distance from the fountain, until your shadow points directly towards it: then looking at the shower, you will observe the colours of the Rainbow, very vivid and strong—those of the water-gall very languid and faint—the gradations of the colours of each in an inverted order: and, what forcibly shews the deceitfulness of vision, the bows appear, notwithstanding the nearness of the artificial shower, to be as far off, and as large, as those which we really see in a natural shower of rain.

A similar bow is often observed among the waves of the sea, the upper parts of the waves being blown about by the wind and so falling down in drops: this is called the *Marine Rainbow*. This appearance is also sometimes seen by moon-light, though it is seldom vivid enough to render the different colours distinguishable: it is then called the *Lunar Rainbow*. Rainbows are even sometimes seen on the ground, when the sun shines on a very thick

thick dew. All these are of the same nature, and are produced by the same causes as the common Rainbow *.

When we consider what a wonderful scenery of nature is here displayed; and yet recollect, that though these variegated beauties are the common objects of vision, how few there are that understand the reason of them, and how much fewer are any way anxious about them: surely those who think the doctrine of colours, &c. highly worthy of contemplation, and who are aware that the knowledge of their causes is truly adorning to a reasonable mind, ought to be thankful that their natural genius enables them to understand such studies!

* I cannot forbear adding a note in this place, to state a fact which is not universally known: *a piece of iron when heated, assumes all the colours of the Rainbow, before it becomes red hot.* This extraordinary circumstance, I believe, has not yet been satisfactorily accounted for.

LESSON XXVII.

ON HALOS AND PARHELIA.

As when two suns appear in th' azure sky,
Mounted in Phœbus' chariot fierie brighte:
Both darting forth faire beams to each man's eye,
And both adorn'd with lamps of flaming light;
All that behold such strange prodigious sight,
Not knowing nature's work, nor what to weene,
Are wrapt with wonder, and with rare affrighte.

SPENSER.

THERE remain yet two appearances caused by the reflection and refraction of light, to be described and accounted for: the first, known by the name of an *Halo* or *Crown*, is very frequently seen without creating any degree of surprize; the other, called a *Parhelion*, *Parheliam*, or *mock sun*, is but very seldom observed; and as it is a curious phænomenon, it is not at all extraordinary that it is, among the common people, considered as portentous. To a description of each of these I shall now proceed.

And first of *Halos*, or *Coronæ*, which are coloured circles, or rather ovals, appearing round the face of the *sun* and *moon*, as well as some of the larger stars, particularly the planet *Jupiter*. Halos round the sun or moon, generally appear oval and excentric

tric to the luminary, having their longest diameter perpendicular to the horizon and extending farther below the luminary than above it: this probably is a deception of vision, arising from the apparent concave of the sky being less than a hemisphere. Those about the moon are often very large, and when seen by the country people, they will commonly observe, "We shall have a change of weather soon, for there is *a bur round the moon*:" perhaps their observation may not be altogether void of a reasonable foundation.

Philosophers sometimes conceive Halos to arise from a refraction of the rays of light in passing through the fine rare vesiculæ of a thin vapour towards the upper parts of the atmosphere. But an opinion more generally received, is that which supposes Halos to be formed by small round grains of hail, composed of two different parts; the one of which is transparent, inclosing the other which is opaque, and the reflection from these producing the appearances: this is the more probable when it is recollected that they are only seen in frosty, rhimy, or hazy weather.

There are several ways of exhibiting phænomena similar to those of Halos: thus, the flame of a candle, placed in the midst of a steam in cold weather, or placed at the distance of some feet on the other side of the window, in each of these circumstances will appear to be encompassed by a coloured Halo. Also, when the window of a room is encrusted over with a thin plate of ice, the moon seen through it will seem surrounded with a large and various coloured Halo.

Parhelia are far more rarely seen, but their appearance is singularly curious. Their apparent size is generally the same as the true sun; but they are not always round, nor always so bright as the sun; and, when several appear, some are brighter than others. They are tinged externally with colours like the rainbow; and many of them have a long fiery tail, opposite to the sun, becoming paler towards the extremity. These tails mostly appear in a white horizontal circle, commonly passing through all the Parhelia, and would go through the centre of the sun, if it were entire.

We have on record, an account of Parhelia seen at *Rome*, in March 1629: at this time four were observed, one of which was very much tinged with various colours like the rainbow; and the others were faintly so. Some were also observed by *Cassini*, in 1683. In *England* and *Scotland*, two have frequently been seen at a time. In *North America* they are often seen, and continue for hours, nay sometimes for several days, being visible from sun-rise to sun-set: when these disappear, rain or snow is there generally expected.

M. Huygens, on applying his attention to these appearances, was soon sensible that they could not arise from such globules as formed the *Halos*: yet since *Parhelia* are always attended with Halos, he was satisfied that their causes must be much alike. Considering, then, what other figures hail-stones might

might possibly have, besides a spherical one, he could find no other so simple as that of a cylinder: and, indeed, he had often observed, that snow consisted of several slender oblong particles, mixed with those of other shapes: and seeing that small globules were sufficient for the production of Halos, he imagined that a great number of small cylinders, floating in the air, might produce similar appearances. He also remembered that *Descartes* had taken notice of certain small columns, which he had seen lying on the ground, the extremities of which were bounded with flat star-like figures, consisting of six rays.

The large white horizontal circle, observed in some of these phænomena, M. Huygens supposed to be produced by the reflection of the sun's rays from the outsides of the upright cylinders; since, when the sun shines upon a number of such cylinders suspended in the air, a white circle must necessarily appear to pass through the sun parallel to the horizon. This he shews very distinctly by a large figure of a cylinder, and by pointing out the progress of the sun's rays reflected from it. For every point of the sun's verticle diameter, as well as his centre, will illuminate a circle of cylinders, of the same apparent height as the illuminating point.—It is observable that no thick clouds are seen in the air when these circles appear; but only such as are very thin, and scarcely visible. For in most of these observations the sky is said to have been very clear and serene; which agrees quite well with this hypothesis; since these minute cylinders must constitute a very thin cloud uniformly extended: through which the sun, and even the colour of the sky may be seen.

The whole of *Huygens*'s dissertation, from which the above hypothesis is deduced, is much too long to be given in this place. Those of my young readers who wish to peruse it, are referred to chap. xi. book I. Dr. *Smith*'s *Optics*.

LESSON XXVIII.

ON FIRE.

Fire, thou swift herald of His face,
Whose glorious rage, at his command,
Levels a palace with the sand,
Blending the lofty spires in ruin with the base!
Ye heavenly flames that singe the air,
Artillery of a jealons God;
Bright arrows that his sounding quivers bear,
To scatter deaths abroad:
Lightnings, adore the Sovereign Arm that flings
His vengeance, and your fires upon the heads of kings.

WATTS.

IN our contemplations, we will now make a transition, to consider the advantages, nature, and effects, of that wonderful agent of nature called *Fire:* and here we shall find numerous reasons for increasing in gratitude and love to the beneficent POWER who produced so astonishing an element chiefly for our use. If there were no such thing as fire, in what would the earth we inhabit, after the setting of the sun, covered with cloudy and nocturnal vapours, differ from the most dismal subterraneous caverns and dungeons; since, during such time, no man would be able to dispatch any kind of business, neither would he have the temerity to move one foot forwards? Without fire, which, by the means of candles, lamps, torches, and the like, affords us light in the greatest darkness, what difference would there be between our condition, and that of men who should be blind half their life-time? Without fire, greater part of the productions of the earth which serve mankind for food, for refreshment, or for dainties, would be absolutely unfit for those purposes; as several of them could neither be chewed by the teeth, nor digested by the stomach. Nay, we may be easily convinced, that neither corn, nor flesh, nor several of the fruits of the ground, nor of trees, would, without the help of fire, be of any service; but would turn to a crude, unwholesome nourishment.

Again,—would not the dreadful cold of winter, if not moderated by fire, be the mean of dispeopling whole countries, and of freezing to death myriads of men, women, and children? And, again,—if there were no fire, though the mines of iron, &c. were more numerous than they are, of what utility would they be; since, without its aid, they could not separate the metal from the ore, nor by any means make those instruments for agriculture, arts, and manufactures, which we now have in such abundance?

For the sake of a supposition, let us imagine, that we were in a state, continually without light, without warmth, without any method of preparing raw food for sustenance, without all the conveniencies, which metals (and principally iron) now afford

afford us: let us suppose, I say, that in such a situation we received information that a person had invented something by the help of which all these defects and wants might be supplied: I would only ask, if we should not, under such circumstances, entertain very high ideas of the wisdom of the inventor?

The ingenious young reader will know how to apply this conjecture and question, without any farther comment upon them.

By *Fire* is here to be understood, that subtile invisible cause by which bodies are made hot to the touch, and expanded or enlarged in bulk; by which fluids are rarefied into vapour; or solid bodies become fluid, and at last either dissipated and carried off in vapour, or else melted into glass. It seems also to be the chief agent in nature, on which animal and vegetable life have an immediate dependence.

Among philosophers, Fire is now usually denominated CALORIC, which appears to be a highly elastic and imponderable substance; and it is so very subtile, that neither has its gravity been yet ascertained, nor its existence, in a simple and uncombined state, been shewn. There can be very little doubt that it radiates with light from the sun: and experiments shew, that, like light, its absorption is affected by the difference of colour and of surface possessed by different bodies. It combines chemically with all bodies, in a quantity proportioned to their affinity with it. By its elastic power, or power of repulsion, it constantly tends

to

to separate the particles of matter; in which it is opposed by the attraction of cohesion: hence attraction of cohesion predominating, the body exists in a *solid* form: caloric existing in such a proportion as to weaken the attraction of cohesion to a certain degree, the body assumes a *liquid* form; and when the quantity of caloric is increased still farther, the body takes a *gaseous* form.

That heat moves, like light, with vast velocity, is inferred from caloric being always found to accompany the rays of light. Dr. *Herschell* has discovered that the coloured rays of light are possessed of a heating power, and that the least refrangible rays possess this power in the highest degree: this power diminishing as the refrangibility increases; the red rays possessing, therefore, the greatest, and the violet the smallest power. This property is directly opposite, in this respect, to the property which the rays of light possess, of deoxidizing substances exposed to their action; this property existing in the rays of light, in proportion to their degrees of refrangibility. It is likewise remarkable, that as the *deoxidizing power* exists, in the highest degree of all, at a certain distance beyond the violet ray, and out of the spectrum, so the calorific power is found to exist, at its *maximum*, at about half an inch beyond the termination of the spectrum, by the red rays.

These calorific rays, and which are even regarded as rays of caloric itself, suffer refraction and reflection, similar to the rays of light; possessing generally, however, less refrangibility than the rays of of light; and having the angle of their reflection equal to the angle of their incidence. This is supposed to be the case, not merely with the caloric immediately derived from the sun, but with that which proceeds from our common fires, candles, and even hot water, and iron heated not so much as to become lucid. It appears, by the experiments of Professor *Pictet,* that the radiation of heat, and even its reflection, takes place independent of light: thus a piece of iron heated, but not so high as to emit any light, being placed in the focus of a concave mirror, will very sensibly affect a thermometer, placed in the focus of another mirror opposed to the former. On the same principle, if ice be employed instead of heated iron, the thermometer will be affected in a contrary direction. From this latter experiment it has been conjectured that cold, as a body, is emitted from the ice, and reflected by the mirror. This opinion, however, appears to be entirely unfounded. On a lighted candle being thus employed, and a plate of clear glass being placed between the mirrors, the caloric appeared to be intercepted, although the light passed with its usual facility; the thermometer sinking 14°, in nine minutes, and rising 12°, in seven minutes after its removal. Caloric is transmitted through some bodies with unabated rapidity, whilst its passage through others is very considerably retarded; and hence bodies have been named either *good or bad conductors.* The cause of this difference has never yet been satisfactorily ascertained. All bodies appear

appear to be capable of conducting caloric, and fluids also possess the property of conducting it slowly.

Heat constantly tends to form an equilibrium, by passing from bodies of an higher and diffusing itself through bodies of a lower temperature.

Two bodies of the same nature, unequally heated, on being brought into contact, soon arrive at an equal temperature, the caloric becoming equally divided between them. But when two bodies, differing in their nature, and differing in the quantity of caloric they possess, are thus allowed to form one common temperature, by communication, this will not be found to be an arithmetical mean between the two original temperatures; but the one will be found to have required a greater or less quantity of caloric than the other, to render it of the common temperature.

In this way it is found that the quantity of caloric which raises mercury 38°, raises water only 12°; consequently the caloric which raises the temperature of water 1°, will raise that of the same weight of mercury 3.16°. The quantity of caloric which a body thus requires to heat it to a given temperature, is called the *specific caloric* of that body. Thus the quantity of caloric which heats water 1°, heats the same quantity of mercury 3.16°; the specific caloric of water is, therefore, 3.16 times greater than that of mercury; and, consequently, if the specific caloric of water be = 1, that of mercury must be = 0.31. It is fully established that the specific caloric is different in

different

different bodies: as when bodies manifest the same temperature by the test of the thermometer, the relative quantity of caloric which they contain is, we discover, very different. Much ingenuity and acute investigation have been employed to ascertain the absolute quantity of caloric which they contain. These endeavours have not, perhaps, been as yet completely successful.

Dr. Black discovered, that whenever a *solid becomes a fluid*, a great portion of heat enters into it, which does not affect the thermometer; and that, on its again *becoming solid*, this portion of heat quits it, without a diminution of its temperature taking place. Snow at 32°, being mixed with an equal quantity of water at 172°, the snow melts, and the mixture is only 32°; so that the water has parted with 140°, which has disappeared, and has combined with the snow, shewing that snow or ice, during its change into water, absorbs, and, indeed, combines with 140°, of caloric. It also appears that water, though cooled down to 32°, does not freeze until it has given out 140° of caloric: on the absorption, or the parting with this dose of caloric, depends therefore the fluidity or solidity of water. Not only the fluidity of such bodies as liquify, but the softness of such bodies as acquire this state by heat, depends also on the quantity of heat which thus combines with them. The malleability and ductility of metals likewise depends on the same cause. The quantity of heat thus imbibed, Dr. Black calls *latent heat*; since it does not manifest itself by its effects on the thermometer.

meter. It has been called by others the *caloric of fluidity*.

At the moment of the chemical union of two different substances, the new compound, not, perhaps, having the same capacity for caloric as its constituents, must either yield a part to neighbouring bodies, or receive it from them: producing thereby a change in their temperature, which is increased in the former, and diminished in the latter case.

Ice, we have seen, imbibes the caloric of surrounding bodies, until it has imbibed sufficient to render it fluid; the temperature of those bodies descending proportionally. On this principle may be explained the effects of freezing mixtures, of snow and different salts, but particularly muriate of lime. During the liquefaction of these mixtures, so rapidly and so considerably is the caloric absorbed, as to produce a most extraordinary degree of cold, such as even to solidify quicksilver.

Another change in bodies is effected by the presence of heat. All liquids, and many solids, assume a gaseous form, when heated to a certain temperature: thus water is made to assume the form of vapour, and become 1800 times more bulky than water itself. This change Dr. Black discovered also to depend on a certain portion of heat combining with the liquid, without producing any increase of temperature. The latent heat of steam was ascertained to be at least 940°. The Doctor proved that all liquids, during their change into vapour, combine with a portion of heat, without

out undergoing a change of temperature; and that on their reduction to a liquid state, a portion of heat is given out, and likewise without manifesting any change of temperature.

Thus it appears, that by a certain dose of caloric solid bodies become liquid, and that by a farther dose they acquire a gaseous form. Hence the general law discovered by Dr. Black; *Whenever a body changes its state, it either combines with caloric, or separates from caloric.*

Dr. Irvine admitted the importance of the facts discovered by Dr. Black; but supposed, that the quantity of heat absorbed by different substances, depended on the *capacities* which those substances possessed for heat: and which he ascertained was different, in different substances; and, in the same substances, under different forms. He also believed that the heat thus absorbed does not exist in any peculiar state: he therefore objected to the term *latent heat,* when intended to imply such a circumstance.

It has been likewise ascertained, that on salts, which contain much water in their composition, as muriate of lime, &c. being dissolved in water, the temperature sinks considerably; but if previously deprived of their water, the temperature rises. This is to be explained by this law—that when the compound, formed by the union of two bodies, is more dense or fluid than the mean density or fluidity of the two bodies before mixture, then the temperature is diminished: but when the fluidity

or

or density becomes less, then the temperature is increased. Thus when the solution of a mixture of salt and snow is completed, the temperature rises. The whole of these phænomena, as Dr. Thomson observes, as well as the evolution of heat during putrefaction or fermentation, are readily explained by Dr. Black's theory of latent heat.

Setting aside certain particularities of a very few bodies, it may be assumed, that every addition of caloric to a body is succeeded by the expansion of that body: and every abstraction of caloric by a diminution of bulk. Gaseous bodies in general expand most: common air expands eight times more than water, and liquids expand more than solids: thus the expansion of water is about forty-five times greater than that of iron.

Mr. Dalton, of Manchester, has ascertained, by a simple apparatus; consisting of a graduated glass tube, open at one end, at which end mercury is introduced to a given point, the rest of the tube being filled by gaseous matter, the dilation of which is measured by the quantity of mercury, which is forced out by the application of heat to the gas; that all gaseous bodies suffer the same degree of expansion from the same addition of caloric, under the same circumstances: and the increase of bulk it $\frac{1}{483}$ part, for 1° elevation of the mercury in the thermometer. M. Gay Lausac also made a series of experiments, the result of which coincided with that of Mr. Dalton's. From these experiments

experiments it appears, that the expansion of all elastic fluids, including steam of water, vapour of ether, &c. is equal and uniform, and nearly equable.

Fire, in a sensible or collective state, is well known to be one of the grandest agents of nature; and for this very reason, perhaps, was regarded amongst most nations, in an early period of the world, either as the creator and productive cause of all things, or, at least, as the substance from which the Creator produced all things. Hence the Persians, Ethiopians, Scythians, and Carthaginians, in the Old World, and the Mexicans and Peruvians in the New, paid divine honours to fire itself, or to the sun, which was esteemed the sublimest representation of this element. Zoroaster ordained the erection of pyrea, or temples dedicated to fire, throughout all Persia. And even the Hebrews imagined fire to be the grandest proof of the presence of the Deity. Under this symbol, He appeared to Moses on Mount Horeb; and to the Hebrews at large on Mount Sinai, on the promulgation of the sacred law; and under this symbol He evinced his protective presence every night, by assuming the form of a fiery pillar. And, impressed with this idea, the Jews were ever anxious to preserve it in a pure and active flame, upon the national altar. When, therefore, the Jews were borne away in captivity to Persia, the priests took the sacred fire of the altar and concealed it in a dry cave, with which none but themselves were acquainted, and where, on their restoration to liberty,

berty, the posterity of those priests found it on their return to Judea. (2 Maccab. i. 18.) Fire was regarded with an equal degree of veneration throughout Greece and Rome. Temples in every city were erected to the goddess Vesta—a name importing fire, whether derived from the Grecian εστια, or the Hebrew : and in every temple a lambent flame was perpetually burning over the altar. And even so late as in the third century of the Christian æra, when Heliogabalus anticipated his own apotheosis, and instituted the worship of himself over all the Roman empire, having erected a magnificent temple to his own divinity, he supplied its altar with sacred fire from the temple of Vesta, which he plundered for this purpose.

The frequent reference to fire in the Holy Scriptures, as emblematical and typical, and its frequent introduction either to add dignity or solemnity to occurrences, suggests important reflections. Sacrifices were consumed by fire, to signify that wrath from Heaven is due to sin, and would fall upon the sinful offerer himself, if the victim did not receive it for him by substitution. When the law was given on Mount Sinai, the heavens flamed with fire, and the mountain burned below, to give the people a sense of the terrors of Divine judgment. With allusion to which exhibition, and other examples of the actual effects of his wrath, God is said to be "*a consuming fire*" to his enemies, while he is as "*a wall of fire*" about those who trust in him, to de-

fend

fend them. Elijah was taken up to heaven "in a chariot of fire;" and the destruction of the world by fire, is a positive doctrine of Scripture. This doctrine, indeed, is perfectly consistent with the most correct philosophy. All bodies contain caloric, and this substance, by its expansive force, tends constantly to extend its energy to surrounding substances. The matter which produces lightning also, whatever it may be, is now found to be universally diffused through the system of nature: so that the heavens which, according to the language of Peter, are to "*melt with fervent heat,*" want no foreign matter to convert them into fire. So, likewise, "the earth and the works that are therein," carry with them the seeds of their own destruction, and will, in the appointed time, be burnt up by that element which now resides within them, and is only waiting for the word from its Creator.

LESSON XXIX.

ON WATER.

Ye, whose vital moisture yields
  Life's purple stream, and fresh supply
Sweet waters, wand'ring through the flow'ry fields,
  Or dropping from the sky;
Confess the Power whose all-sufficient name,
Nor needs your aid to build, nor to support our frame.

WATTS.

IF any such person as an Atheist should peruse these Lessons, if he be not yet convinced of the existence of a DEITY, let him pass on with me to the contemplation of *Water:* and here I may venture to say, that he will at least agree with me when I assert, that if there had been no such thing as water in the world, all mankind, and almost all living creatures, even in the midst of a superfluity of air and other food, would certainly perish in a very short time; since thirst, if it be not extinguished, is soon fatal, all men and the greater part of the animal kingdom being unable to exist without drink.

But it may be also observed, that even if it were possible that men and other creatures could exist without drinking, their condition would still be very

very miserable deprived of Water: for without its nourishment, neither grass, nor plants, nor trees, would be able to spring out of the earth; the consequence of which would be, that animals, and consequently mankind would be deprived of food, as well as drink, whence death must speedily follow. From these passages I would not wish to have it inferred, that it is not in the power of the ALMIGHTY to furnish us with a substitute for Water: this the reader may easily judge is not my intention: my only design is, to ask, if these things be produced by chance, as Atheists assert, how it comes about that this same chance is always on our side? For it must appear very strange, that it is owing to mere chance, that creatures in general have the faculty of supporting their lives by Water, and likewise that Water has, by a very *lucky hit*, acquired the properties which are necessary for that purpose!

From the Mosaic account of the creation of the world, we learn, that the division and partition of the Water into proper channels and courses, was part of the workmanship of the second and third days: we there also learn, that the business of the creation was completed in six days. GOD could certainly have *spoken* the whole world into existence in an instant; but his love for his creatures led him to consult their happiness, to make their felicity flow from their duty: for the regular manner in which HE has pleased to create all things, points out to us a lesson which should never be forgotten, namely, that we should so regulate the

manner

manner of spending our time in this world; that the performance of one duty may not interfere with or obstruct another.

Water is an uninflammable fluid, and, when pure, is transparent, colourless, and void both of taste and smell. Mr. Cavendish made the discovery that it is formed by the union of *hydrogen* and *oxygen*. It may, therefore, be considered as an *oxide of hydrogen*: oxygen and hydrogen appearing to unite, only in that certain proportion of which water is the result. The proof of its composition is thus obtained: water, in a state of vapour, being made to pass over iron wire twisted and made red hot, the iron is oxidized, a considerable portion of the water disappears, and hydrogen gas is produced; the iron depriving the water of its oxygen, by which it becomes an oxide, while the hydrogen, combining with caloric, forms the hydrogen gas. Again: 15 parts of hydrogen gas being burnt in a close vessel, with 85 parts of oxygen, water is formed nearly of the same weight as the gases employed: it appearing that, at a temperature lower than that of ignition, the attraction of the respective bases of the two gases to caloric, is stronger than their attraction to each other, which prevents their decomposition; but that at the degree of ignition the attraction of the bases are stronger to each other than to caloric; hence they unite and form water, the caloric and light, their imponderable parts, being disengaged with flame.

The composition of water by the *ponderable* parts

parts of the gases is beautifully evinced, by the experiments of Dr. *Pearson*, by means of the electric spark. Water may be decomposed also by the influence of the galvanic pile. Fresh leaves also being immersed in water, and exposed to the sun, the Water will be decomposed: the oxygen will rise in bubbles, and the hydrogen will enter into combination in the plant.

The ingenious Mrs. *Fulhame* teaches, that Water is essential to the oxygenizement of combustible bodies. Thus, in the reduction of metals, she supposes the Water suffers decomposition; the reducing substance attracting the oxygen of the water, whilst its hydrogen, uniting in its nascent state, with the oxygen of the metal, effects its reduction by a double affinity. Hence, and from a series of well-adapted experiments, she infers, that, first, the hydrogen of Water is the only substance that restores bodies to their combustible state. Secondly, Water is the only source of the oxygen, which oxygenizes combustible bodies. Thirdly, No case of combustion is effected by a single affinity.

At the temperature, marked 32° F., Water parts with caloric, has its volume increased by a confused crystallization, formed by crystallized needles crossing each other at 60°, or 120°, and assumes a *solid* form, when it is termed ICE. The temperature being increased, it re-assumes the *liquid* form of Water, in which a considerable quantity of caloric becomes fixed, and is prevented from passing into a state of vapour, by the pressure of the atmosphere.

mosphere. But if, in the most common state of the atmosphere, the Water be heated to the temperature of 212° F. it then boils, and is converted into an *elastic* fluid, or AQUEOUS VAPOURS, or STEAM, which occupies about 1800 times the space that Water does, and is an invisible fluid, lighter than common air, as 10 to 12, according to *Kirwan*, and as 10 to 14, according to *Saussure*. The degree of heat necessary to make Water boil in an open vessel is, however, variable, according to the purity of the Water and the weight of the atmosphere. The requisite degree of heat is generally between 205° and 214° of Fahrenheit's thermometer. When the pressure of the air is removed, Water will boil with 90° of heat. Water, when confined in the strong metallic vessel, called *Papin's Digester*, may be heated so intensely as to dissolve most earths, and to fuse metallic bodies.

Next to fire, Water is found to be the most penetrative of all bodies, and the most difficult to be confined. It will pass through leather, bladders, and other substances which will confine air: it will make its way gradually through wood; and is only retainable in glass and some metals. Nay, it was found by experiment at Florence, that when shut up in a spherical vessel of gold, which was pressed with a great force, it made its way through the pores of the gold.

Water, by this penetrative quality alone, may be inferred to enter the composition of all bodies, vegetable, animal, fossil, and even mineral: with this particular circumstance, that it is easily, and with

with a gentle heat, separable again from bodies it had united with. And yet the same Water, as little cohesive as it is, and as easily separated from most bodies, will cohere firmly with some others, and bind them together in the most solid masses: as in the tempering of earth or ashes, clay or powdered bones, with water, and then causing them to be dried and burnt, when the masses become hard as stones; though, without the Water, they would have become mere dust or powder. Indeed, it appears wonderful, that Water, which is an almost universal dissolvent, should nevertheless be, in many instances, a great coagulator.

It has been imagined by some that Water is incompressible, and therefore non-elastic: but Mr. *Canton* has proved, by accurate experiments, that Water is actually compressed, even by the weight of the atmosphere. Besides, the diminution of size which Water suffers when it passes to a less degree of heat, sufficiently shews that the particles of this fluid are, like those of all other known substances, capable of approaching nearer together.

But the most remarkable property of Water is, that which has been already spoken of in the Twentieth Lesson: the discovery of which, as it appears to be one of the most curious and important which modern times can boast of, I must again recur to. For this discovery we are indebted to *Count Rumford;* and it is given in his Essays. After proving, in a very satisfactory way, that the particles of fluids are incapable of imparting heat *to* *each other*, and that when their temperature is undergoing any change, an intestine motion is kept up in them, by a successive alteration taking place in the specific gravity of their particles, he proceeds to shew, that "all bodies are condensed "by cold without limitation, *Water only excepted*," and describes the wonderful effects produced in consequence of this particular fact*.

"Though in temperatures above blood-heat (says the Count), "the expansion of Water with "heat is very considerable, yet in the neighbour-"hood of the freezing point it is almost nothing. "And what is still more remarkable, as it is an ex-"ception to one of the most general laws of nature "with which we are acquainted, when in cooling "it comes within eight or nine degrees of Fahren-"heit's

* The circumstances of this remarkable anomaly have been for some time believed to be the following:—

When heat is applied to water, ice cold, or at a temperature not far distant, it causes a diminution of the fluid. The water contracts, and continues to contract, with the temperature, till it reaches the 40th or 41st degree. Between this point and the 42d or 43d, it suffers scarcely any perceptible change; but when heated beyond the last-mentioned degree, it begins to expand, and increases in volume with every subsequent rise of temperature.

During the abstraction of heat, the peculiarity in the constitution of water equally appears. Warm water, as it cools, shrinks, as other bodies do, till it arrives at the temperature of 43° or 42°. It then suffers a loss of two degrees without any alteration of density. But when farther cooled, it begins to dilate, and continues to dilate, as the temperature falls, till congelation actually commences, whether this occurs as soon as the water reaches the 32°, or after it has descended any number of degrees below it.

"heit's scale of the freezing point, instead of going "on to be farther condensed, as it loses more of its "heat, it *actually expands*, as it grows colder, "and continues to expand more and more as it is "more cooled."

After enlarging upon this subject, he proceeds thus:—"As nourishment and life are conveyed "to all living creatures through the medium of "Water; *liquid, living* Water; to preserve life, "it was absolutely necessary to preserve a great "quantity of Water in a fluid state, in winter as "well as in summer. But in cold climates the "temperature of the atmosphere, during many "months in the year, is so much below the "freezing point, that had not measures been taken "to prevent so fatal an accident, all the water "must inevitably have been changed to ice, which "would infallibly have caused the destruction of "every living thing."

Count Rumford then shews how very powerfully this wonderful contrivance tends to retard the cooling of Water, when it is exposed in a cold atmosphere, and its consequent tendency to prevent all those dreadful evils which must have necessarily ensued, had it not been for this remarkable property: but instead of making farther extracts, which, as they must be short, would be inadequate to the purpose, I must refer my young reader to the Essays themselves, for the time bestowed on the perusal of which he will find himself amply repaid.

Water, as a fluid, is governed by several laws peculiar to itself, to notice all of which would require a volume: one of its most curious properties is, that its *pressure*, or *force*, varies in the proportion of its depth, without any regard to its breadth: if it were not for this remarkable property, it would be impossible for ships, or any other vessels, to put out to sea,—for if the lateral pressure varied with the breadth, it is evident that every sailing vessel would be forced against the nearest shore with great violence, and, of course, there would be an insuperable bar in the way of navigation.

As it would be absolutely impossible to make a calculation of the quantity of subterraneous Waters, I shall not attempi it; but as it is a much easier matter to have an idea of the enormous quantity of Water on the earth's surface contained in seas, we will here set about it. It is a reasonable supposition that of the earth's surface two-thirds are seas: now if we suppose one common depth to be the tenth part of a mile, we shall find that there is Water sufficient to cover the whole globe to the height of six hundred feet; and if this Water were reduced into one mass, it would form a globe of more than sixty miles diameter.

In reflecting upon the various changes of Water, we have a curious kind of *perpetual motion* placed in view:—Vapours are raised from the ocean, by means of the sun and other agents in the process of evaporation; and these are transported by the winds, &c. through every climate. The progress of these

these vapours is interrupted by the tops of mountains, and other causes, whence they accumulate into clouds, and descend in the form of rain, snow, &c. as explained in the Nineteenth Lesson: after having refreshed the surface of the earth, the surplus proceeds, by virtue of its intrinsic gravity, to steer its course through rivulets, &c. to the lower parts, where it meets with rivers, which conduct it to the sea; from whence it again undergoes a similar process, and so on continually. Here I cannot help adverting to the great utility and advantage of the distribution of the Waters and the dry land; which, although it may seem rude and undesigned to a careless view, yet is admirably adapted to our benefit and convenience. The Earth and Waters are so placed about the globe, as to minister to one another's uses. The great oceans, with the seas and the lakes, are so extensive, and so situated as to produce sufficient vapours for clouds and rains, to mitigate the heats, and to refresh the earth with fertile showers. The mountains and the smaller hills are distributed in such a manner as to afford proper situations for fountains, and the sources of rivers; and this, whether they are supplied from the condensation of vapours, or from subterraneous channels. Nay, so abundant is this great blessing which the most indulgent Creator hath bestowed upon us, by means of the distribution of the Earth and Waters, that there is more than a scanty, bare sufficiency, even a surplus and plenty, of this most

 necessary

necessary article afforded to the world: this, too, is so well ordered, by means of the hills and vales on the surface of the earth, as not to suffer a sufficient quantity to remain stagnant at one time, to be of any material injury to mankind. How ought our hearts to overflow with gratitude and praise, for such beneficence and wisdom as are here made manifest!

LESSON XXX.

FOUNTAINS OR SPRINGS.

Tell by what paths, what subterranean ways,
Back to the fountain's head the sea conveys
The refluent rivers, and the land repays:
Tell what superior, what controuling cause,
Makes waters, in contempt of Nature's laws,
Climb up, and gain the aspiring mountain's height,
Swift and forgetful of their native weight.

BLACKMORE.

THE conjectures of philosophers, concerning the *origin of Fountains*, have been various: and though the subject has been discussed frequently for more than two thousand years, it is to be lamented that it is yet attended with considerable difficulty.

Aristotle, whose thoughts on the matter have reached us, was of opinion, that the air contained in the caverns of the earth, being condensed by cold near its surface, was thereby changed into water, and, making its way through, formed fountains or springs. Most of the ancient philosophers after him, embraced this opinion; but the moderns have entirely rejected it, as they have no experience of any such transmutation of air into water.

Among the hypotheses which have lately been proposed to account for the formation of Springs, I shall describe to you only three, they being the only ones which in my opinion carry with them any degree of probability.

The first hypothesis is, that Springs are owing to rain and melted snow. The water penetrates the earth till it meets with a soil, or stratum of earth, of a nature sufficiently solid to sustain it, and prevent it from descending lower in such minute quantities. It then glides gently along in that way which the stratum declines, and in its passage meets with fresh quantities which have been filtered through in the same manner: these gradually descend together till they arrive at an aperture in the surface, through which they escape and form a spring, and perhaps the source of a brook or rivulet.

Another hypothesis, so nearly allied to that just mentioned that it is almost unnecessary to distinguish them in a work of this kind, is that of the ingenious Dr. *Halley*. When this gentleman made his celestial observations upon the tops of the mountains at *St. Helena*, he found that the quantity of vapour which fell there (even when the sky was clear) was so great, that his observations were thereby much impeded: his glasses were so covered with water through the condensation of the vapours, that he was obliged to wipe them every ten minutes. In reflecting upon this, he was led to suppose that the water raised by evaporation from the seas and large rivers might afford a sufficient supply for the water discharged by Fountains. In order to determine, with some degree of accuracy, how much water would be raised in vapour in any space of time,

time, he took a vessel of water salted to the same degree with that of sea-water, in which he placed a thermometer, and by means of a pan of coals brought the water to the same degree of heat as would be produced by the sun in summer: he then affixed the vessel of water with the thermometer in it, to one end of a pair of scales, and exactly counterpoised it with weights on the other. Then, at the end of two hours, he found by the alteration in the weight of the vessel, that a sixtieth part of an inch in the depth of the water was gone off in vapour; and therefore, in twelve hours, one tenth of an inch would have gone off.

From this experiment the Doctor calculates (in as accurate a manner as the subject will admit) the quantity of water raised by evaporation from the *Mediterranean Sea*, to be at least five thousand two hundred and eighty millions of tuns of water in a day; and from the *River Thames* twenty millions three hundred thousand tuns per day, on the average. If, as it appeared reasonable to conclude, other seas and rivers should afford vapour in the same proportion, when they are acted upon by the sun in a similar degree; or in greater or less proportions as they are acted upon in a greater or less degree; this was thought, by the Doctor, a source abundantly sufficient for the supply of Fountains.

The waters thus raised by evaporation, he imagined would keep rising, and float in extremely small and light bubbles, till, being condensed by the cold, they become specifially heavier than the air, when they would descend, or being driven by the winds

winds against the sides of mountains (some of which surpass the usual height to which the vapours would of themselves ascend) are compelled by the stream of air to mount up with it to their tops, and, being presently precipitated, enter the crannies of the mountains, and glide down, as described in the former hypothesis.

In the third hypothesis it is imagined, that the water is conveyed from the sea to the places where there are Fountains, by some subterranean passage; either by ascending in very small portions in capillary tubes, or by being conveyed in larger portions by means of *Charybdes*. Charybdis is a name given to an opening which is supposed to be in the bottom of the sea. The *Fluxus moschonicus* or *Maalstrome*, on the coast of Norway, is supposed to be owing to some such subterranean indraught; and it is asserted also, by several, that the Mediterranean Sea could not be emptied of the vast quantities of water which it receives, but would overflow its boundaries, unless part were taken off by such a charybdis, which is either in some part of the bason of that sea, or near the mouth of it. In support of this supposition may be mentioned that strong under-current, described by all those who have treated of this sea. A large charybdis, placed near the strait's mouth, may be hid under the immensity of waters there, and as it would continually draw in the lower waters in large quantities, it would necessarily cause such an under-current.

If it be admitted, that there are such orifices as these charybdes at the bottoms of some seas,

it

it is natural to inquire of what use they are. And perhaps none will offer a more probable answer to this inquiry, than those who say the waters of the sea are by such means conveyed through subterranean channels to the sides of mountains and hills, whence they gush out at convenient apertures, and form springs.

Each of the hypotheses here advanced admits of objections. To the first two it is objected that they are not the only ways in which Springs are produced: for as causes may always be measured by their effects, it is unphilosophical to conclude, that an inconstant cause will produce a constant effect—and therefore Springs which constantly send forth the same, or nearly the same quantities of water, cannot be supplied in the manner pointed out under the two first hypotheses, where the causes, as rain, snow, or vapours, are inconstant or variable.

Suppose the truth of this remark be allowed, it does not follow from this, that all Springs are produced in some other way. Perhaps, if the nature of Springs, and the nature of the hypothesis be compared, we shall, by such comparison, be brought to a very different conclusion.

Let us consider the first hypothesis. Neither rain nor snow continues without intermission: but there are intervals between the showers, during which neither rain nor snow descends. Is it not probable, that those Springs which flow and stop alternately, and are therefore called *intermitting* Springs, are caused by these showers? It may, perhaps, be objected, that in such Springs, the

time

time of flowing does not seem at all connected with the time of the shower. But in answer to this, I would observe, that it is not an easy matter to judge of this, as it cannot be determined which was the shower that caused the flowing of the Spring. Those showers which cause the Spring to flow may perhaps fall at a great distance from it; while those which fall near it may have an effect upon some Spring at a distance. Or there may be four or five showers fall in the interval, between the flowing of the Spring and that shower which caused it to flow.

But perhaps it may be said, that this hypothesis will not satisfactorily account for those Springs which ebb and flow every six hours, or some such short period. It will not: we must therefore have recourse to the third hypothesis, and suppose that Springs which ebb and flow thus regularly are supplied by *charybdes*, placed in some parts of the sea of such a depth as to cause their discharges to be effected by the tide, and when the tide ebbs and flows at periods similar to those of the Spring.

The second hypothesis will assist us in accounting for *reciprocating* Springs, or those which flow constantly with a stream subject to increase and decrease. If these are supplied by condensed vapours, their streams will increase or decrease in proportion as the vapour which supplied them was produced in a greater or less degree by the union of heat, wind, and other causes.

As to those Springs which are constant and regular in their discharge, we may suppose, that they are supplied from *charybdes*, situated at such a depth

depth as to be not at all affected by the ebbing and flowing of the sea; but convey the water always in equal portions in equal times, and, of course, supply the Springs with regularity.

Against this hypothesis of charybdes, I imagine two objections will be opposed; but I think neither of them will overset it. And first, it may be said, that if many of the Springs are supplied in this way, the charybdes must be numerous, and therefore it is surprising that not more of them are discovered. Here I would reply, that if there are many, suppose a charybdis to a Spring, it follows that they must, comparatively speaking, be very small, and of course, their effects may not be perceptible upon so large and deep a body of water. A hole a quarter of an inch in diameter, would let out much liquor from a full hogshead, though it would not disturb the tranquillity of the liquor at the surface.

But, in the second place, it may be said, that I cannot explain the way in which water is conducted so high above its source. I cannot; but this is no proof that it is not so conducted—no more than it would be a proof that a man was lifeless, because he could not account for his own existence. The properties of various kinds of matter have been determined; but only in such circumstances as would admit of experiments being tried: in those cases where we can only form a judgment by analogy, we are always liable to fall into error, though we may sometimes escape it.

Since the late discoveries in Electricity and Magnetism, matter has been found to possess qualities which

which philosophers of an earlier period were not aware of: and in all probability, matter differently modified, or under different circumstances, may possess properties which are yet undiscovered. Let this stimulate us to fresh exertions in the cause of philosophy; and if, after all, we are obliged to confess ourselves purblind and ignorant in a great degree, let us not despair; for Religion points out a cheering prospect: she directs us to a period when all our faculties shall be expanded, and all our inquiries satisfied:

> "When God's almighty hand shall lift the curtain high,
> And all creation's wonders open to our eye."

LESSON XXXI.

ON THE TIDES.

———Now the mighty mass of water swells
Resistless, heaving on the broken rocks,
And the full river turning, till again
The tide revertive, unattracted leaves
A yellow waste of idle sands behind.

THOMSON.

PHILOSOPHERS in every age of the world have been greatly puzzled to explain and account for the *Tides* of the sea, which ebb and flow twice in twenty-four hours; but in despite of every attempt, the doctrine of them remained in obscurity, until the great Sir *Isaac Newton* developed the mystery. This eminent philosopher having demonstrated that there is a principle in all bodies, by which they mutually draw or attract each other in certain proportions according as their distances or size vary, proved that as fluids are very easily put in motion by any force acting upon them, those parts of the sea which are immediately below the moon, must be attracted towards it, and consequently wherever the moon is nearly vertical, the sea will be raised, which occasions the flowing of the Tide there. A similar reason occasions the flowing of the Tide likewise in those places where the moon is in the nadir,

nadir, and which must be diametrically opposite to the former: for in the hemisphere farthest from the moon, the parts in the nadir being less attracted by her than the other parts which are nearer to her, gravitate less towards the earth's centre, and consequently must be higher than the rest. Those parts of the earth, on the contrary, where the moon appears on the horizon, will have low water: for as the waters in the zenith and nadir rise at the same time, the waters in their neighbourhood will press towards those places to maintain the equilibrium; to supply the place of these, others will move the same way, and so on, to the places ninety degrees distant from the zenith and nadir, where the water will be the lowest.

Let the diurnal rotation of the earth be now taken into the consideration, and it is evident, that every portion will pass twice through the elevated, and twice through the depressed parts, so as to produce two Tides in the day. But the places of high and low water are now altered; for the impressed motions of rising and falling are retained for some time after the forces which produce them are greatest: and the greatest elevation happens about three hours after the meridian of the place has passed under the luminary, when it points about half a quadrant to the east of it: and the water continues to descend for 90 degrees hence, or till the meridian points about half a quadrant to the east of the next quarter. But in shallow seas, and in the mouths of rivers, the Tides are retarded till the fourth, fifth, or perhaps, sixth hour, after the meridian

meridian of the place has passed under the luminary.

The force of the sun to raise the Tides, is about a third that of the moon: but it is evident, that when the forces of both conspire, so as to elevate and depress the water in the same places, then the Tides are greatest, and are called *Spring Tides*, which happen about the new and full moon.

When the moon is in her quarters, she elevates the water most where it is most depressed by the sun, and the contrary; and the Tides, being raised by the difference of their forces, are least, or *Neap Tides*. But because of the continuation of motion, these effects are greatest and least, some time after the forces are: so that the greatest Spring Tides commonly happen three days after the new and full moons; and the least Neap Tides three days after the first and third quarters.

By the action of the sun the time of high water is also changed, being sometimes sooner, and sometimes later than it would happen by the action of the moon alone. For in the transit of the moon from new or full to a quarter, when the tide raised by the sun alone would precede that raised by the moon alone, the high water which is produced by their united actions, will happen at an intermediate time, nearer to, but yet before, the time at which it would be raised by the action of the moon. But when the moon is passing from her quarters to the new or full moon, since the sun alone would produce

produce a greater tide, the time of high water is retarded.

The greatest Spring Tide will happen when the moon is in perige, if other things are the same: and the succeeding Spring Tide, when the moon is in apoge, will be least. But because the earth is nearer the sun in winter than in summer; and the effect of a luminary is also greater, the nearer it approaches to the plane of the equator; the greatest Spring Tides, and the least Neap Tides, will generally happen immediately after the autumnal and before the vernal equinox.

In places remote from the equator, the two immediately succeeding Tides are unequal, whenever the luminary declines from the equator. Thus it is observed, that the evening tides in summer exceed the morning Tides; and the contrary, in winter. For, if the greatest elevation immediately under the luminary points to one side of the equator, the opposite greatest elevation points as much to the other side. And those places, which are on the same side of the equator with the luminary, approach nearer to the greatest elevation, when the luminary is above the horizon, than to the greatest opposite elevation, when the luminary is below the horizon.

This inequality is greatest, when the sun and moon have the greatest declination. It is also greatest in places most remote from the equator. The nearer the place approaches to the poles, the farther it is removed from the greatest elevation on the opposite side of the equator. Thus the less

Tide

Tide is continually diminished, till at last it entirely vanishes, and leaves only one Tide in the day. Hence it is found by observation, that, when the moon has declination, there is only one Tide in twenty-four hours in all places in the polar regions, in which the moon is either always above or always below the horizon, during a whole rotation of the earth about its axis.

These things would happen uniformly in the manner above described, if the whole surface of the earth were covered with water; but since there is a multitude of islands, continents, &c. which interrupt the natural course of the water, varieties of appearances are to be met with in different places, which cannot be explained without regarding the situation of shores, straits, and other objects: and as this would lead me too great a length, without being of much utility, I shall here take my leave of the subject, with remarking, that the most correct popular view of it with which I am acquainted is given by Laplace in his *Exposition du Systême du Monde.*

LESSON XXXII.

ON DAYS AND NIGHTS.

My God, all nature owns thy sway:
Thou giv'st the Night, and Thou the Day!
When all thy lov'd creation wakes,
When Morning, rich in lustre, breaks,
And bathes in dew the opening flow'r,
To Thee we owe her fragrant hour;
And when she pours her choral song,
Her melodies to Thee belong!
Or when, in paler tints array'd,
The Evening slowly spreads her shade;
That soothing shade, that grateful gloom,
Can more than Day's enliv'ning bloom,
Still ev'ry fond and vain desire,
And calmer, purer thoughts inspire;
From earth the pensive spirit free,
And lead the soften'd heart to Thee

MISS WILLIAMS.

PREVIOUSLY to the dawn of the true philosophy, when several erroneous opinions were entertained by philosophers, the principal one with regard to the form of the earth was, that it was a vastly wide extended plain; that the visible horizon bounded the earth, and the ocean bounded the horizon. To account for Day and Night, it was then imagined that the sun in the morning emerged from the eastern ocean, and, after pursuing his daily

daily track, was immerged into the western ocean, whence, in the course of the Night, he travelled on to the eastern in order to perform his next diurnal journey: an absurd doctrine, which is now entirely laid aside; except, indeed, by the most illiterate.

But as my young readers will readily admit the near approach of the earth to a spherical form, I must endeavour to explain to them the occasion of *Day and Night* in a more rational manner.—On account of the immense distance of the earth from the sun, and the earth's minute size when compared with him, it is evident that the rays of light emitted from that luminary (setting aside the effects of the atmosphere) will fall upon the earth in parallel directions, and will always illuminate a hemisphere of the earth, whilst the other hemisphere remains in darkness. Hence then, so long as any particular place on the earth continues in the darkened hemisphere, it will be night at that place: but, as soon as that place, by the diurnal rotation of the earth from west to east, is brought to the verge of the enlightened hemisphere, then is *Day-break*; and

—— The *morn*, in russet mantle clad,
Walks o'er the dew of yon high eastern hill.

SHAKESPEARE.

When the meridian of that place is, by the rotatory motion, brought directly beneath the sun, it is then *Noon* there, and at every place in the enlightened part of the same meridian: but in the darkened part of the same meridian it is is then midnight. As the place is carried forward, the afternoon hours keep wasting, until it arrive at the edge of the darkened hemisphere, and then approaches sober *Evening*, shedding her dusky influence round: that part of the globe which is directly opposite, is, at the same moment, just emerged from darkness into Day-light: and thus, by the earth's rotation, the whole is obviously accounted for.

—When to the western main the Sun descends,
To other lands a rising day he lends;
The spreading dawn another region spies,
And o'er the Antipodes* begins to rise:
While we in Sleep's embraces waste the night,
The climes oppos'd enjoy meridian light;
And when those lands the busy sun forsakes,
With ns again the rosy Morning wakes.

GAY.

To explain the reason of the *different lengths* of Days and Nights will be part of the subject of the next Lesson: but I shall first present you with an agreeable method of shewing all those places of the earth which are enlightened by the sun at any time. In order to this, let a terrestrial globe be taken from its several appendages, and placed upon a pedestal in the sun-shine, in such a manner that its north pole may point directly towards the north pole of the heavens, and that the meridian of the place where you are may be directly toward the south. Then the sun will

* Those people are called *Antipodes*, who, living on the other side of the earth, have their feet directly opposite to ours.

shine

shine upon all the like places of the globe, as he does really on the earth, rising to some when he is setting to others: as you may perceive by noticing where the enlighten'd half of the globe is divided from the half in the shade; all those places, on which the sun shines at any time, having day,—and all those on which he does not shine, having night: also, when any place is near the middle of the enlightened part, it is then nearly noon there; and those places which are about the middle of the darkened part, have then midnight.

The vicissitudes of Days and Nights have raised in the minds of several prose and poetical writers very serious and excellent reflections concerning the sublunary state: with one of which this Lesson may be concluded.

For ever running an enchanted round,
Passes the Day, deceitful, vain, and void;
As fleets the vision o'er the formful brain,
This moment hurrying wild th' impassion'd soul,
The next in nothing lost. 'Tis so to him
The dreamer of this earth, an idle blank;
A sight of horror to the cruel wretch,
Who all day long in sordid pleasure roll'd,
Himself an useless load, has squander'd vile,
Upon his scoundrel train, what might have cheer'd
A drooping family of modest worth:
But to the generous still-improving mind,
That gives the hopeless heart to sing for joy,
Diffusing kind beneficence around,
Boastless as now descends the silent dew;
To him the long review of order'd life
Is inward rapture only to be felt.

THOMSON.

LESSON XXXIII.

ON THE SEASONS.

Observe the circling year; how unperceiv'd
Her Seasons change! behold, by slow degrees,
Stern Winter tam'd into a ruder Spring;
The ripen'd Spring a milder Summer glows;
Departing Summer sheds Pomona's store;
And aged Autumn brews the Winter's storm.

ARMSTRONG.

I THINK there is scarcely one of the youthful perusers of these pages, but must have an inclination (if he be not already acquainted with it) to be made sensible in some measure of the reason and cause of that agreeable succession of the *Seasons* which constitute the year. Here we meet with a variety, the limits of which are not ascertainable. With pleasure we behold the varied appearances of nature: whether Spring arrays herself in her spotted robe; or Summer scorches with his sultry beams; or Autumn pours forth her exuberant stores; or Winter with his howling tempest drives us to our habitations;—still we are admirers of nature, and disposed

————"To mark the mighty Hand
That, ever busy, wheels the silent spheres;
Works in the secret deep; shoots streaming thence
The fair profusion that o'erspreads the Spring;

Flings

Flings from the sun direct the flaming day;
Feeds ev'ry creature; hurls the tempest forth:
And as on earth this grateful change revolves,
With transport touches all the springs of life."

It may have been observed that, when explaining the nature of the tides, I said, "The earth is nearer the sun in Winter than in Summer." This may to many persons appear improbable, but it is absolutely fact: for the apparent diameter of the sun is about 32′ 48″ on the shortest day, and only 31′ 30″ on the longest: whence it is manifest that his distance from us must be less in the former case than in the latter. But the effects occasioned by the difference of distance are more than counterbalanced to the inhabitants of the earth's northern hemisphere: for, though the sun in Summer be farther from us; yet, on account of his being more nearly in a vertical position, his rays fall more directly on any part, and of course are denser and thicker; and this, not only because the same quantity of rays fall on a less space of the earth, but because they are not so much refracted and attenuated by the atmosphere, as when they fall upon it more obliquely.

The diversity of seasons is occasioned by the earth's annual motion in her orbit; and in this motion two peculiar circumstances must be well understood, because on their combination the whole phænomena depend. 1. The earth's axis does not always keep the same relative situation with regard to the sun as the centre of its orbit;

but, on the contrary, it always keeps very nearly in a parallel position, or points always towards the same part of the heavens. 2. The axis of the earth is inclined to the plane of the earth's orbit, which may be conceived by supposing a spindle put through a ball, with one end of it touching the ground, or table; then by moving the ball directly forwards whilst the one end of the spindle continues to touch the ground, or table, and the other points towards the heavens, a tolerable conception of the inclination of the earth's axis to her orbit may be obtained.

The most easy method of acquiring a right idea of the varieties of the Seasons, and the different lengths of days and nights will be by an experiment which I shall now endeavour to describe. Let two large circular hoops nearly of equal size be procured: let one of these be fixed in an horizontal position, and let the other be fixed within it in such a manner as to cross it in an angle of 23½ degrees, having one half above the horizontal hoop, and the other half below. When night is arrived, the flame of a candle must be fixed exactly in the centre of the hoops, and a small terrestrial globe must be taken from its appendages, having a string tied to its north pole, from which string the globe may be suspended. In this experiment, the candle flame must be supposed to represent the sun, and the inclined hoop the earth's orbit: just on the inside of this hoop, the globe suspended from the string must be carried gently round in a direction from west to east; then

then its axis will always be parallel to itself, and the various seasons will be represented in the different parts of the path. Thus, when the globe is at one of the places where the hoops intersect, its poles are equally illuminated, and the days are every where of the same length: then Spring commences to the inhabitants of the northern hemisphere; being about the 20th of March. As the globe is carried on, the days keep increasing, until it has arrived at the lowest part of the hoops; when the north pole will appear a considerable way in the illuminated hemisphere, and the south pole as much in the darkened one; then is our beginning of Summer and their beginning of Winter; and here it may be perceived that any parallel of latitude toward the north pole is considerably more in the enlightened hemisphere than in the darkened one; while, on the contrary, in the southern hemisphere, a far greater part of the parallel of latitude is darkened than enlightened: hence, our days are then longest, and theirs shortest; which happens about the 21st of June. The globe being carried on until it arrive at the intersection of the hoops on the other side; each of its poles is again illuminated, and the days every where of equal length, because each parallel of latitude is half in the enlightened and half in the darkened part: then commences Autumn with us, being about the 22d of September. As the globe is carried on, the days with us shorten, until it has arrived at the highest part of the hoop: then the north pole is in the darkened hemisphere, and the southern one in the enlightened part; our day is at the shortest, while in the southern hemisphere the day is longest; our Winter commences and their Summer; being about the 21st of December. As the motion of the globe is continued, our days lengthen; and when it has again arrived at the intersection of the hoops, we have Spring, and the inhabitants of the southern hemisphere have Autumn. In the course of this experiment it will be found, that each of the poles continues enlightened half through the annual revolution, and darkened through the other half: consequently, at the poles of the earth, there is but one day and one night through the year.

At the equator the sun's rays fall perpendicularly on the earth, and therefore act more powerfully; whence arises the great heat of the torrid zone. On advancing towards both poles, the rays fall more and more obliquely, and therefore act with less force and less; whence this space is occupied, first by the temperate zones extending on each side the tropics, and then by the frigid zones extending from these to the poles. So weak is the sun's power in these last owing to the great obliquity with which its rays strike the earth, that they are buried in almost perpetual snow and ice. But these are merely the differences of *climate:* the differences of *Season* depend not upon these causes merely, but also upon the length of time that any portion of the earth is exposed to the solar rays.

During

During the short days, the sun's influence is less, both with respect to the intensity of its rays and the time of their continuance, which therefore produces Winter: during the long days, it is greater in both respects, and therefore causes Summer. The middle seasons of Spring and Autumn correspond with the equality of nights and days. It is to be remarked, however, that this correspondence is not perfectly exact; for the severest frosts usually take place after the days have begun to lengthen, and the most oppressive heats are found to happen when the days are decreasing: the reason of which is, that the earth, having imbibed more heat than it gave out during the summer months, is not exhausted of its superabundant warmth till about the close of the year: in like manner, because the waste of the earth's heat is greater in Winter than its supply, it continues to imbibe heat during the Spring, and is not saturated till after the Summer Solstice. Hence also arises the difference between the Spring and Autumn, though the position of the sun, in respect to the earth, is in both the same. The heat of the Spring is inferior to that of Autumn, both in point of regularity and degree; for, on account of the deficiency of warmth in the earth, it is constantly imbibing heat from the lower part of the atmosphere; hence originates a large collection of clouds, which, intercepting the solar rays, combines, together with the absorption of the earth, to deprive the air of much of its heat:

 whereas

whereas in Autumn, the earth being hotter than the air, gives out regularly a large portion of warmth, which, naturally tending to disperse the clouds, affords a free passage to the solar rays. Thus Autumn ought in general to be hotter than Spring, for these two reasons: first, that the earth itself gives out a considerable quantity of heat; and, secondly, that the rays of the sun meet with fewer interruptions in passing thence to the earth. At the equator there is no proper difference of Seasons except as occasioned by rainy or windy periods, which proceed from other causes; and the case is much the same on each side of it for some distance.

Several of the British poets have presented us with a variety of descriptions of the Seasons; some serious, some humorous and comic. As an instance of the latter, we have a droll account of Winter's effects, in a song in *Shakespeare*'s play of "*Love's labour lost.*" But the obvious similarity between infancy, youth, manhood, and old age of human life, and the Spring, Summer, Autumn, and Winter of the year, suggests a subject for the most sublime reflections. The excellence of those which Mr. *Thomson* has made on this head, will supersede the necessity of my apologizing for giving them insertion here.

———Behold, fond man!
See here thy pictur'd life: pass some few years,
Thy flowering Spring, thy Summer's ardent strength,
Thy sober Autumn fading into age,
And pale concluding Winter comes at last

And

And shuts the scene. Ah! whither now are fled
Those dreams of greatness; those unsolid hopes
Of happiness; those longings after fame;
Those restless cares; those busy bustling days;
Those gay-spent festive nights; those veering thoughts,
Lost between good and ill, that shar'd thy life?
All now are vanished! Virtue sole survives,
Immortal never-failing friend of man;
His guide to happiness on high. And see!
'Tis come, the glorious morn! the second birth
Of heav'n and earth! Awakening nature hears
The new-creating word, and starts to life,
In every heighten'd form, from pain and death
For ever free. The great eternal scheme,
Involving all, and in a perfect whole
Uniting, as the prospect wider spreads,
To reason's eye refin'd clears up apace.
Ye vainly wise! ye blind presumptuous! now,
Confounded in the dust, adore that Power
And Wisdom oft arraign'd: see now the cause
Why unassuming worth in secret liv'd,
And died neglected; why the good man's share
In life, was gall and bitterness of soul;
Why the lone widow and her orphans pin'd
In starving solitude; while luxury,
In palaces, lay straining her low thought,
To form unreal wants; why heav'n-born truth,
And moderation fair, wore the red marks
Of superstition's scourge; why licens'd pain,
That cruel spoiler, that embosom'd foe,
Imbitter'd all our bliss. Ye good distrest!
Ye noble few! who here unbending stand
Beneath life's pressure, yet bear up a while,
And what your bounded view, which only saw
A little part, deem'd evil, is no more:
The storms of wintry time will quickly pass,
And one unbounded spring encircle all!

THOMSON'S WINTER.

LESSON XXXIV.

VEGETABLES OR PLANTS.

Your contemplations farther yet pursue;
The wondrous world of Vegetables view:
Observe the forest oak, the mountain pine,
The tow'ring cedar, and the humble vine,
The bending willow that o'ershades the flood,
And each spontaneous offspring of the wood.

BLACKMORE.

MY young readers having undoubtedly experienced delight in viewing the beauties of the Vegetable Creation, I am in hopes of contributing to their satisfaction, while I endeavour to explain the nature of *Vegetables* and *Vegetation*.

A Vegetable or Plant is an organized body, consisting of various parts, taking in its nourishment usually by a root, and increasing its dimensions by growth. Vegetables may be divided into three classes; namely, herbs, shrubs, and trees. Herbs are those sorts of Vegetables whose stalks are soft, and have no wood in them; as parsley, lettuce, violets, grass, thistles, and an infinite number of others. Shrubs are those Plants which, though woody, never grow into trees, but bow down their

branches

branches near the earth's surface: such are those Plants which produce roses, honeysuckles, gooseberries, raspberries, and the like. But trees shoot up in one great stem or body, and rise to a considerable distance from the ground before they spread their branches: as the oak, the ash, the elm, the beach, the fir, the walnut tree, the pear tree, and many others.

The most considerable parts of Plants are the root, the stalk or stem, the leaves, the flowers, and the seed. Most Plants have these several parts; though there are some that have not all of them: the aloe, for instance, has no stalk; the savine has no leaves; the fern has no flowers.

The uses of most of the parts of Plants are very obvious: thus, the root evidently serves as a balance or counterpoise to the head, and by that means enables the Plant to stand firmly in the ground. In what other way could enormous oaks be kept upright and fixed, but by the counterbalance of their extensive, turgid roots? The fibrous parts of the roots of Plants, like so many mouths, absorb nutritious juices from the earth, and thus convey to the Plants the chief of their nourishment. The root also discharges the office of a parent, by preserving the embryo Plants in her bosom, during the severity of the winter, in form of bulbs or buds.

The trunk, or stem of plants, consists of various parts, as bark, wood, pith, sap vessels, &c. The bark of Plants performs the same offices to them that the skin does to animals: it clothes and defends

fends them from injuries, inhales the moisture of the air and conveys from the Plant the superfluous humid particles. The bark (as well as the wood) is supplied with innumerable vessels, which convey the fluids to and from every part of the Plant: the wood also is furnished with others, which contain air, and are distributed through its substance. The stability of trees and shrubs consists in the wood, which corresponds with the bones of animals. The pith, which is a fine tissue of vessels originating in the centre of the stem, is supposed to be the seat of life. The fluids of Plants are: the sap, analogous to the blood of animals,—and the proper juice, which is of various colours and consistence, in different individuals; as white or milky in the dandelion, resinous in the fir, and producing gum in cherry or plum trees.

The leaves contribute both to the benefit and the ornament of the plant: they are supposed to answer the purpose of lungs; and by their readiness to be moved by the wind, they may in some measure act the part of muscles. They are very porous on both their surfaces, and inhale and exhale freely. In some Plants (as Venus's Fly-trap), the leaves are armed with long teeth, like the antenna of insects: they are so irritable, that when an insect creeps up them, they fold up, and crush or pierce it to death.

The uses of the flowers and seed, are too evident to need enumeration.

The most general method of propagating Plants is is by seed: some, however, are raised by a part of the root of the old plant set in the ground, as potatoes; others, by new roots propagated from the old ones, as hyacinths and tulips; others by cutting off branches and putting them into the ground which will there take root and grow, as vines; and others are propagated by grafting, and budding, or inoculation.

What is most difficult with respect to Plants (and what has been the subject of much controversy, though yet undetermined), is to explain the manner in which they receive their nourishment. The earth has not so much to do in this business as has been commonly supposed. This is known from the experiments of Mr. *Boyle* and Dr. *Woodward*. These gentlemen raised several Plants in earth watered with rain or spring water, and even distilled water; and upon weighing the dry earth, both before and after the production of the Plants, they found that very little of it was diminished or taken up by the Plant.

If the earth contributes so little towards the production and nourishment of Plants, it seems natural to apprehend that water must be much concerned; and that this is the case in great measure is evident, from the quantity of water which most plants require to keep them in a state of health and vigour. But there is some other agent besides water; else, how can the growth of Plants in sandy desarts where it seldom rains be accounted for, and these Plants such as contain juices in great abundance?

Dr. *Hunter*,

Dr. *Hunter*, so well known and so justly celebrated both as an anatomist and a naturalist, is induced, by a number of experiments accurately conducted, to believe, that all Vegetables receive their principal nourishment from oily particles incorporated with water by means of an alkaline salt, or absorbent earth. Till oil is made miscible, it cannot enter the radical vessels of Vegetables; and on that account, Providence has bountifully supplied all natural soils with chalky or other absorbent particles: and those soils which are assisted by art are full of materials for that purpose; as lime, marl, and the volatile alkaline salt of putrid dunghills.

The argument in favour of oil being the principal food of Plants is confirmed by the observation, that all Vegetables, whose seeds are of an oily nature, are found to be remarkable impoverishers of the soil; as hemp, rape, and flax: and the best manures for lands worn out by these crops are such as have a good deal of oil in their composition, provided that they are laid on with lime, chalk, marl, or soap-ashes, so as to render the oily particles miscible with water.

But Plants not only receive nourishment by their roots, but also by their leaves. Vegetables that have a succulent leaf, such as peas, beans, and buck wheat, draw much of their nourishment from the air; and on that account impoverish the soil less than wheat, oats, barley, or rye, the leaves of which are of a firmer texture. The leaves of all kinds of grain are succulent for a time, during which

which the Plants take little from the earth; but as soon as the ear begins to be formed, they lose their softness, and diminish in their attractive power. The radical fibres are then more vigorously employed in extracting the oily particles from the earth, for the nourishment of the plant.

The leaves of Plants serve not only to imbibe the dew and rain, which contain salt, sulphur, &c. but they serve also as excretory ducts to separate and carry off the redundant watery fluid, which by being long detained in the Plants, would turn rancid and prejudicial to them. The annual sunflower is an extraordinary instance of this fact: it is said to perspire nineteen times as much as a man in twenty-four hours. Fine weather encourages the perspiration of Vegetables; but in heavy, moist, and wet weather the inhalation is greatest. The effluvia of Plants is thought unwholesome to persons of delicate constitutions; but particularly so at night, and in a dull state of the atmosphere: the matter perspired by the yew tree, in particular, is said to be very noxious.

Let us now endeavour to illustrate the subject of *Vegetation*, by taking a view of what happens to a bean after it has been committed to the earth. In a few days, sooner or later, according to the temperature of the weather and disposition of the soil, the external coverings open at one end, and disclose to the naked eye part of the body of the grain. This substance consists of two lobes, between which the seminal Plant is securely lodged. Soon after the opening of the membranes, a sharp pointed body appears, which is the root. By a kind of instinctive principle (if the expression may be allowed), it seeks a passage downward, and fixes itself into the soil. At this period the root is a smooth and polished body, and has, perhaps, but little power to absorb any thing from the earth for the nutriment of the germ. The two lobes next begin to separate; and the germ, with its leaves, may be plainly discovered. As the germ increases in size, the lobes are farther separated, and the tender leaves, being closely joined, push themselves forward in the form of a wedge. These leaves take a contrary direction to that of the root: they seek a passage upward; which having obtained, they lay aside their wedge-like form, and spread themselves in an horizontal direction, as being the best adapted for receiving the rains and dew. The radicle, every hour increasing in size and vigour, pushes itself deeper into the earth, from which it now draws some nutritive particles. At the same time the leaves of the germ, being of a succulent nature, assist the Plant by attracting from the atmosphere such particles as the tender vessels are fit to convey. These particles, however, are of a watery kind, and have not in their own nature a sufficiency of nutriment for the increasing Plant. Vegetables, as well as animals, during their tender state, require a large share of balmy nourishment. As soon as an animal is brought to life, the milk of its mother is supplied in a liberal stream: but, at this period, the tender germ seems only to have the crude and watery juices of the earth for its support. This, however, is not the case; for the Vegetable lives upon a similar fluid, though differently supplied. For its use the farinaceous lobes are melted down into a milky juice, which, as long as it lasts, is conveyed to the tender Plant, by means of innumerable small vessels which are spread through the substance of the lobes; and which, uniting into one common trunk, enter the body of the germ, and thus supply that balmy liquor, without which the Plant must inevitably have perished, its root being then too small to absorb a sufficiency of food, and its body too weak to assimilate it into nourishment. Thus admirable and well contrived is the method of Providence, in supporting the Plant in its earliest and tenderest stages! As the plant increases in size, the balmy juice diminishes, till at last it is quite exhausted. The trunk of small vessels then dries up, and the external covering of the seed appears connected with the root in the form of a shrivelled bag. In the process of vegetation there is no mortality: from the moment that the seed is lodged in its parent earth, the vegetative soul begins its operations, and, in the whole successive gradation of them, illustrates the wisdom, power, and bounty of Him who created and rules the UNIVERSE.

These attributes of the ALMIGHTY are also strikingly manifested, in the provision which he has afforded them against the winter season to secure them from the effects of cold. Those called *herbaceous*, which die down to the root every autumn,

are

are now safely concealed under ground, preparing their new shoots to burst forth when the earth is softened in spring. Shrubs and trees which are exposed to the open air have all their soft and tender parts closely wrapt up in buds, which by their firmness resist all the power of frosts; the larger kind of buds, and those which are almost ready to expand, are farther guarded by a covering of resin or gum, such as the horse-chesnut, the sycamore, and the lime. Their external covering, however, and the closeness of their internal texture, are of themselves, as some say, not adequate to resist the intense cold of a winter's night: a bud *detached* from its stem, enclosed in glass, and thus protected from all access of internal air, if suspended from a tree during a sharp frost, will be entirely penetrated and its parts deranged by the cold, while the buds on the same tree will not have sustained the slightest injury: either the detached bud must have been injured by reason of the cold entering it at the part where it was broken from the stalk; or we must attribute to the *living principle* in Vegetables, the power of resisting cold to a very considerable degree;—probably each of these is true in some measure; but how Vegetables require this latter-mentioned property, must be left for future observations to determine.

After the frost is moderated, and the earth sufficiently thawed, the first vital function in trees is the *ascent of the sap*, which is taken up by the absorbent vessels composing the inner bark of the tree, and reaching to the extremity of the fibres of the

the roots. The water and oil, thus imbibed by the roots, is there mixed with a quantity of saccharine matter, and formed into sap, whence it is distributed in great abundance to every individual bud. The amazing quantity of sweet liquid sap provided for the nourishment of some trees, is evident from a prevalent custom in this country, of *tapping* the birch in the early part of spring; thus obtaining from each tree more than a quart of liquor, which is fermented into a species of wine. This great accession of nourishment, by means of the ascent of the sap, causes the bud to swell, to break through its covering, and to spread into blossoms, or lengthen into a shoot bearing leaves. This is the first process, and, properly speaking, is all that belongs to the *springing* or *elongation* of trees; and, in many Plants, namely, all those which are annual or deciduous, there is no other process. The Plant absorbs juices from the earth, and, in proportion to the quantity of these juices, increases in size; it expands its blossoms, perfects its fruit; and when the ground is incapable, by drought or frost, of yielding any more moisture, or when the vessels are not able to draw it up, the Plant perishes. But in *trees* though the beginning and end of the first process is exactly similar to what takes place in *annuals*, yet there is a second process, which at the same time that it adds to their bulk, enables them to go on increasing through a long series of years.

This second process begins soon after the first, in this way. At the base of the foot-stalk of each leaf a small bud is gradually formed; but the absorbent vessels

vessels of the leaf, having exhausted themselves in the formation of the bud, are unable to bring it nearer to maturity. In this state it exactly resembles a seed, containing within itself the rudiments of vegetation, but destitute of absorbent vessels to nourish and evolve the embryo. Being surrounded, however, by sap, like a seed in moist earth, it is in a proper situation for growing; the influence of the sun sets in motion the juices of the bud, and of the seed; and the first operation in both of them, is to send forth the roots downwards a certain depth, for the purpose of obtaining the necessary moisture. The bud, accordingly, shoots down its roots upon the inner bark of the tree, till they reach the part covered by the earth. Winter now arriving, the cold and defect of moisture, owing to the clogged condition of the absorbent vessels, cause the fruit and leaves to fall; so that, except the provision of buds with roots, the remainder of the tree, like an annual plant, is entirely dead: the leaves, the flowers, and fruit, are gone; and what was the inner bark is no longer organized, while the roots of the buds form a new inner bark; and thus the buds with their roots contain all that remains alive of the whole tree. It is owing to this annual renovation of the *inner bark*, that the tree increases in bulk; and a new coating being added every year, we are hence furnished with an easy and exact method of ascertaining the age of a tree, by counting the number of concentric circles of which the trunk is composed. A tree, therefore, properly speaking, is rather a congeries of a multitude

titude of annual Plants, than a perennial individual. The sap in trees always rises as soon as the frost is abated, that when the stimulus of the warm weather in the spring acts upon the bud, there should be at hand a supply of food for its nourishment; and if, by any means, the sap is prevented from ascending in proper time, the tree inevitably perishes, as has been very frequently observed.

Before I conclude this Lesson, I cannot forbear saying a few words on the different manners in which Plants *disseminate their seed.* Having gone through the progressive stages of springing, flowering, and seeding, they have at length brought to maturity the rudiments of a future progeny, which are now to be deposited in the fostering bosom of the earth. Seeds are scattered by the hand of nature in various ways. Those of them which are furnished with plumes, or wings, are dispersed about by the high winds which blow soon after the Autumnal Equinox, the time of dissemination. Hence Plants with such seeds are, of all others, the most generally to be met with: as dandelion, groundsel, thistles, &c. Others by means of hooks, with which they are furnished, lay hold of passing animals, and are thus carried to distant places: the common burs are examples of this contrivance. Several when ripe are thrown out with considerable force, from their receptacle, by means of a strong spiral elastic spring; of this the *impatiens*, or touch-me-not, and all the species of *cardamine*, or cuckoo-flower, are instances. Many are contained in

berries,

berries, which being eaten by birds, the seeds are discharged again uninjured, and grow wherever they happen to fall. In these, and in many other ways, is the distribution of various kinds of Vegetables provided for. The shedding of the seed being finished, the parent Vegetable, if of the *herbaceous* kind, either totally perishes or withers down to the root; if a *shrub*, or *tree*, it casts all those tender leaves that in the Spring and Summer it had put forth. Thus it continues until the following Spring, when

. . . . These naked shoots,
Barren as lances, among which the wind
Makes wintry music, sighing as it goes,
Shall put their graceful foliage on again,
And more aspiring, and with ampler spread,
Shall boast new charms, and more than they have lost.

COWPER.

LESSON

LESSON XXXV.

EARTHQUAKES.

The earth shook and trembled; the foundations also of the hills moved, and were shaken, because He was wroth.

DAVID.

HISTORIANS relate innumerable instances of the dreadful and various effects of those tremendous phænomena called *Earthquakes:* from which I shall select two only. The first is the description of the Earthquake at Calabria, in the year 1638: it happened whilst the celebrated Father Kircher was on his journey to visit Mount Ætna; and I shall present it in the language of that great prodigy of learning.

"Having hired a boat (says he), in company with four more (two friars of the order of St. Francis, and two seculars), we launched from the harbour of Messina, in Sicily; and arrived, the same day, at the promontory of Pelorus. Our destination was for the city of Euphæmia, in Calabria; where we had some business to transact; and where we designed to tarry for some time. However, Providence seemed willing to cross our design; for we were obliged to continue three days at Pelorus, on account of the weather; and

and though we often put out to sea, yet we were as often driven back. At length, wearied with the delay, we resolved to prosecute our voyage; and, although the sea seemed more than usually agitated, we ventured forward. The gulph of Charybdis, which we approached, seemed whirled round in such a manner, as to form a vast hollow, verging to a point in the centre. Proceeding onward, and turning my eyes to Ætna, I saw it cast forth large volumes of smoke, of mountainous sizes, which entirely covered the island, and blotted out the very shores from my view. This, together with the dreadful noise and the sulphurous stench which was strongly perceived, filled me with apprehensions that some more dreadful calamity was impending. The sea itself seemed to wear a very unusual appearance: they who have seen a lake in a violent shower of rain, covered all over with bubbles, will conceive some idea of its agitations. My surprise was increased by the calmness and serenity of the weather; not a breeze, not a cloud, which might be supposed to put all Nature thus into motion. I therefore warned my companions, that an earthquake was approaching; and after some time, making for the shore with all possible diligence, we landed at Tropæa, happy and thankful for having escaped the threatening dangers of the sea.

" But our triumphs at land were of short duration; for we had scarcely arrived at the Jesuits' College, in that city, when our ears were stunned with a horrid sound, resembling that of an infinite

number

number of chariots, driven fierçely forward; the wheels rattling, and the thongs cracking. Soon after this, a most dreadful earthquake ensued; so that the whole tract upon which we stood, seemed to vibrate, as if we were in the scale of a balance, that continued wavering. This motion, however, soon grew more violent; and being no longer able to keep my legs, I was thrown prostrate upon the ground. In the mean time, the universal ruin round me redoubled my amazement. The crash of falling houses, the tottering of towers, and the groans of the dying, all contributed to raise my terror and despair. On every side of me, I saw nothing but a scene of ruin; and danger threatening wherever I should fly. I commended myself to God, as my last great refuge. At that hour, O how vain was every sublunary happiness! Wealth, honour, empire, wisdom, all mere useless sounds, and as empty as the bubbles in the deep! Just standing on the threshold of eternity, nothing but God was my pleasure; and the nearer I approached, I only loved him the more. After some time, however, finding that I remained unhurt, amidst the general concussion, I resolved to venture for safety; and running as fast as I could, I reached the shore, but almost terrified out of my reason. I did not search long here, till I found the boat in which I had landed; and my companions also, whose terrors were even greater than mine. Our meeting was not of that kind, where every one is desirous of telling his own happy escape: it was all silence, and a gloomy dread of impending terrors.

"Leaving this seat of desolation, we prosecuted our voyage along the coast; and the next day came to Rochetta, where we landed, although the earth still continued in violent agitations. But we had scarcely arrived at our inn, when we were once more obliged to return to the boat; and, in about half an hour, we saw the greater part of the town, and the inn at which we had set up, dashed to the ground, and burying the inhabitants beneath the ruins."

"In this manner, proceeding onward in our little vessel, finding no safety at land, and yet, from the smallness of our boat, having but a very dangerous continuance at sea, we at length landed at Lopizium, a castle midway between Tropæa and Euphæmia, the city to which, as I said before, we were bound. Here, wherever I turned my eyes, nothing but scenes of ruin and horror appeared towns and castles levelled to the ground; Strombalo, though at sixty miles distance belching forth flames in an unusual manner, and with a noise which I could distinctly hear. But my attention was quickly turned from more remote, to contiguous danger. The rumbling sound of an approaching earthquake, which we by this time were grown acquainted with, alarmed us for the consequence: it every moment seemed to grow louder, and to approach nearer. The place on which we stood now began to shake most dreadfully, so that, being unable

able to stand, my companions and I caught hold of whatever shrub grew next to us, and supported ourselves in that manner."

"After some time, this violent paroxysm ceasing, we again stood up, in order to prosecute our voyage to Euphæmia, which lay within sight. In the mean time, while we were preparing for this purpose, I turned my eyes towards the city, but could see only a frightful dark cloud, that seemed to rest upon the place. This the more surprised us, as the weather was so very serene. We waited, therefore, till the cloud had passed away: then turning to look for the city, it was totally sunk. Wonderful to tell! nothing but a dismal and putrid lake was seen where it stood. We looked about to find some one that could tell us of its sad catastrophe, but could see no person. All was become a melancholy solitude; a scene of hideous desolation. Thus proceeding pensively along, in quest of some human being that could give us a little information, we at length saw a boy sitting by the shore, and appearing stupified with terror. Of him, therefore, we inquired concerning the fate of the city; but he could not be prevailed on to give us an answer. We entreated him, with every expression of tenderness and pity, to tell us; but his senses were quite wrapt up in the contemplation of the danger he had escaped. We offered him some victuals; but he seemed to loath the sight. We still persisted in our offices of kindness; but he only pointed to the place of the city, like one out of his senses, and then, running up into the woods, was never heard of after. Such was the fate of the city of Euphæmia: and as we continued our melancholy course along the shore, the whole coast, for the space of two hundred miles, presented nothing but the remains of cities; and men scattered, without a habitation, over the fields. Proceeding thus along, we at length ended our distressful voyage, by arriving at Naples, after having escaped a thousand dangers both at sea and land."

The great and almost universal Earthquake which happened on the 1st of November, 1755, affords a dreadful example of the chief attendants of these striking phænomena, on which account the young reader shall be presented with the following description of it.

At Lisbon its effects were most severe. In 1750, there had been a sensible trembling of the earth felt in that city: for four years afterwards, there had been an excessive drought; insomuch that some springs, formerly very plentiful of water, were dried and totally lost. The predominant winds were north and north-east, accompanied with various, though very small, tremors of the earth. The year 1755 proved very wet and rainy; the summer cooler than usual; and for forty days before the earthquake, the weather was clear, but not remarkably so. The last day of October, the sun was obscured, with a a singular gloominess in the atmosphere. The 1st of November, early in the morning, a thick fog arose, which was soon dissipated by the heat of the sun; no wind

wind was stirring; the sea was calm, and the weather as warm as in June or July in this country. At 35 minutes after nine, without the least warning, except a rumbling noise not unlike the artificial thunder in our theatres, a most dreadful earthquake shook, by short but quick vibrations, the foundations of all the city, so that many buildings instantly fell. Then, with a scarce preceptible pause, the nature of the motion was changed, and the houses were tossed from side to side, with a motion like that of a waggon violently driven over rough stones. The second shock laid almost the whole city in ruins, with prodigious slaughter of the people. The earthquake lasted in all about six minutes. At the moment of its beginning, some persons on the river, near a mile from the city, heard their boat make a noise as if it had run aground, though they were then in deep water; and at the same time they saw the houses falling on both sides of the river. The bed of the river Tagus was in many places raised to its surface. Ships were driven from their anchors, and jostled together with great violence; nor did their masters know whether they were afloat or aground. A large new quay sunk to an unfathomable depth, with several hundreds of people who were upon it; nor was one of the dead bodies ever found. The bar was at first seen dry from shore: but suddenly the sea came rolling in like a mountain; and about Belem Castle the water rose 50 feet almost in an instant. About noon, there was another shock! when the walls of several houses that yet remained were seen to open from top to bottom more than a quarter of a yard, and afterwards closed again so exactly that scarcely any mark of the injury was left.

At Colares, about 20 miles from Lisbon, and two miles from the sea, on the last day of October, the weather was clear, and uncommonly warm for the season. About four o'clock in the afternoon there arose a fog, which came from the sea, and covered the valleys; a thing unusual at that season of the year. Soon after, the wind changing to the east, the fog returned to the sea, collecting itself, and becoming exceeding thick. As the fog retired, the sea rose with a prodigious roaring. The first of November, the day broke with a serene sky, the wind continuing at east; but about nine o'clock the sun began to grow dim; and about half an hour after was heard a rumbling noise like that of chariots, which increased to such a degree that it became equal to the explosions of the largest cannon. Immediately a shock of an earthquake was felt, which was quickly succeeded by a second and third; and at the same time several light flames of fire issued from the mountains resembling the kindling of charcoal. In these three shocks, the walls of the buildings moved from east to west. In another situation, from whence the sea coast could be discovered, there issued from one of the hills called the *Fojo* a great quantity of smoke, very thick, but not very black. This still increased with the fourth shock, and afterwards continued to issue in a greater or less degree. Just as the subterraneous rumblings were heard, the smoke was always observed

served to burst forth at the Fojo; and the quantity of smoke was always proportioned to the noise. On visiting the place from whence the smoke was seen to arise, no signs of fire could be perceived near it.

At Oporto (near the mouth of the river Douro), the earthquake began about 40 minutes past nine. The sky was very serene; when a dreadful hollow noise like thunder, or the rattling of coaches at a distance, was heard, and almost at the same instant the earth began to shake. In the space of a minute or two, the river rose and fell five or six feet, and continued to do so for four hours. It ran up at first with so much violence, that it broke a ship's hawser. In some parts the river opened, and seemed to discharge vast quantities of air; and the agitation in the sea was so great about a league beyond the bar, that air was supposed to have been discharged there also.

St. Ube's, a sea-port town about 20 miles south of Lisbon, was entirely swallowed up by the repeated shocks and the vast surf of the sea. Huge pieces of rock were detached at the same time from the promontory at the west end of the town, which consists of a chain of mountains containing fine jasper of different colours.

The same earthquake was felt all over Spain, except in Catalonia, Arragon, and Valencia. At Ayamonte (near where the Guadiana falls into the Bay of Cadiz), a little before 10 o'clock on the 1st of November, the earthquake was felt; having been immediately preceded by a hollow rushing

 noise.

noise. Here the shocks continued for 14 or 15 minutes, damaged almost all the buildings, throwing down some, and leaving others irreparably shattered. In little more than half an hour after, the sea and river, with all the canals, overflowed their banks with great violence, laying under water all the coasts of the islands adjacent to the city and its neighbourhood, and flowing into the very streets. The water came on in vast black mountains, white with foam at the top, and demolished more than one half of a tower at the bar named *De Canala*. In the adjacent strands, every thing was irrecoverably lost; for all that was overflowed sunk, and the beach became a sea, without the least resemblance of what it was before. Many persons perished; for although they got aboard some vessels, yet part of these foundered; and others being forced out to sea, the unhappy passengers were so terrified that they threw themselves overboard. The day was serene, and not a breath of wind stirring.

At Cadiz, some minutes after nine in the morning, the earthquake began, and lasted about five minutes. The water of the cisterns under ground washed backwards and forwards, so that a great froth arose. At ten minutes after eleven, a wave was seen coming from the sea, at eight miles distance, at least 60 feet higher than usual. It dashed against the west part of the town, which is very rocky. Though these rocks broke a great deal of its force, it at last came upon the city walls, beat in the breast-work, and carried pieces of the building,

ing, of eight or ten tons weight, to the distance of 40 or 50 yards. When the wave was gone, some parts that are deep at low water, were left quite dry; for the water returned with the same violence with which it came. At half an hour after 11 came a second wave, and after that four other remarkable ones; the first at ten minutes before 12; the second, half an hour b fore 1; the third, ten minutes after 1; and the fourth, ten minutes before 2. Similar waves, but smaller, and gradually lessening, continued with uncertain intervals till the evening.

At Gibraltar, the earthquake was not felt till after ten. It began with a tremulous motion of the earth, which lasted about half a minute. Then followed a violent shock: after that, a trembling of the earth, for five or six seconds; then another shock was not so violent as the first, which gradually went off as it began. The whole lasted about two minutes. Some of the guns on the battery were seen to rise, others to sink, the earth having an undulating motion. Most people were seized with giddiness and sickness, and some fell down; others were stupified; and many that were walking or riding felt no motion in the earth, but were sick. The sea rose six feet every 15 minutes; and then fell so low, that boats and all the small craft near the shore were left aground, as were also numbers of small fish. The flux and reflux lasted till next morning, having decreased gradually from two in the afternoon. At Madrid, the earthquake came on the same time as at Gibraltar, and lasted about six minutes.

In Africa, the earthquake was felt almost as severely as it had been in Europe. Great part of the town of Algiers was destroyed. At Arzilla (a town in the kingdom of Fez), about ten in the morning, the sea suddenly rose with such impetuosity, that it lifted up a vessel in the bay, and dropped it with such force on the land, that it was broken to pieces; and a boat was found two musket-shots within land from the sea. At Fez and Mequinez, great numbers of houses fell down, and a multitude of people were buried in the ruins. At Morocco, by the falling down of a great number of houses, many people lost their lives: and at Salle, a great deal of damage also was done. At Tangier, the earthquake began at ten in the morning, and lasted ten or twelve minutes. At Tetuan, the earthquake began at the same time, but lasted only seven or eight minutes. There were three shocks so extremely violent, that it was feared the whole city would be destroyed.

In the city of Funchal, in the island of Madeira, a shock of this earthquake was first perceived at thirty-eight minutes past nine in the morning. It was preceded by a rumbling noise in the air, like that of empty carriages passing hastily over a stone pavement. The observer felt the floor immediately to move with a tremulous motion, vibrating very quickly. The shock continued more than a minute; during which interval, the vibrations, though continual, were weakened and increased in force twice very sensibly. The increase after the first remission of the shock was the most intense. The noise in the air accompanied the shock during the whole

whole of its continuance, and lasted some seconds after the motion of the earth had ceased; dying away like a peal of distant thunder rolling through the air. At three quarters past eleven, the sea, which was quite calm, it being a fine day, and no wind stirring, retired suddenly some paces; then rising with a great swell without the least noise, and as suddenly advancing, overflowed the shore, and entered the city. It rose fifteen feet perpendicularly above the high-water mark, although the tide, which flows there seven feet, was then at half ebb. The water immediately receded; and after having fluctuated four or five times between high and low water-mark, it subsided, the sea remaining calm as before. In the northern part of the island the inundation was more violent, and the sea there retiring above one hundred paces at first, and suddenly returning, overflowed the shore, forcing open doors, breaking down the walls of several magazines and storehouses, leaving great quantities of fish ashore and in the streets of the village of Machico. All this was the effect of one rising of the sea, for it never afterwards flowed high enough to reach the high-water mark. It continued, however, to fluctuate here much longer before it subsided than at Funchal; and in some places farther to the westward, it was hardly, if at all, perceptible.

These were the phænomena with which this remarkable earthquake was attended in those places where it was violent. The effects of it, however, reached to an immense distance; and were perceived chiefly by the agitations of the waters, or

by

by some slight motion of the earth. The utmost boundaries of this earthquake to the south are unknown; the barbarity of the African nations rendering it impossible to procure any intelligence from them, except where the effects were dreadful. On the north, however, we are assured, that it reached as far as Norway and Sweden. In the former, the waters of several rivers and lakes were violently agitated. In the latter, shocks were felt in several provinces, and all the rivers and lakes were strongly agitated especially in Dalecarlia. The river Dala suddenly overflowed its banks, and as suddenly retired. At the same time a lake at the distance of a league from it, and which had no manner of communication with it, bubbled up with great violence. At Fahlun, a town in Dalecarlia, several strong shocks were felt.

In many places of Germany, the effects of the earthquake were very perceptible; but in Holland, the agitations were still more remarkable. At Alphen on the Rhine, between Leyden and Woerden, in the afternoon of the first of November, the waters were agitated to such a violent degree that buoys were broken from their chains, large vessels snapped their cables, smaller ones were thrown out of the water upon the land, and others lying on land were set afloat. At Amsterdam, about 11 in the forenoon, the air being perfectly calm, the waters were suddenly agitated in their canals, so that several boats broke loose; chandeliers were observed to vibrate in the churches; but no motion of the earth, or concussion of any building, was observed.

served. At Haerlem, in the forenoon, for nearly four minutes together, not only the water in the rivers, canals, &c. but also all kinds of fluids in smaller quantities, as in coolers, tubs, backs, &c. were surprisingly agitated, and dashed over the sides, though no motion was perceptible in the vessels themselves. In these small quantities also the fluid apparently ascended prior to its turbulent motion; and in many places, even the rivers and canals rose twelve inches perpendicularly.

The agitation of the waters was also perceived in various parts of Great Britain and Ireland. At Barlborough in Derbyshire, between 11 and 12 in the forenoon, in a boat-house on the west side of a large body of water called *Pibley Dam*, supposed to cover at least thirty acres of land, was heard a surprising and terrible noise; a large swell of water came in a current from the south, and rose two feet on the sloped dam-head at the north end of the water. It then subsided; but returned again immediately, though with less violence. The water was thus agitated for three quarters of an hour; but the current grew every time weaker and weaker, till at last it entirely ceased.

At Busbridge in Surrey, at half an hour after 10 in the morning, the weather being remarkably still, without the least wind, in a canal near 700 feet long and 58 feet broad, with a small spring constantly running through it, a very unusual noise was heard at the east end, and the water there observed to be in great agitation. It raised itself in a heap or ridge in the middle; and this heap

heap extended lengthwise about 30 yards, rising between two or three feet above the usual level. After this, the ridge heeled or vibrated towards the north side of the canal with great force, and flowed above eight feet over the grass walk on that side. On its return back into the canal, it again ridged in the middle, and then heeled with yet greater force to the south side, and flowed over its grass walk. During this latter motion, the bottom on the north side was left dry for several feet. This appearance lasted for about a quarter of an hour, after which the water became smooth and quiet as before. During the whole time, the sand at the bottom was thrown up and mixed with water; and there was a continual noise like that of water turning a mill. At Cobham in Surrey, Dunstall in Suffolk, Earsy Court in Berkshire, Eatonbridge in Kent, and many other places, the waters were variously agitated.

At Eyam-bridge, Derbyshire (in the Peak), the overseer of the lead mines sitting in his writing-room about 11 o'clock, felt a sudden shock, which very sensibly raised him up in his chair, and caused several pieces of plaister to drop from the sides of the room. The roof was so violently shaken, that he imagined the engine shaft had been falling in. Upon this he immediately ran to see what was the matter, but found every thing in perfect safety. At this time two miners were employed in carting, or drawing along the drifts of the mines, the ore and other materials to be raised up at the shafts. The drift in which they were working was about 120 yards deep, and the space from one end to the other

other 50 yards or upwards. The miner at the end of the drift had just loaded his cart, and was drawing it along; but he was suddenly surprised by a shock, which so terrified him that he immediately quitted his employment, and ran to the west end of the drift to his partner, who was no less terrified than himself. They durst not attempt to climb the shaft, lest that should be running in upon them: but while they were consulting what means they should take for their safety, they were surprized by a second shock more violent than the first; which frightened them so much, that they both ran precipitately to the other end of the drift. They then went down to another miner who worked about 12 yards below them. He told them that the violence of the second shock had been so great, that it caused the rocks to grind upon one another. His account was interrupted by a third shock, which after an interval of four or five minutes, was succeeded by a fourth; and, about the same space of time after, by a fifth; none of which were so violent as the second. They heard, after every shock, a loud rumbling in the bowels of the earth, which continued about half a minute, gradually decreasing, or seeming to remove to a greater distance.

At Shireburn Castle, Oxfordshire, a little after ten in the morning, a very strange motion was observed in the water of a moat which encompasses the house. There was a pretty thick fog, not a breath of air, and the surface of the water all over the moat as smooth as a looking-glass, except at one corner, where it flowed into the shore,

and

and retired again successively, in a surprising manner. In what manner it began to move is uncertain, as nobody observed the beginning of its motion. The flux and reflux, when seen, were quite regular. Every flood began gently; its velocity increased by degrees, when at last it rushed in with great impetuosity, till it had attained its full height. Having remained for a little time stationary, it then retired, ebbing gently at first, but afterwards sinking away with great swiftness. At every flux, the whole body of water seemed to be violently thrown against the bank; but neither during the time of the flux nor that of reflux did there appear even the least wrinkle of a wave on the other parts of the moat. Lord Parker, who had observed this motion, being desirous to know whether it was universal over the moat, sent a person to the other corner of it, at the same time that he himself stood about 25 yards from him, to examine whether the water moved there or not. He could perceive no motion there, or hardly any; but another, who went to the north-east corner of the moat, diagonally opposite to his lordship, found it as considerable there as where he was. His lordship imagining, that in all probability the water at the corner diagonally opposite to where he was would sink as that by him rose, he ordered the person to signify, by calling out, when the water by him began to sink, and when to rise. This he did; but, to his lordship's great surprize, immediately after the water began to rise at his own end, he heard his voice calling that it began to rise with him

also;

also; and in the same manner he heard that it was sinking at his end: soon after he perceived it to sink by himself. A pond just below was agitated in a similar manner; but the risings and sinkings of it happened at different times from those at the pond where Lord Parker stood.

At White Rock, in Glamorganshire, about two hours ebb of the tide, and near three quarters after six in the evening, a vast quantity of water rushed up with a prodigious noise; floated two large vessels, the least of them above 200 tons; broke their moorings, drove them across the river, and had like to have overset them. The whole rise and fall of this extraordinary body of water did not last above ten minutes; nor was it felt in any other part of the river, so that it seemed to have gushed out of the earth at that place.

Similar instances occurred at Loch Lomond and Loch Ness in Scotland.—At Kinsale in Ireland, and all along the coast to the westward, many similar phenomena were observed.

Shocks were also perceived in several parts of France; as at Bayonne, Bourdeaux, and Lyons; and commotions of the waters were observed at Angoulême, Bleville, Havre de Grace, &c. but not attended with the remarkable circumstances above mentioned.

These are the most striking phenomena with which the earthquake of November 1, 1755. was attended on the surface of the earth. Those which happened below ground cannot be known but by the changes observed in springs, &c. which were in many places very remarkable.—At Colares, on the afternoon of the 31st of October, the water of a fountain was greatly decreased: on the morning of the first of November, it ran very muddy; and, after the earthquake, returned to its usual state both as to quantity and clearness. On the hills, numbers of rocks were split: and there were several rents in the ground, but none considerable. In some places where formerly there had been no water, springs burst forth, which continued to run. —Some of the largest mountains in Portugal were impetuously shaken as it were from their foundation; most of them opened at their summit, split and rent in a wonderful manner, and huge masses of them were thrown down into the subjacent valleys.—From the rock called *Pedra de Alvidar*, near the hill Fojo, a kind of parapet was broken off, which was thrown up from its foundation in the sea.—At Varge, on the river Macaas, at the time of the earthquake, many springs of water burst forth; some spouted to the height of 18 or 20 feet, throwing up sand of various colours, which remained on the ground. A mountainous point, seven or eight leagues from St. Ube's, cleft asunder, and threw off several vast masses of rock. —In Barbary, a large hill was rent in two: the two halves fell different ways, and buried two large towns. In another place, a mountain burst open, and a stream issued from it as red as blood. At Tangier, all the fountains were dried up, so that there was no water to be had till night.—A very remarkable change was observed on the medicinal

waters

waters of Toplitz, a village in Bohemia famous for its baths. These waters were discovered in the year 762; from which time the principal spring of them had constantly thrown out hot water in the same quantity, and of the same quality. On the morning of the earthquake, between 11 and 12 in the forenoon, the principal spring cast forth such a quantity of water, that in the space of half an hour all the baths ran over. About half an hour before this great increase of the water, the spring flowed turbid and muddy; then having stopped entirely for a minute, it broke forth again with prodigious violence, driving before it a considerable quantity of reddish ochre. After this it became clear, and flowed as pure as before. It still continues to do so; but the water is in greater quantity, and hotter, than before the earthquake. At Angoulême in France, a subterraneous noise like thunder was heard; and presently after the earth opened, and discharged a torrent of water mixed with red sand. Most of the springs in the neighbourhood sunk in such a manner, that for some time they were thought to be quite dry. In Britain, no considerable alteration was observed in the earth, except that, near the lead mine abovementioned in Derbyshire, a cleft was observed about a foot deep, six inches wide, and 150 yards in length.

At sea, the shocks of this earthquake were felt most violently. Off St. Lucar, the captain of the Nancy frigate felt his ship so violently shaken, that he thought she had struck the ground: but on

heaving

heaving the lead, found she was in a great depth of water. Captain Clarke from Denina, in N. lat 36. 24. between nine and ten in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. The master of a vessel bound to the American islands, being in N. lat. 25°, W. long. 40. and writing in his cabin, heard a violent noise, as he imagined, in the steerage; and while he was asking what the matter was, the ship was put into a strange agitation, and seemed as if she had been suddenly jerked up and suspended by a rope fastened to the mast-head. He immediately started up with great terror and astonishment: and looking out of the cabin window, saw land, as he took it to be, at the distance of about a mile. But, coming upon the deck, the land was no more to be seen, but he perceived a violent current cross the ship's way to the leeward. In about a minute, this current returned with great impetuosity, and at a league's distance he saw three craggy-pointed rocks throwing up waters of various colours resembling fire. This phenomenon, in about two minutes ended in a black cloud, which ascended very heavily. After it had risen above the horizon, no rocks were to be seen; though the cloud, still ascending, was long visible, the weather being extremely clear.—Between nine and ten in the morning, another ship, 40 leagues west of St. Vincent, was so strongly agitated, that the anchors, which were lashed, bounced up, and the men were thrown a foot and a half perpendicularly up from the deck. Immediately after this, the ship sunk in the water as low as the main chains. The lead shewed a great depth of water, and the line was tinged of a yellow colour, and smelt of sulphur. The shock lasted about ten minutes, but they felt smaller ones for the space of 24 hours.

Such were the phænomena of this very remarkable and destructive earthquake, which extended over a tract of at least four millions of square miles.

There have been various hypotheses entertained with regard to the production of Earthquakes; nor does it appear an easy task to account for them with great precision. Those which are only felt at small distances are probably occasioned by the action of subterraneous fires, and the explosion of volcanoes. But there have been Earthquakes which are felt at great distances, and have shaken an extensive tract of country: this kind of Earthquakes is by some persons accounted for in the following manner.

To understand properly what may be the cause of these phænomena, it must be remembered, that all inflammable matters capable of explosion produce, like gunpowder, by inflammation, a great quantity of air; that this air produced by fire is in a state of very great rarefaction; and that, by a state of compression in which it is found in the bowels of the earth, it must produce very violent effects. It is then conjectured, that at a considerable depth, as at about one or two hundred fathoms, pyrites and other sulphureous matters are to be met with; and that by the fermentation produced

duced by the filtration of water, and other causes, they inflame: the inflaming will produce a great quantity of vapourized air, the spring of which, compressed in a small space, like that of a cavern, will not only shake the earth immediately above, but will search for passages, in order to make its escape. It will therefore naturally force its way through those parts where it meets least obstruction, and will proceed through any channels or caverns where it can find a passage. This subterraneous air or vapour will also produce in its passage a noise and motion proportioned to its force and the resistance it meets with: and these effects will be continued till it finds a vent, perhaps in the sea, or till its force be diminished by being greatly expanded. This explanation corresponds entirely with all the phænomena that are observed respecting Earthquakes: for they proceed with a wave-like motion, and are felt at different places, not at the same instant, but at different times in proportion to the distance.

Yet plausible as the above hypothesis may appear, it is objected against by several of the modern philosophers, who, in opposition thereto, assert, that Earthquakes are produced by an accumulation of the electric fluid in the bowels of the earth.

Mr. *Nicholson*, in his *Introduction to Natural Philosophy*, says, "It is extremely probable, that "Earthquakes owe their original to the discharge "between a cloud and the earth, in a highly elec- "tric state, or even between two clouds." In support of this opinion, he advances the following arguments:

arguments:—"They happen most frequently in dry " and hot countries, which are most subject to " lightning and other electrical phænomena; and " are even foretold by the electric coruscations and " other appearances in the air, for some days pre- " ceding the event. Earthquakes are attended by " no fire, vapour, or smell, which, however could " hardly fail to appear, if the common opinion, of " their being occasioned by a subterraneous ex- " plosion, were true. The effect of an explosion " of this nature would be a gradual lifting of the " earth, after which it would fall again, and, no " doubt, destroy or change the course of springs, " and considerably alter the face of the country: " the contrary to which is true; for, as far as ob- " servation can determine, the shock of an Earth- " quake is instantaneous to the greatest distances, " and seldom does more mischief than overthrow- " ing buildings. Earthquakes are usually accom- " panied by rain, and sometimes by the most dread- " ful thunder-storms. All these, and many more " circumstances, but especially the almost instan- " taneous motion of the shock, induce us to look " for their cause in electricity, the only power in " nature that acknowledges no sensible transition " of time in its operations."—Against this reasoning, it has been objected, that if the accounts which historians have transmitted us of Earthquakes in the last century, be correct, the circumstances attending these awful events are frequently widely different from what Mr. Nicholson supposes them to be. At present, each of these disagreeing hypo-

theses

theses has many advocates, though that which Mr. Nicholson supports seems to be gaining ground:—however, whether Earthquakes be produced by the explosion of sulphureous matters, or by the power of the electric fluid, we may safely infer, that the natural cause of their production is inherent in the earth. Hence the contemplative young reader will conclude, that we might be continually in expectation of the whole earth being destroyed by this invisible agent of nature; if we were not certain that it is always controlled by a wise and good, as well as powerful, BEING, who keeps it safely curbed, or gives it liberty to range, as it may by HIM be thought most suitable to his Divine purposes.

LESSON

LESSON XXXVI.

ON VOLCANOS.

The dread Volcano ministers to good:
Its smother'd flames might undermine the world.
Loud Ætnas fulminate in love to man.

YOUNG.

A WONDERFUL appearance on the face of nature, which we have not yet reflected upon, is a *burning mountain*, or *Volcano;* to describe which, in the manner it deserves, would almost surpass the power of words. A Volcano contains in its bowels sulphur, bitumen, pumice stones, and other materials which serve as food to a subterraneous fire, the effects of which are more violent than those of gunpowder, or even of thunder: hence a Volcano has been sometimes compared to a cannon of a very large size. The orifice or mouth of a Volcano is, in some cases, more than a mile across: and from this mouth are emitted torrents of smoke and flame; rivers of bitumen, sulphur, and melted metal, the mixture bearing the name of *lava;* clouds of cinders and stones, and sometimes it ejects enormous rocks to many leagues distance, when merely to stir them would baffle the utmost efforts of human strength. The combustion is so terrible, and the quantity of burnt, fused, calcined, and vitrified materials which is thrown out at the orifice, is so plentiful, that they enter towns and forests, cover the fields to more than an hundred feet in thickness, and sometimes form hills and mountains. The action of this fire is so great, and the force of explosion so violent, that its reaction has been known to shake the earth, agitate the sea, overthrow mountains, and raise the most solid edifices and towns, even to very considerable distances.

A mixture of sulphur, filings of iron, and of water, buried at a certain depth below the earth's surface, will exhibit in miniature, all the appearances of a Volcano: hence some are induced to conclude, that in the bowels of burning mountains, there are different kinds of inflammable substances, which ferment when acted upon by peculiar means (probably by moisture), and produce eruptions and explosions, of different degrees of strength, according to the quantity of inflammable matters accumulated.

The number of Volcanos now known is very considerable; not less, I believe, than 400. In Europe there are Ætna, Vesuvius, Hecla, Stromboli, Vulcano; in Asia, one in Mount Taurus, three in Kamschatka, five in Japan, two in the Philippines, and a great number more in the different South Sea Islands; in Africa, one in Fez, one in the island Bourbon, one in Fuego, one of the Cape Verd Islands: and in America, several in the Andes, Morne Garou, in St. Vincent,

cent, and two discovered by Captain Cook on the western coast of North America.

Nearly all the Volcanos yet known are situated at a small distance from the sea: and most of them have been burning from time immemorial; though some few have burst out during late years. Volcanos seem all to occupy the tops of mountains: some of them which are situated in the ocean, do not rise much above the surface; but even these seem to be the apices of mountains, the greater part of which are covered by the sea.

Of each of the Volcanos in Europe, I shall here present you with a short account. From Mount Ætna the eruptions of flame and smoke are discovered at a great distance, by those who sail on the Mediterranean, even as far as the harbour of Malta, which is more than 40 leagues from the shore of Sicily. Though fire and smoke are continually vomited up by it, yet at some particular times it rages with greater violence. In the year 1536, it shook all Sicily from the first to the twelfth of May; after that there was heard a most horrible bellowing and cracking, as if great guns had been fired: there were a great many houses overthrown throughout the whole island. When this storm had continued about eleven days, the earth opened in several places, and dreadful gapings appeared here and there, from which issued fire and flame with great violence, which in four days consumed and burnt up every thing that was within five leages of Ætna. A little after, the funnel, which is on the top of the

 mountain,

mountain, disgorged a great quantity of hot embers and ashes, for three whole days together, which were not only dispersed throughout the whole island, but also carried beyond sea to Italy; and several ships that were sailing to Venice, at two hundred leagues distance, suffered damage. *Facellus*, who has given an historical account of the eruptions of this mountain, says, that the bottom of it is one hundred leagues in circuit.

Mount Hecla rages sometimes with as great violence as Ætna, and casts out large stones. The imprisoned fire often, for want of vent, produces horrible sounds like lamentations and howlings; which make the credulous and superstitious think it the place of hell, where the souls of the wicked are tormented. The country in the vicinity of Hecla abounds with boiling springs; of which many travellers present interesting accounts.

The declivity of Mount Vesuvius towards the sea, is every where planted with vines and fruit trees, and it is equally fertile towards the bottom. The circumjacent plain affords a delightful prospect, and the air is clear and wholesome. The south and west sides of the mountain form very different views; being, like the top, covered with black cinders and stones. The height of this mountain has been computed to be about 3900 feet above the surface of the sea. Vesuvius has been a volcano beyond the reach of history and tradition: but there are on record more than 30 eruptions which have taken place since the one that destroyed the city of *Herculaneum*, in the time of Titus.

Titus. Some of these have been very furious and violent, desolating the country for miles around; and ships at sea, at the distance of sixty miles, have, in some of these eruptions, been covered with cinders, to the astonishment of the sailors.

A great eruption of Vesuvius happened on the 12th of August, 1805: the following account of it is given in an extract of a letter from Naples, dated August 13th:—

"Yesterday, at ten o'clock at night, the eruption of Vesuvius, of which the earthquake seemed to be the forerunner, took place. We were going to visit the crater when the cries of the people and a volume of flame informed us that the volcano had opened. The lava precipitated itself in three seconds from the last peak of the mountain, and took a direction towards the valley, situated between Torre del Greco and Torre del l'Annunziata, two towns on the sea coast, beyond Portici, and seven or eight miles from Naples.

"We set off immediately to see this wonderful and tremendous phenomenon nearer. From the place of our departure, we saw the whole course of the lava, which extended nearly two miles, from the crater to the houses that join the two towns. The sight was the most magnificently frightful that could be seen. I contemplated the cascades of flame pouring from the top of the mountain, and shuddered at seeing an immense torrent of fire ravage the finest fields, overthrow houses, and destroy in a few minutes the hopes and resources of a hundred families.

 "A line

" A line of fire marked the profile of the mountain: a cloud of smoke, which seemed to send forth from time to time flashes of lightning, hung over the scene, and the moon appeared to be pale. Nothing can adequately describe the grandeur of the scene, or give an accurate idea of the horror of it. As we approached the spot ravaged by this river of hell, ruined inhabitants having quitted their houses—desolated families trying to save their furniture and provisions, last and feeble resource—an immense crowd of curious spectators, retreating step by step from the advancing lava, and testifying by extraordinary cries their wonder, fear, and pity—the frightful bellowing of the mountain, the frequent explosions which burst from the bottom of the torrent, the crackling of the trees devoured by the flames, the noise of the walls falling, and the lugubrious sound of a bell which the religious of the Camaldules, isolated on a little hill and surrounded by two torrents of fire, rang in their distress!—Such are the details of the frightful scene to which I was witness.

" The moment we arrived, the lava was crossing the great road below Torre del Greco. To see it better, we got into a beautiful house on the road side:—from the terrace we saw the fire at no more than fifteen paces from us:—in a minute we descended, and twenty minutes afterwards there remained of the house but three large walls. I approached as near as the heat and flow of the current would permit me: I attempted at different times to burn the end of my handkerchief in it—

I could

I could only do it by tying it to my cane. The lava does not run in liquid waves: it resembles an immense quantity of coals on fire, which an invincible strength had heaped up and pushed on with violence. When it met with a wall, it collected to the height of seven or ten feet, burnt it, and overthrew it at once. I saw some walls get red hot, like iron, and melt, if I may use the expression, into the lava. In its greatest speed and on an horizontal road, I reckoned that the torrent travelled at the rate of eighteen inches a minute. Its smell resembled that of iron red hot."

A still more recent eruption will make the year 1810 an epoch in the annals of Vesuvius, on account of the manner in which it began, and the disasters it has produced. It is considered as a very extraordinary circumstance, that this eruption was not preceded by the usual indications; every convulsion of Vesuvius being previously announced by the drying up of the wells of Naples. This phenomenon did not take place on this occasion, and, to the great surprise of the inhabitants, Vesuvius began to emit flames on the night of the 10th of September.

On the morning of the 11th, the flames became more intense, and the lava began to flow from the east and south-east sides of the mountain. Towards evening the conflagration increased, and about twilight two grand streams of fire were seen to flow down the ridge of the Volcano; night produced no change in this state of things.

On the morning of the 12th, a hollow sound was heard, which continued increasing; the fire and smoke also augmented in intensity, and towards evening the horizon was obscured. The breeze, usual in these parts, having blown from the south-east, dissipated the accumulated clouds. The mountain continued to vomit lava and a dense smoke, which even at a distance was strongly sulphureous: the hollow noise in the sides of the mountain continued to increase.

"Curious to witness as near as possible one of the most astonishing phenomena of Nature, and forgetting the misfortune of Pliny, I set out" (says an English traveller) "from Naples, and at eight in the evening I reached Portici. From thence to the summit of the mountain, the road is long and difficult. About half way there is a hermitage, which has long served for refuge and shelter to the traveller:—a good hermit has there fixed his residence, and takes care to furnish, for a moderate sum, refreshments, which to the fatigued traveller are worth their weight in gold. The environs of this hermitage produce the famous wine called Lachryma Christi.—From the hermitage to the foot of the cave there is a long quarter of a league of road, tolerably good; but in order to reach from thence the crater, it is necessary to climb a mountain of cinders, where at every step you sink up to the mid-leg. It took my companions, myself, and our guides, two hours to make this ascent; and it was already midnight when we reached the crater.

"The fire of the Volcano served us for a torch: the noise had totally ceased for two hours: the

flame

flame had also considerably decreased. These circumstances augmented our security, and supplied us with the necessary confidence in traversing such dangerous ground. We approached as near as the heat would permit, and we set fire to the sticks of our guides in the lava, which slowly ran through the hollows from the crater. The surface of this inflamed matter nearly resembles metal in a state of fusion; but as it flows, it carries a kind of scum which hardens as it cools, and then forms masses of scoria, which dash against each other, and roll all on fire, with noise, to the foot of the mountain. Strong fumes of sulphuric acid gas arise in abundance from these scoria, and by their caustic and penetrating qualities render respiration difficult.

" We seemed to be pretty secure in this situation, and were far from thinking of retiring, when a frightful explosion, which launched into the air fragments of burning rocks to the distance of more than 100 toises, reminded us of the danger to which we were exposed. None of us hesitated a moment in embracing a retreat; and in five minutes we cleared, in our descent, a space of ground which we had taken two hours to climb.

" We had not reached the hermitage before a noise more frightful than ever was heard; and the Volcano, in all its fury, began to launch a mass equal to some thousand cart-loads of stones and fragments of burning rocks, with a projectile force which it would be difficult to calculate. As the projection was vertical, almost the whole of this burning mass fell back again into the mouth of the Volcano, which vomited it forth anew to receive it again, with the exception of some fragments which flew off, to fall at a distance, and alarm the inquisitive spectator.

"The 13th commenced with nearly the same appearances as those of the preceding day. The Volcano was tranquil, and the lava ran slowly in the channels which it had formed during the night; but at four in the afternoon a frightful and continued noise, accompanied with frequent explosions, announced a new eruption: the shocks of the Volcano were so violent that at Fort de L'Œuf, built upon a rock, where I then was, at the distance of nearly four leagues, I felt oscillations similar to those produced by an earthquake.

"About five o'clock the eruption commenced, and continued during the greater part of the night. This time the burning matter flowed down all the sides of the mountain, with a force hitherto unprecedented; all Vesuvius seemed on fire.—The lava has caused the greatest losses: houses and whole estates have been overwhelmed; and at this day families in tears, and reduced to despair, search in vain for the inheritance of their ancestors, buried under the destroying lava.

"At ten at night, the hermitage was no longer accessible: a river of fire had obstructed the road. The districts situated on the south-east quarter of the mountain had still more to suffer. Mount Vesuvius presented the appearance of one vast

flame,

flame, and the seaman at a great distance might contemplate at his leisure this terrific illumination of nature."

Among the great number of curious facts which M. *Humboldt* has collected in his travels, one of the most extraordinary is the following, which he communicated to the French National Institute. Many of the Volcanos of the Cordilliers of the Andes throw up at intervals eruptions of mud mixed with vast quantities of fresh water, and, what is extremely remarkable, an infinite multitude of *fishes*. The Volcano of Imbaburu, for example, once threw up such a vast number of them near the village of Iborra, that their putrefaction caused a sickness. This phenomenon, astonishing as it is, is not, however, unfrequent: on the contrary, it very often takes place; and public authority has preserved accounts of the periods at which this has happened, in an authentic manner, along with those of the earthquakes. What is very singular is, that the fish are not broken in the least, although their bodies are very soft; they do not even appear to have been exposed to a great heat. The Indians, indeed, assert that they sometimes arrive *alive* at the foot of the mountain.

Sometimes these animals are ejected from the mouth of the crater, sometimes they are vomited forth at the lateral cavities; but always at from 24 to 2600 yards above the neighbouring plains. M. *Humboldt* thinks that they live in the lakes situated at this height in the inside of the crater:

and

and what confirms this opinion is, that the same species is found in the rivulets which run at the foot of these mountains. It is the only species of fish which lives at the height of 2800 yards in the realm of Quito. This species is new to our naturalists. M. *Humboldt* has delineated it on the spot, and given it the name of *Pimelodrus Cyclopum,* which signifies *thrown up by the Cyclops*—a name in some respects analogous to their origin.

Dr. *Woodward* mentions the existence of Volcanos as a special favour of Providence, and says—"There are scarcely any countries that are much "annoyed with earthquakes that have not one of "these fiery vents. And these are constantly all "in flames whenever any earthquake happens; "they disgorging that fire which, whilst under-"neath, was the cause of the disaster. Indeed," says he, "were it not for these *diverticula* "whereby it thus gaineth an *exit,* it would rage "in the bowels of the earth much more furiously, "and make greater havoc than it doth now. So "that though those countries, where there are "such Volcanos, are usually more or less trou-"bled with earthquakes; yet, were these Volca-"nos wanting, they would be much more annoyed "with them than they now are; yea, in all proba-"bility to that degree, as to render the earth, for "a vast space around them, perfectly uninhabit-"able. In one word, so beneficial are these to "the territories where they are, that there do not "want instances of some which have been res-

" cued from earthquakes by the breaking forth of " a new Volcano there; this continually discharg- " ing that matter, which being till then barricaded " up, and imprisoned in the bowels of the earth, " was the occasion of very great and frequent ca- " lamities."

Let me then be permitted to observe in this place, that though we cannot, in every case, see the beneficent tendency of particular creatures and things in the universe, we ought to attribute this to our limited capacities; and not arraign ALMIGHTY SOVEREIGNTY, as is the custom with too many carping sciolists of the present day. However dreadful and destructive subterraneous fires may appear: on proper reflection it may be inferred, that they are as necessary in promoting and sustaining the operations of this part of the universe, as the natural heat in men's bodies is to the preservation and support of their being.

As every body possesses inherently the principles of its own dissolution, it is by many wise and learned men imagined that the *general conflagration* may at last be brought about by means of these fires. Amongst the natural means of causing it we are acquainted with, some persons embrace the opinion here mentioned, whilst others are inclined to think the effect will be produced by comets: but though finite creatures may conjecture on this subject, it is most probable that it will never be ascertained by mortals. Such knowledge is not *necessary* for us; and may be withheld for the wisest and most beneficent reasons.

LESSON

LESSON XXXVII.

ON THE EYE.

In the materials of the human frame,
What num'rous wonders might we quickly name:
Let it suffice that I describe a few,
And treat my readers with a short review.

WE will now direct our contemplations to the *human fabric*; and here the science of *Anatomy* discovers to us ten thousand beauties which the narrow limits I have prescribed myself preclude my mentioning: indeed it would not be possible, in a performance of this kind, to explain adequately the geometrical and mechanical accuracy with which the AUTHOR OF NATURE has constructed every part of the body, to carry on the animal economy, and answer the various purposes of life. All I propose to perform in this and the two following Lessons is, by touching upon the nature and wonders of the *Eye*, of *Concoction*, and of the *Circulation of the Blood*, to give my young readers some little insight into these matters, as an inducement for them to set apart a portion of their leisure time for the purpose of acquiring a farther acquaintance with *Anatomy*.

And

And first, for a short description of the *organ of Sight*, that noble instrument which

> —— Takes in at once the landscape of the world,
> At a small inlet which a grain might close,
> And half creates the wondrous world we see.
>
> YOUNG.

The Eye is in form nearly globular: it consists of three coats and three humours. The part of the outward coat hid from our sight is called the *Sclerotica:* the front part, which rather projects out, the *Cornea:* the next within this coat is that called the *Choroides*, which serves, as it were, for a lining to the other; in the front it joins with that part known by the name of the *Iris*, because it is in different persons of different colours, as blue, brown, green, &c. The *iris* is composed of two sets of muscular fibres; the one, of a circular form, which contracts the hole in the middle called the *Pupil*, when the light would otherwise be too strong for the Eye; and the other, of radial fibres, tending every where from the circumference of the *iris* towards the middle of the *pupil:* these, by their contraction, dilate and enlarge the *pupil*, when the light is weak, in order to admit more rays. The third coat is only a fine expansion of the optic nerve, which spreads like net work all over the inside of the *choroides*, and is therefore called the *Retina:* upon it are in a manner painted the images of all visible objects, by the rays of light which either flow or are reflected from them.

Immediately under the *cornea* is a fine transparent

rent fluid, like water, which is therefore called the *aqueous humour*: it gives a protuberant figure to the *cornea*, and has the same limpidity and refractive power as water. At the back of this lies a humour transparent like crystal, and much of the consistence of hard jelly: it is shaped like a double convex glass, and is a little more convex on the back than on the fore part: it is named the *crystalline humour*, and is of service in converging the rays which pass through it, to its focus at the bottom of the Eye. This humour is enclosed in a fine transparent membrane from which proceed radial fibres, called the *ligamentum ciliare*, all around its edge, joining to the circumference of the *iris*. These fibres have a power of dilating and contracting occasionally, by which means the convexity of the *crystalline humour* is altered; and it is also thereby shifted a little backward or forward in the Eye, so as to adapt its focal distance at the bottom of the Eye to the different distances of objects: a provision without which we could only see objects distinctly at one particular distance from the Eye. At the back of the *crystalline*, lies the *vitreous humour*, which is transparent like glass, as its name denotes, and is largest of all in quantity; filling the rest of the Eye, and giving it a globular shape: it is much of the consistence of the white of an egg, its refractive power very little exceeding that of water.

As rays are emitted or reflected from every point of an object, some of these from the side next the Eye will fall upon the *cornea*, and, by passing on

through

through the *pupil* and different humours, will be converged to various points on the *retina* at the bottom of the Eye, and will form upon it an inverted picture of the object; or, if this inverted image be not formed, the object cannot be seen: when, unfortunately, any of the parts of the Eye are so injured as to lose their transparency, the person becomes blind.

But it is not sufficient, in order to our seeing objects, that their images should be painted on the retina: some persons, it is said, are blind, though this takes place. Hence it should seem, that images painted on the retina are not the immediate object of vision, and that the perception of the soul is communicated some other way. The small nerves of the retina (it is now generally admitted) are agitated by the rays of light which form the image at the bottom of the Eye; and this agitation is transmitted by the optic nerve to the brain. It is there the mental perception is formed; but the most dextrous anatomist is unable to pursue these nerves to their source: the union of the soul with the body will probably for ever remain a mystery.

There is an astonishing apparatus of muscles, with which the Eye is furnished, to produce all the necessary and convenient motions: among these I cannot help alluding to that admirable contrivance by which the pupil is contracted or dilated, according as vision requires. This variability of the pupil is essentially necessary to vision: for, if an involuntary contraction were not to take place when the Eye was brought into a very enlight-

ened

ened situation, the great number of rays which would enter, would probably much injure the fine contexture of nerves at the bottom of the Eye, on which the images of objects are pourtrayed; and if the pupil did not expand when the eye was in a dark place, the few feeble rays which would enter the Eye, would not form any impression on the retina. Hence it is a very remarkable and providential circumstance, that the change in the pupil should take place almost spontaneously and independent of any act of the will.

The five following associated circumstances seem to have some influence on our judgment concerning distance: the number of objects which intervene, the degree of distinctness in which the minute parts are seen, the degree of brightness, the inclination of the optic axes, and the conformation of the Eye. Thus, distance is chiefly conceived from experience; and the more distant an object is, the less it appears: when therefore, from certain circumstances, we cannot form a just conception of distance, and when we cannot judge of objects but by the image which is pourtrayed in our Eyes, we are then necessarily deceived as to their size. Thus every person must be aware how liable we are, in travelling by night, to mistake a distant tree for a bush that is near, or a bush near at hand for a tree at a distance. In the same manner if we do not distinguish objects by their shape, and by it also judge of distance, the fallacy is likely to continue: in this case, a fly, which may pass before us slowly, will seem to be a bird

at

at a considerable distance; and a horse, which may be in the middle of a plain, not moving, and in an attitude similar, for instance, to that of a sheep, may in the dusk appear in every sense like a sheep.

If, therefore, we are benighted in a strange place, where no judgment of distance can be formed, we are every moment liable to deceptions of vision. Hence originate most of the dreadful stories of spectres, and of those wonderful, hideous and gigantic figures, which many persons speak of having seen. Though it is commonly asserted, that such figures exist solely in the imagination; yet it is highly probable, that they might appear to the Eye in every respect as described. This remark will be allowed to have the greater force, when it is considered, that if the size of an object be in great measure estimated by the angle which it forms in the Eye, it is magnified according to its propinquity: of course, if it seemed at first to the spectator (who is equally incapable of distinguishing what he sees, and of judging at what distance it is,) a few feet high, when at the distance of thirty or forty yards from him: it must look to him, when he is within a few feet of it, of a size stupendously increased. At this he will naturally be terrified, unless he touch and thus distinguish the seemingly enormous object; for in the instant he has an actual perception of what it is, the enormity will diminish, and the object will appear in its real state: if, on the other hand, he be afraid to approach it, and flee from the spot with precipita-

tion,

tion, the only idea remaining of what was presented to his view, will be that of an image, gigantic in its size, and horrible in its form. The prejudice about spectres and hobgoblins, therefore, in some degree originates from nature, and such visionary objects depend not entirely on the imagination alone, as has been frequently supposed.

If room would permit, it would be a pleasing employment to point out many advantages which arise from the form, the size, the motion, and the situation of the Eye, each of which has a tendency to evince the wisdom and goodness of the Omnipotent Creator. But this has been well done by Dr. *Derham* and Dr. *Paley;* to whose works I must refer you. The celebrated *Euler*, in his "*Letters to a German Princess*," points out an astonishing difference between the human Eye, and any artificial eye which can be constructed : he then makes some admirable reflections, part of which I now lay before you. "The Eye which the Creator has "formed, is subject to no one of all the imperfec- "tions under which the imaginary construction of "the free thinker labours. In this we discover the "true reason, why Infinite Wisdom has employed "several transparent substances in the formation "of the Eye: it is thereby secured against all the "defects which characterize every work of man. "What a noble subject of contemplation! *He who "formed the Eye, shall he not see? and he who "planted the ear, shall he not hear?* The Eye "alone being a master-piece that far transcends "the human understanding, what an exalted idea

"must

" must we form of Him, who has bestowed this " wonderful gift, and in the highest perfection, not " on man only, but on the brute creation, nay, " on the vilest of insects!"

Indeed, if we do but reflect upon the many diversified and beautiful scenes which are made visible to us by means of the organ of Sight, and consider the deplorable state, and the many inconveniences those persons lie under, who are deprived of this blessing, our hearts ought to overflow with thankfulness to that kind BEING who has bestowed so useful an instrument as the Eye upon us, to add to our convenience and delight; and whose superintendency protects it from those injuries to which it is continually exposed.

LESSON XXXVIII.

ON CONCOCTION.

——The concoctive powers, with various art,
Subdue the cruder aliments to chyle;
The chyle to blood; the foamy purple tide
To liquors, which thro' finer arteries
To different parts their winding course pursue.
ARMSTRONG.

AMONG all the wise contrivances observed in the human fabric, none can excite our attention and admiration more than the disposition and mechanism of those parts, by which our aliment is concocted, or fitted for our daily support and nourishment.

To have a clear idea of the manner in which *Concoction* is performed, we must distinguish it into three stages: the first of which is performed in the progress of the aliment from the mouth down to the lacteals; which are vessels that receive the chyle from the intestines; the second is performed in the passage of the milky liquor called chyle, through the lacteal vessels to the loins, and then up under the collar bone, where it mingles with the blood: the third, or ultimate stage of Concoction, is performed by the circulation of the blood and chyle together through the lungs, and the whole arterial system. In all these stages the

the design of the SUPREME CONTRIVER has evidently been to grind and dissolve the aliment, and to incorporate it with a large quantity of animal juices already prepared, in such a manner as to reduce it at last to the very same substance with our blood and humours. How wonderfully and completely this design has been executed, my young readers will presently be able to judge.

In the first stage of Concoction, by a curious configuration of parts, and aetion of muscles, adapted to their respective functions, our food is ground small by the teeth, and moistened by a copious saliva in the mouth. It is in the next place swallowed, and conveyed down the gullet, where it is farther mollified and lubricated by a viscid unctuous humour, distilled from the glands of that canal. From thence it slips into the stomach, where several causes concur towards its complete dissolution. It is diluted by the juices, swelled and subtilized by the internal air, and it is macerated and dissolved by the heat which it meets with in the cavity. It is also agitated and attenuated by the perpetual friction of the coats of the stomach, and the pulsation of the arteries there; by the alternate elevation and depression of the diaphragm or midriff in breathing; and by the compression of the strong muscles of the belly. After a proper stay, it is gradually propelled into the intestines, in the form of a thick, smooth, uniform, ash-coloured fluid.

When our aliment, thus prepared, arrives at the intestines, it is there mixed with three different sorts

sorts of liquors. It receives two kinds of bile; the one, thick, yellow, and extremely bitter, from the gall-bladder; the other, scarcely bitter, or yellow, but in a much larger quantity, from the liver. The third liquor that falls here upon the food, issues plentifully from a large glandular substance, called the Pancreas or sweet-bread, and is a limpid mild fluid, like the saliva, which serves to dilute and sweeten what may be too thick and acrimonious. The two saponaceous biles resolve and attenuate viscid substances; incorporate oily fluids with aqueous ones, making the whole mixture homogeneous; and by their penetrating and detergent qualities render the chyle fit to enter the lacteal veins, into which it is conveyed, partly by their absorbent nature, and partly by the peristaltic motion of the intestines.

If we now consider the change which our aliment has undergone, in the mouth, gullet, and stomach, together with the large quantity of bile, and pancreatic juice poured upon it in the intestines: and if we reflect also on the incessant action of the muscles, blending, churning, and incorporating the whole, we shall readily perceive that their united agency must alter the flavours and properties of the different kinds of food, in such a manner as to bring the chyle nearer in its nature to our animal juices, than to the original substances from which it was formed. Our food, thus changed into chyle, constitutes the first stage of Concoction; and we shall find the same assimilation carried on through the second.

The

The next stage begins with the slender lacteal veins, where they arise from the intestines by an innumerable multitude of invisible pores, through which the fine, white, fluid part of the chyle is strained or absorbed; while, at the same time, the gross, yellow, fibrous part, conveyed slowly forward, and further attenuated in the long intestinal tube, is perpetually pressed and drained of its remaining chyle, until the dregs, becoming at last useless, are ejected out of the body.

These lacteal veins issue from the intestines in various directions, now straight and then oblique, often uniting and growing larger, but presently separating again. They frequently meet at acute angles, and enter into soft glands dispersed through the mesentery, from which they proceed larger than before, and more turgid, with a fine lymphatic fluid: in most places also they run contiguous to the mesenteric arteries, by whose pulsation their load is pushed forward. And thus, after various communications, separations, and protrusions, the lacteal veins pour their chyle into a sort of cistern or reservoir formed for that purpose, between the lowest portion of the diaphaygm and highest vertebre of the loins. It is very remarkable, that these veins are furnished with proper valves, which permit the chyle to move forward, but effectually stop its return; and that a great number of veins purely lymphatic, as well as the lacteal ones, empty themselves into the same cistern.

In all this contrivance it is evident, that the chyle, being more and more diluted and blended with abundance of lymph from the glands through which it passes, and from other sources, approaches still nearer to the nature of our animal juices, and consequently becomes more fit for nutrition.

The chyle is pushed from its reservoir into a narrow transparent pipe, called the thoracic duct, which climbs in a perpendicular direction by the side of the back-bone, from the loins up to the collar-bone, and opens into the subclavian vein: where, by the peculiar arrangement of several small valves, the chyle mingles gently with the blood after it has been thoroughly elaborated; and attenuated with lymph from every part of the thorax, or great cavity of the breast, and is from thence soon conveyed to the heart.

Thus we may perceive, that by a wonderful mechanism, a large quantity of chyle and lymph is forced upwards, in a perpendicular course, through a thin slender pipe; but to render this more plain, the following particulars must be attended to:— First, to the progress of the chyle, urged forward and continued from the ante edent action of the intestines, and the beating of the mesenteric arteries. Secondly, to the motion of the diaphragm and lungs, in respiration, pressing the thoracic duct that lies under them, whilst the thorax, rising and falling, resists their action, whereby the duct is squeezed between two contrary forces, and the liquor which it contains pushed upwards. Thirdly, this duct runs close by the side of the great artery (called by anatomists, the superior portion of the descending

descending aorta) whose strong pulsation presses its yielding sides, and compels the chyle and lymph to mount in an upright ascent. Fourthly, it must be observed, that this duct is accommodated with valves, which permit its contents to move upwards by every compression, but never to fall back again.

Thus terminates the second stage of Concoction, when the chyle falls into the heart. And it may be seen that in the progress through these two stages, our aliment has been mixed accurately with all the nourishing juices and with all the substances or principles which compose the blood, viz. saliva, mucus, lymph, bile, water, salts, oil, and spirits.

But here it will be proper to take notice, that the most fluid and subtile parts of our aliment, before and after it is elaborated into chyle, pass into the blood by certain absorbent veins dispersed all over the mouth, gullet, stomach, and intestines: when we consider how quickly refreshment and strength are communicated to weary, faint, and hungry people, immediately upon drinking a glass of good wine, or eating any cordial spoon-meat, this remark will appear the more obvious.

The third stage begins where the chyle mingles with the blood, and, falling soon into the right ventricle of the heart, is from thence propelled into the lungs. It will appear that the lungs are the principal instruments of converting the chyle into the blood; especially if we consider their structure, first with regard to the air-vessels of which they are composed, and secondly with regard to their blood-vessels: for we shall then clearly perceive the change which their fabric and action must produce on the chyle.

The windpipe is composed of segments of cartilaginous rings on the fore part, to give a free passage to the air in respiration; and of a strong membrane on its back part, to bend with the neck, and give way to the gullet in deglutition. This pipe is lined throughout with an infinity of glands, which perpetually distil an unctuous dense humour to lubricate and anoint the passages of the air. Soon after the windpipe has descended into the cavity of the breast, it is divided into two great branches; and these two are subdivided into innumerable ramifications called bronchia, which become smaller in their progress (not much unlike a bushy tree inverted), until at last they terminate in millions of little bladders which hang in clusters at their extremities, and are inflated by their admission of air, and subside at its expulsion. The clusters constitute the lobes of the lungs.

The blood-vessels of the lungs next deserve our attention. The branches of the pulmonary artery run along with those of the windpipe, and are ultimately subdivided into an endless number of capillary ramifications, which are spread, like a fine net work, over the surface of every individual air-bladder; and the pulmonary vein, whose extreme branches receive the blood and chyle from those of the arteries, run likewise in form of a net over all the air-bladders of the bronchia.

From

From this admirable structure of the lungs, it is obvious, that the crude mixture of the blood and chyle, passing through the minute ramifications of the pulmonary artery and vein, is compressed and ground by two contrary forces, viz. by that of the heart, driving the mixture forward against the sides of the bronchia and air-bladders; and by the elastic force of the air equally repelling this mixture from the contrary side.

By these two opposite forces the chyle and blood are more intimately blended and incorporated; and by the admission and expulsion of the air in respiration, the vessels are alternately inflated and compressed (and probably some subtile air or æther is received into the blood) by which means the mixture is still farther attenuated and dissolved; and after various circulations through the lungs and heart, and the whole arterial system, is at last perfectly assimilated with the blood, being fitted to nourish the body, and answer the different purposes of animal life.

When the blood thus prepared from the aliment, is, by repeated circulations, gradually drained of all its bland and useful parts, and begins to acquire too great a degree of acrimony, it is carried off by both sensible and insensible evacuations, through the several channels and distributions of nature. By these evacuations the body is made languid, and requires a fresh supply of aliment; while at the same time the saliva, and juices of the stomach and intestines, becoming thin and acrid by multiplied circulations, vellicate the nerves of those passages, and excite hunger, as a faithful monitor, to remind us of that refreshment which is now become necessary. And here I close my account of the process of Concoction; in the consideration of which the young reader will find abundant cause for astonishment and admiration.

LESSON XXXIX.

ON THE CIRCULATION OF THE BLOOD.

The Blood, the fountain whence the spirits flow;
The gen'rous stream that waters ev'ry part,
And motion, vigour, and warm life conveys
To ev'ry particle that moves or lives.

ARMSTRONG.

THOUGH it be common to talk familiarly of the *Circulation of the Blood*, yet perhaps very few of my young readers are well acquainted with it: I shall therefore appropriate this Lesson to the purpose of giving them a brief, though I hope intelligible, description of the manner in which the Circulation is performed. This important secret was brought to light by *William Harvey*, an English physician, a little before the year 1600: and when it is considered thoroughly, it will appear to be one of the most stupendous works of matchless skill.

To form a distinct judgment of the mechanism and importance of the Circulation, it will be necessary to describe the structure of the arteries, veins, and nerves; and take notice of some experiments made upon them; and then must be considered the cavities of the heart, by means of which the Blood is propelled through the body. To these I now proceed.

The arteries are blood-vessels consisting of a close texture of strong elastic fibres, woven in various webs, laid in different directions, and interspersed with an infinity of delicate nerves, veins, and minuter arteries. They are divided and subdivided into numberless branches and ramifications, that become smaller and smaller as they recede from the heart, until at last their extremities are found much more slender than the hairs of our heads, (and are therefore called capillary arteries), which either unite in continued pipes with the beginnings of the veins, or terminate in small receptacles, from which the veins derive their origin. The arteries have no valves, but only have their trunks spring from the heart: they throb and beat perpetually whilst life remains; their extremities differing in the thickness of their coats and some other particulars, according to the nature of the part which they pervade. All the arteries in the lungs (except the small ones that convey nourishment to them) are derived from the great pulmonary artery, which issues from the right ventricle of the heart. And all the arteries in the rest of the body proceed from the aorta, (which obtained this name, because the ancients thought it contained air only), whose trunk springs from the left ventricle of the heart.

The veins resemble the arteries in their figure and distribution; but their cavities are larger, and thier their branches, perhaps, more numerous. Their coats are much weaker and more slender than those of the arteries. They are furnished with several valves, contrived in such a manner as to permit the Blood to pass freely from the smaller into the larger branches, but to stop its retrogression. They neither throb nor beat. Their beginnings form continued pipes with the extremities of the arteries, or arise from some gland or receptacle where the arteries terminate. All the veins in the lungs, from their capillary beginnings growing still larger, unite at last and discharge their Blood into the left auricle of the heart: and all those in the rest of the body empty themselves in like manner, into the vena cava, which opens into the right auricle of the heart.

The nerves deduce their origin from the brain, or its appendages, in several pairs, of a cylindric form, (like so many skeins of thread with their respective sheaths), which in their progress decrease by endless divisions and subdivisions, until at last they spread themselves into a texture of filaments, so slender, and so closely interwoven with each other over the whole body, that the point of a needle can hardly be put upon any part of it, without touching the delicate branch of some nerve.

It has been found by many trials, that when an artery is laid bare, and a ligature made upon it, if it be opened with a lancet between the ligature and the heart, the Blood will rush out with great violence; and a rapid, jerking stream will continue (if it be not stopped by art) until, through loss of Blood, the animal faints or dies. But if the same artery be opened between the ligature and extremities, a few drops only will ooze out from the wounded coats.

On the other hand, when a vein is laid bare, and a ligature made upon it, if it be opened between the ligature and the extremities, the Blood will gush out, as we see in common venesection. But if the same vein be opened between the binding and the heart, no Blood will appear. From these experiments it is obvious to the slightest attention, that the Blood flows from the heart, through the arteries, to the extreme parts of the body; and returns again through the veins to the heart.

For the regular performance and continuation of this motion of the Blood through all the different parts of the body, the heart, which is the *primum mobile*, giving the first impulse, is furnished with four distinct muscular cavities, that is, with an auricle and a ventricle on the right side, and an auricle and a ventricle on the left. Through these cavities, curiously adapted to their respective offices, the Blood circulates in the following order:—it is received from the veins, first into the right auricle, which, contracting itself, pushes the Blood into the right ventricle at that instant dilated. The moment this ventricle is filled, it contracts itself with great force, and impels the Blood into the pulmonary artery, which passing through the lungs, and returning by the pulmonary

pulmonary veins, is received into the left auricle of the heart, and from thence it is pushed into the left ventricle; which, being thus filled, contracts itself, and drives the Blood with great rapidity to all the parts of the body, and from them it returns again through the veins into the right auricle of the heart, as before.

It is very remarkable, that we have here a double Circulation: one, from the right ventricle, *through the lungs*, to the left auricle of the heart, in order to convert the chyle into Blood, and finally prepare it for the nourishment of the animal; the other, from the left ventricle, *through the whole body*, to the right auricle of the heart, which serves to apply that nourishment to every part, besides various other purposes.

But to proceed—Of these four muscular cavities, the two auricles are contracted at the same instant, while the two ventricles are dilated; the ventricles, in their turn, are contracting themselves at the very instant that the auricles are dilating. The arteries, in like manner, beat in alternate time with the ventricles of the heart.

The nerves, as well as the veins and arteries, act their part in this rotation of the Blood; for if the eighth pair of nerves which proceeds from the brain to the heart be bound up, the motion of the heart immediately languishes, and soon ceases entirely.

Thus we have a species of *perpetual motion*, which none but a Being of infinite wisdom and power

power could produce; yet whose continuation requires the constant aid of the same hand that first gave it existence. The brain transmits animal spirits to the heart, to give it a vigorous contraction. The heart, at the same time, pushes the Blood into the brain to supply it with new spirits; by which means the head and the heart give continual mutual support to each other. But this is not all; the action of the heart sends the Blood and other vital humours over the whole body by the arteries, and distributes nourishment and vigour to *every part* (while perhaps the animal spirits, from the extremities of the nerves, return again into the Blood), and the whole refluent mass is conveyed back through the veins into the heart, which enables it, without intermission, to persist in rolling this *tide of life*.

But here it must not be supposed, that the arteries pass on to the extremities of the limbs, before they communicate with the returning veins: for upon this supposition, after an amputation has been performed, whatever Blood might be brought to the stump by the arteries, it is certain, none of it could be carried back again to the heart; because the intercourse between the heart and the limbs would, in this case, be entirely cut off. But the all-wise AUTHOR of our being has provided for this exigency, by forming a great number of less branches from the larger arteries, which constantly communicate with corresponding branches of the returning veins. And hence, it is easy to conceive

conceive how the Circulation is carried on after amputation has been performed *.

From what little has been advanced in this and the two preceding Lessons, the unprejudiced young reader will find a striking display of the wisdom and goodness of our CREATOR. To those who still hold to the negation of such a Being, I scarcely know what to say: for they who live, move, think, and act, must be left without excuse, if they deny or forget GOD, or refuse to honour or be thankful to him. Those who withstand the evidence of the works of nature, when properly observed, are not likely to be convinced by rational deductions; but will probably continue infidels (unless their hearts be changed by Divine Grace) until they are convinced of their fatal mistake, by experiencing the indignation of that ALMIGHTY BEING, whose existence they have so impiously denied.

But this, I sincerely hope, will not be the case with any of the youthful perusers of these Lessons. However, in this sceptical age, when every part of Divine Truth is questioned, opposed, and, alas! too frequently holden in derision, it becomes us to be

* With respect to the velocity of the circulating Blood, and the time in which the whole quantity thereof has undergone a complete circulation; although several computations have been made, the matter is not decisively settled. Dr. *Jurin* and Dr. *Keill* have most distinguished themselves in inquiries of this nature; but they are far from agreeing in their conclusions. The substance of their calculations and experiments may be seen in Dr. *Rees*'s improved edition of CHAMBERS'S CYCLOPÆDIA, under the articles *Blood* and *Heart*.

wary; and not only so, but to join in a general endeavour to persuade those who are deviating from the true path, speedily to return thereto.

Come! all ye nations! bless the LORD,
To him your grateful homage pay:
Your voices raise with one accord,
JEHOVAH's praises to display.

From clay our complex frames he moulds.
And succours us in time of need:
Like sheep when wandering from their folds
He calls us back, and does us feed.

Then through the world let's shout his praise,
Ten thousand million tongues should join,
To Heaven their thankful incense raise,
And sound their MAKER's love divine.

When rolling years have ceas'd their rounds,
Yet shall his goodness onward tend:
For his great mercy has no bounds;
His truth and love shall never end!

LESSON XL.

CONCLUDING REMARKS AND ADVICE.

Ye guardian Powers! who make mankind your care,
Give me to know wise Nature's hidden depths,
Trace each mysterious cause, with judgment read
Th' expanded volume, and submiss adore
That great creative Will, who at a word
Spoke forth this wondrous scene.

SOMERVILLE.

WHEN we consider the contracted and confined nature of human knowledge, even in its present improved state, we must not anticipate to ourselves the pleasure of obtaining such a degree of philosophic skill, as is described in the above-cited lines of the poet: for it may be recollected that, when endeavouring to elucidate the causes of some of the grand phenomena of nature, we more frequently proceeded upon conjecture and hypotheses than upon any real and permanent foundation. However, though this be admitted, it need not be thence concluded that we should be entirely inattentive to philosophic speculations: for contemplations of this kind, when properly regulated, have a tendency to correct wrong opinions, which we might otherwise entertain of the wisdom and goodness of that Being who created the universe.

It is in conformity to this sentiment, that I have, in the foregoing Lessons, attempted to describe to you the nature and supposed causes of some few of the numerous objects and appearances in creation: and I hope that, even from the descriptions which I have given, faint and imperfect as they must be acknowledged to be, I shall be justified in adopting the language of Mr. *Cotes*, when he says, "That man must be blind, who from the most "wise and excellent disposal of things, cannot "immediately perceive the infinite wisdom and "goodness of the Almighty Creator; and he "must be mad, who refuses to acknowledge "them."

I have, in the course of these Lessons, frequently referred you to such works of eminent writers, as may be consulted with advantage: I shall now, previous to drawing a conclusion, mention some other authors in whose works you may meet with more information; not only on the subjects treated upon in this performance, but on several, which the narrow limits I am confined to have hindered me from even mentioning.

On *Anatomy*, I would recommend the works of *Borelli*, *Harvey*, *Hunter*, *Jurin*, *Keill*, *Motherby*, *Monro*, and *Nieuwentyt*. On *Astronomical* subjects, *Bonnycastle*, *Bryan*, *Emerson*, *Ferguson*

Gregory

Gregory, Keill, Long, Maskelyne, Vince, and *Wales,* are writers of distinguished reputation. The best writers on *Electricity,* are *Brooks, Cavallo, Ferguson, Franklin, Morgan,* and *Priestley.* On *Optics,* the performances of *Harris, Martin,* NEWTON, *Smith,* and *Wood,* will particularly merit your attention. Various other parts of Philosophy, or *Natural Philosophy* in general, may be found treated on, either in a popular or scientific way, in the works of *Adams, Cavallo, Desaguliers, Emerson, Enfield, Ferguson, Gregory, Keill, Martin, Mariotte,* NEWTON, *Nicholson, Nieuwentyt, Rowning, Rutherforth,* and *Ryland.* There has also been lately issued into the world, a Dictionary, by my highly esteemed friend, Dr. *Charles Hutton,* in which abundant information on astronomical, mathematical, and philosophical subjects may be met with. I would also recommend to your notice the periodical publications in which philosophical and mathematical questions are discussed: the principal of these are, the *Ladies' Diary* and *Supplement, Gentleman's Diary,* and *Mathematical Repository;* besides monthly productions, several of which are worth notice. Nor can I here omit pointing out, *Maclaurin's View of Sir Isaac Newton's Philosophical Discoveries;* and, to those who are acquainted with the French language, the *Traité Elémentaire de Physique, par M. R. J. Haüy,* as works which will amply repay the student for any attention he may pay them. And, since the author of a book commonly wishes

it

it to be read, and generally thinks it will be found worthy a perusal, it would be a mere affectation of modesty, were I not to recommend to the notice of my readers, the treatises on Astronomy and Mechanics advertised at the end of this volume.

Finally, I must entreat my young readers early to imbibe correct religious principles*; for it is religion only that can regulate the heart,—it causes it to melt in sympathy at another's distress, or to glow with pleasure at another's happiness,—it is this alone that can harmonize the mind,

"Attuning all its passions into peace."

The astronomer, if enlightened by it, must contemplate, with wonder and admiration, those luminaries on which his eye so often gazes with pleasure. The philosopher too, when the wonders of nature are open to his view, with what adoration and gratitude must he look to that great Source from whence they flow! Nay, in all professions, how imperfect is man, unless illumined by the bright rays of Religion, which, like that glorious fountain of light, the sun, will enlighten all our paths.

Let me beg of you, therefore, to study, with par-

* "With the talents of an angel, a man may be a fool; if "he judge amiss in the *supreme point*, judging aright in all "else but aggravates his folly—as it shews him wrong, though "blest with the best capacity of being right."

DR. YOUNG.

ticular

ticular attention, that much-neglected book the BIBLE; where energy of language, sublimity of sentiment, and the most exquisite beauties of oriental poetry, are among the least of its perfections*: from reading this book, and from contemplating the works of nature, we may learn that GOD is a *supreme, eternal, self-existent, necessary,* and *independent* Being: that he is also *invisible, immortal, incomprehensible, omnipotent, omniscient, omnipresent,* and *supremely good.* We may also thence deduce, that He manages the world in wisdom and goodness, and governs it in justice, truth, and holiness; that "not a sparrow "falls to the ground without HIM;" that "even

* The Bible, on account of the precepts it contains, and the consolations which may be derived from it, is above all praise. But before it can be of advantage to a reader, he ought to be convinced of the truth of Revelation. Young persons should assent to the doctrines in this Divine Book; not because they were born in a country where they have been *told* that they were true; nor merely because they have been assented to, and defended, by very eminent men; but because the evidences, accompanying the various parts of the volume, have CONVINCED them, that it has GOD for its author, TRUTH for its matter, and SALVATION for its end. I cannot help adding, that when youth make these evidences the subject of their pursuit, they should bear in mind a precept, which ought always to accompany them when pursuing truth: namely, "As far as possible get rid of *old prejudices,* and watch continually against *new ones.*"

For more on this most interesting of all subjects, I trust the reader may advantageously consult my "Letters on the Evidences, Doctrines, and Duties of the Christian Religion."

"the

"the hairs of our head are all numbered;" and that all *second causes* derive their origin, permanency, and efficacy from HIM alone.

Since, then, THE LORD GOD is himself the Source and Perfection of all beauty and excellency the Author of our existence, and the bountiful Giver of all good gifts; we undoubtedly ought to love him with our whole heart, and to serve him with all our powers; we ought to reverence his majesty and authority, and endeavour above all things to obtain his favour; we ought to devote ourselves entirely to his service, and make all our actions tend to the advancement of his glory. And as his mercy and goodness are unbounded, so should be our gratitude and praise.

JEHOVAH reigns: let ev'ry nation hear,
And at his footstool bow with holy fear;
Let heav'n's high arches echo with his name,
And the wide peopled earth his praise proclaim;
Then send it down to hell's deep gloom resounding,
Through all her caves in dreadful murmurs sounding.

He rules with wide and absolute command,
O'er the broad ocean and the stedfast land:
JEHOVAH reigns unbounded and alone,
And all creation hangs beneath his throne:
He reigns alone; let no inferior nature
Usurp or share the throne of the Creator.

He saw the struggling beams of infant light
Shoot through the massy gloom of ancient night;
His Spirit hush'd the elemental strife,
And brooded o'er the kindling seeds of life;
Seasons and months began the long procession,
And measur'd o'er the year in bright succession.

The

The joyful sun sprung up th' ethereal way.
Strong as a giant, as a bridegroom gay :
And the pale moon diffus'd her shadowy light
Superior o'er the dusky brow of night ;
Ten thousand glittering lamps the skies adorning,
Numerous as dew-drops from the womb of morning.

Earth's blooming face with rising flow'rs he dress'd,
And spread a verdant mantle o'er her breast ;
Then from the hollow of his hand he pours
The circling waters round her winding shores,—
The new-born world in their cool arms embracing,
And with soft murmurs still her banks caressing.

At length she rose complete in finish'd pride,
All fair and spotless like a virgin bride ;
Fresh with untarnish'd lustre as she stood,
Her MAKER bless'd his work, and call'd it good :
The morning stars, with joyful acclamation,
Exulting sung, and hail'd the new creation.

Yet this fair world, the creature of a day,
Though built by God's right hand, must pass away !
And long oblivion creep o'er mortal things,
The fate of empires, and the pride of kings :
Eternal night shall veil their proudest story,
And drop the curtain o'er all human glory.

The sun himself, with weary clouds opprest,
Shall in his silent, dark pavilion rest ;
His golden urn shall broke and useless lie,
Amidst the common ruins of the sky !
The stars rush headlong in the wild commotion,
And bathe their glittering foreheads in the ocean.

But fix'd, O GOD ! for ever stands thy throne ;
JEHOVAH reigns, a universe alone ;
Th' eternal fire that feeds each vital flame,
Collected or diffused is still the same,
He dwells within his own unfathom'd essence,
And fills all space with his unbounded presence.

But

But oh ! our highest notes the theme debase,
And silence is our least injurious praise :
Cease, cease your songs, the daring flight controul,—
Revere him in the stillness of the soul ;
With silent duty meekly bend before him,
And deep within your inmost hearts—adore him.

MRS. BARBAULD.

APPENDIX

APPENDIX

CONTAINING

SOME ADDITIONAL REMARKS

ON

HEAT, COLD, AND LIGHT.

THERE is but little probability of our arriving at any great degree of accuracy in our opinions concerning these subjects, if in our reasonings upon them we only consider them separately; for there are several cases in which they have a dependence upon each other, which can only be traced out by considering them together. To answer this purpose, the following pages are written.

As in the course of our discussion, the degrees of heat and cold will be spoken of, it appears necessary to premise a little with regard to the instrument by which they are usually (though not always) measured. This instrument is called a *thermometer*: to describe it with a nice particularity is not requisite, since more may be learnt from five minutes' examination of one, than could be gathered from a description which might fill half a dozen pages. In order that thermometers of different sizes may produce exactly the same conclusion in determining the heat or cold of bodies

applied

applied thereto, it is necessary to fix upon two certain points at some distance, of each of which we can judge by unvarying criteria. These in *Fahrenheit's Thermometer* (the one most generally used in England) are the *boiling* and *freezing points* of water. With regard to the former of these, it should be recollected as observed in the Twenty-ninth Lesson, that the degree of heat at which water boils, is varied by the difference of the pressure of the atmosphere. The boiling heat is therefore taken at some certain degree of pressure: the degree now used is such as makes the mercury in a barometer stand at 29½ inches. As to the latter of these points, it does not appear to be a proper criterion; or at least, if it be, it has a wrong name affixed to it; for it is well known that, though fluids always *thaw* at the same degree of heat, yet the degree at which they *freeze* is liable to be varied with circumstances. It would therefore be better, if in future this latter point were laid aside, and instead thereof the *thawing* point made use of.

The different degrees of heat and cold are generally estimated by their distance either above or below the freezing point. Those above may be denoted by the affirmative sign: those below by the negative one: though sometimes the words at length are used; and at others, the expressions *above or below nothing* are made use of; but this latter method seems somewhat absurd.

Those who purchase thermometers ready made should pay particular attention to the tube and

corresponding

corresponding divisions: it is frequently found that the tubes, instead of being cylindrical, are smallest in the middle, and widen gradually towards each end, like two conic frustrums joined at their less bases. When this is the case, it is proper that the divisions, instead of being equal, should be longest in the middle, and decrease by regular gradations toward each end, so that the cavity in the tube shall contain the same quantity of fluid between every two divisions.

We now proceed to the more immediate objects of this Appendix, namely, *Heat*, *Cold*, and *Light:* The two latter of these will not be considered very attentively; only as they are connected with the former, which will be handled more at large.

Heat and Cold are to be considered either as particular sensations, or as the causes of powers which bodies possess of exciting those sensations. Thus, we say that we ourselves are hot or cold, and that the fire or ice which heats or cools us is likewise hot or cold: though the sensations we experience are certainly very different things from that which enables those bodies to excite them. It must be observed that the sensations of Heat and Cold are very fallacious ones, in so far as they are effected by the temperature of the body in which they are excited: for we may feel a substance hot when it is in the same circumstances in which we should feel it cool at another time. To elucidate this, we may observe that when we have been accustomed to live in an atmosphere of betwixt + 60° and + 70°, if the Heat fall to + 60°

we feel it cold: but, on the contrary, if we have lived in an atmosphere of between + 40° and + 50°, if the Heat rise to + 60° we feel it very hot. Again, let two basons of water be taken, one heated only to + 35°. the other to + 110°, and put one hand into the one, the other into the other bason, for some time: if we then immerse both hands in water heated to + 60°, we shall with one hand feel this Cold, with the other Hot. Hence it may be reasonably inferred, that we cannot judge with precision of Heat or Cold by the sensations they excite in us.

In the next place, we are to consider Heat and Cold as the cause of powers which bodies possess of exciting particular sensations. As to *Cold*, it is seldom supposed to be either matter itself or a quality: it is more commonly looked upon as a deprivation of Heat; for the less the heat, found in a body, the greater the Cold, and *vice versa*.—There are particular cases in which Cold may be produced. 1. When some particular chemical attraction takes place, Cold is produced. 2. The conversion of solids into liquids, and of liquids into vapour, produces Cold, as is shewn by chemists. And 3. Cold may be produced by animal powers. It is not intended to relate experiments by which these may be proved: but the grand question which we most wish to determine, is, with respect to *Heat*, whether it be matter under some particular form, or only a quality. That our reasonings on this important subject may have the better effect, we must first reflect upon the various means of of producing Heat. There are several ways by which Heat may be generated. 1. By means of the sun's rays. 2. By exciting vibrations in solids. 3. By the taking place of certain chemical attractions. 4. By conversion of vapours into fluids, and of fluids into solids. 5. By animal powers. 6. In volcanos.

And first, if a cold body be exposed to the rays of the sun, it will be heated.

It has been frequently conjectured that the sun is *fire*, burning and heating other bodies in like manner as a culinary fire: but the celebrated Dr. *Fordyce* has asserted, that the sun is probably not at all hot in itself; neither are the solar rays hot, but have only a power of producing Heat on being applied to other bodies. An opinion very little different from this is also entertained by Dr. *William Herschel*, and supported with the authority of demonstration. As a farther consideration of this subject may tend to correct our notions concerning *Light*, it is here attempted.

It is a constant rule, with regard to hot bodies that they heat all colder bodies which are brought near them. Though it must be allowed (as will be hereafter seen) that some bodies will receive Heat with more readiness than others: however, this will not easily form an objection to what immediately follows.

Now, if we take a large burning glass, and hold a piece of iron in its focus, such Heat will be produced as to melt the iron. But the glass through which all the rays passed is scarcely heated at all: and when they fell on the iron they were no hotter than water when it is poured on vitriolic acid. But if we place water, which is perfectly transparent, in the focus, no heat will be produced: nay, if spirits of wine were placed in the focus, they would scarcely be heated. But the same Heat which melts iron, would more than suffice to make water boil. From this experiment, then, without advancing farther arguments, it appears that the rays in themselves have no Heat; and there is no reason to suppose that the sun is hotter than the earth we inhabit.

It is a question that has been much agitated, whether the solar rays be matter, or only an arrangement of matter; but their materiality is now pretty generally admitted: but a question which has not yet been answered satisfactorily, is, "If "Light be matter, what becomes of it?" Perhaps there is a distinction between Light and the solar rays, which has not yet been properly attended to.

The sun's rays heat bodies only when they are *bent* or *destroyed*. (The term *absorbed* does not in our opinion exactly answer the purpose.) Hence they do not heat water if perfectly transparent; neither do they heat the air above the clouds: at least, as very little bending takes place in these cases, the heat is so trifling as to be scarcely worth mentioning. The upper regions of the air, then, are extremely cold, though exposed to the direct action of the sun.

When a ray of Light is reflected, it does not *touch* the body reflecting it; but is thrown back before it arrives at the surface: therefore the more white

white bodies are, or the more highly they are polished, the less they are heated, because they reflect more of the rays: and when a body is perfectly white it reflects all the light, and is not heated at all.

Bodies, in proportion as they deviate from white, destroy the more solar rays, and a perfectly black body would destroy them all: hence bodies are more heated, *cæt. par.* as they are darker coloured, by this cause of Heat.

When a body is rough, asi f we make a piece of glass so (which may have no colour) it destroys part of the rays, or, at least, suffers them to approach so near its surface before it reflects them that they cause it to be heated.

Thus far our reasonings induce us to suppose that *Heat* is a *quality*: but Heat, as a quality, cannot exist without a substance to exist in. So that, if it were possible to produce a *perfect vacuum*, there could be no Heat therein. This also leads us to conclude, that the denser a body is, the more Heat may be therein produced; other circumstances being the same.

Heat, it is affirmed, can only be produced by the solar rays at the surfaces of bodies: consequently the interior parts can only be heated by communication. And if we keep in mind that Heat is more readily transmitted, communicated, and received, by some bodies than others; it will then appear that, as a body receives Heat with more facility, it will be the more heated by the

sun's

sun's rays; as a piece of iron will be more heated than a piece of wood.

We have seen, then,—that the solar rays are not hot in themselves,—that they produce Heat only when they are bent or destroyed,—that therefore they do not heat transparent bodies, nor do they heat in passing through them, but only at their entrance and passing out again.

It is evident, since the rays of the sun have a power of producing Heat, that they will heat a body more, the greater the quantity is that falls on it. From this principle, combined with some particular circumstances, arises the different Heat and Cold of the seasons, and of the different parts of the earth. For instance, the Heat about the equator has been known to arise to + 110°: and it is said, that the Cold in Siberia has been as low as + 160°; but the accuracy of this may be doubted, for I do not see how so great a degree of Cold can be precisely measured.

The Heat produced by the solar rays is increased also by reflection of them: if they be frequently reflected, a greater Heat is produced than even if they be all destroyed. Thus we find that, if we receive them into a box so constructed as to reflect them frequently from side to side, more Heat will be produced than in a box made black, so as to destroy them almost all. Hence, in vallies, even in temperate climates, where the rays are reflected frequently, very great Heat is also produced.

The different distances of the planets from the sun,

sun, it is imagined, makes a great difference in the number of the rays and in the momentum with which they fall on them. So that it has been thought that Mercury is exceedingly hot, and Georgium Sidus cold beyond conception: but since the Heat produced in bodies depends on their disposition to receive it, the several planets may be so composed as to have but a very trifling difference in the Heat produced by the solar rays. Hence, then, what has been hitherto said concerning the Heat of the planets as calculated on the supposition of the sun being the source of Heat, may be called in question: and, perhaps the Newtonian opinion concerning comets (recited in the astronomical part of this work) may in time be entirely abandoned, and some later hypothesis become generally received.

Thus much for the first method of producing Heat.

The next method of producing Heat is by exciting vibration in solids. Whether fluids can be thus heated, we do not know: there is no clear instance of Heat being produced by their vibration. We may excite vibration in solids, by friction or by collision. If we rub together or strike two bodies, if they have any elasticity they will vibrate. The rougher bodies are which are rubbed together, the greater vibration is produced, and therefore the greater heat. The vibration is also, *cæt. par.* in proportion to the elasticity of bodies.

In *Count Rumford's* ninth Essay, which is an inquiry

inquiry into the source of the Heat that is excited by friction, many interesting experiments are related. From these experiments it appears, that sufficient Heat was produced by the friction of two metallic surfaces (when the access of atmospherical air was entirely prevented) to make water actually boil. It appeared that a very considerable quantity of Heat was excited by the friction, and given off in a constant stream *in all directions,* without interruption or intermission, and without any signs of diminution or exhaustion.

This ingenious philosopher, when reasoning on these experiments, gives satisfactory reasons to prove that the Heat could not be furnished either by the air, or by the water which surrounded the machinery. And, considering that the source of the Heat generated in these experiments, appeared evidently to be *inexhaustible,* he naturally concluded, that *Heat* could not be *matter:* for, says he, "It is hardly necessary to add, that any thing "which any *insulated* body, or system of bodies, "can continue to furnish *without limitation, cannot possibly be a material substance.*"

Another method of producing Heat is by the taking place of chemical attractions. Every chemical attraction, as far as we know, in taking place, produces either Heat or Cold: whether it be simple combination, elective attraction, or compound elective attraction. Some of the chemical attractions are attended, besides the production of Heat, with another striking phænomenon, namely,

namely, the producing of *Light*. For instance, this is produced by the combination of resp. air with phlogiston; and other instances might be adduced. This strikes out an interesting subject of philosophical inquiry.

The fourth and fifth methods of producing Heat might be descanted upon very copiously; but perhaps this would have but little tendency towards determining what Heat is.

Lastly, Heat is produced in volcanos. This has commonly been supposed to be by burning of fuel. But it is evident that it cannot be *produced* by this cause, or by any other known means of the production of Heat. The burning of fuel, it is known, destroys a proportionate quantity of air: to produce a very great degree of Heat requires still more to be applied than is naturally combined with phlogiston. Now the whole island *Santalina* is a mass of iron ore very difficult of fusion, which was fused and thrown up from the bottom of the sea in the midst betwixt two shores, by this Heat; where no air could therefore possibly come. And if it could, it would have required more in quantity than would have exhausted the whole atmosphere, to animate fuel enough to have produced the Heat. In Friesland, some time ago, there was a tract of country 100 miles across, the whole of which (with men, animals, trees, and whatever was on it) was melted into one common mass. This Heat then cannot be produced by the burning of fuel; much less can it be by the decomposition of pyrites, which is indeed the

burning

burning of sulphur. And by what means such intense Heat is produced, we are at a loss to determine.

Having spoken of the various methods of producing Heat, we must next observe, that bodies may be heated by communication. And several experiments might be described to shew, that some bodies will both communicate and receive Heat more readily than others. It is the same with respect to Cold as to heat: for those bodies which receive Heat most readily, most readily part with it; and if they do this, they must also suffer it to pass through them (speaking of it as though it were a body) from one substance to another, or conduct it most readily, and *vice versa*.

Iron is a good *conductor* of Heat: on the contrary, wood is one of the best *non-conductors* of Heat known. That the former is a conductor, and the latter a non-conductor, of Heat, is evident from the following simple experiment; if you take a nail or a small piece of iron, and hold in the flame of a fire or candle, it will speedily become so hot all over, as to oblige you to relinquish your hold; but if you take a small piece of wood and hold in the flame, you may keep hold of it till it is nearly all consumed by the fire, without being incommoded by the heat of the wood. Hence heat passes with ease in iron, and with difficulty in wood.

From the results of various experiments, *Count Rumford* * concludes that *water*, *oil*, *mercury*, and

* In the Essays of this philosopher, very ingenious principles are applied to practical uses in the *great art of living*. That my

and *air*, are *non-conductors* of Heat: indeed, he thinks it essential to all fluids, that they should be *non-conductors*

my young readers may have an idea of the advantages which may arise, from applying philosophical principles to such purposes, I present them with the following extracts:—

In Essay VI. the Count says, "Among all the various "substances of which coverings may be formed for confining "Heat none can be applied with greater advantage than at-"mospheric air. It is what Nature employs for that purpose; "and we cannot do better than imitate her.

"The warmth of the wool and fur of beasts, and of the fea-"thers of birds, is undoubtedly owing to the air in their in-"terstices; which air, being strongly attracted by these "substances, is confined; and forms a barrier, which not only "prevents the cold winds from approaching the body of the "animal, but which opposes an almost insurmountable ob-"stacle to the escape of the Heat of the animal into the at-"mosphere. And in the same manner, the air in snow serves "to preserve the Heat of the earth in winter. The warmth "of all kinds of artificial clothing may be shewn to depend "on the same cause; and were this circumstance more ge-"nerally known, and more attended to, very important im-"provements in the management of Heat could not fail to "result from it. A great part of our lives is spent in guard-"ing against the extremes of Heat and of Cold, and in ope-"rations in which the use of Fire is indispensable; and yet "how little progress has been made in that most useful and "most important of the Arts—the management of Heat!

"Double windows have been in use many years in most of "the northern parts of Europe, and their great utility, in "rendering the houses furnished with them warm and com-"fortable in winter, is universally acknowledged,—but I "have never heard that any body has thought of employing "them in hot countries to keep their apartments cool in sum-"mer;—yet how easy and natural is this application of so "simple and so useful an invention!—If a double window "can prevent the Heat which is *in* a room from passing *out*

"*of*

non-conductors of Heat; or that all interchange and communication of Heat *among their particles*, as from one of them to the other, is absolutely impossible. Glass, when rendered of a loose texture, conducts Heat with very great difficulty; insomuch that the lava of a volcano has, sixteen years after an eruption, been found *red hot* a foot under the surface of such glass, though this was quite cool. This circumstance might very probably give the hint for the assertion (paradoxical as it may seem without proper deliberation) that it would be no difficult matter to convey an iron ball *red hot* from London to Lincoln: to perform this, it must be inclosed in pumice stone, which is very porous glass, formed by volcanos, and then covered over with fur. It is also easy, by covering a room with fire to preserve the air in it of the same

"*of it*, one would imagine it would require no great effort of "genius to discover that it would be equally efficacious for "preventing the Heat *without* from coming *in*. But natural "as this conclusion may appear, I believe it has never yet "occurred to any body; at least I am quite certain that I "have never seen a double window, either in Italy, or in any "other hot country, I have had occasion to visit."

A little farther on, he says,—"There is no *communication* "of Heat *between one particle of air and another particle of air*. "From hence it follows, that though air may, and undoubt"edly does, *carry off* Heat, and *transport it* from one place, or "from one body to another, yet a mass of air in a quiescent "state, or with all its particles at rest, *could it remain in that* "*state*, would be totally impervious to Heat; or such a mass "of air would be a *perfect non-conductor*."

Much curious and valuable information on this subject may be found in Professor LESLIE's *Experimental Inquiry into the Nature and Propagation of Heat*, lately published.

same temperature, without bringing any thing into it either hot or cold, for a very great length of time.

As to the effects produced by Heat, it is known to expand bodies ; and some late chemists affirm, that it tends to diminish every attraction we are acquainted with: they produce experiments to evince that Heat diminishes the attraction—of gravitation,—of cohesion,—of magnetism, —of electricity, and chemical attractions. But though it may be the case in particular instances, it will be better not to be too sanguine in imagining that such effects will take place *universally*. The assertion may be disputed with regard to the attraction of gravitation, and that of electricity. However, those who allow that Heat universally diminishes the electrical attraction, will strongly contend in support of their opinion, because they may thereby explain with facility the reason of the frequency of thunder-storms in summer.

From a review of what has been here advanced, we shall find that there are few, or, perhaps, we may confidently say, no appearances, but what will admit of as easy an explanation, by conjecturing that Heat is a quality, as by supposing that it is a substance. Nay, some of the phænomena, particularly those which attend the production of Heat by friction, or vibration in solids, will (as must appear from what has been previously observed) induce us to incline more to the former hypothesis than to the latter. Besides, whether Heat be a substance, or a quality, it is manifest, that

that it may be created and annihilated. Now, we have no idea of matter being created and annihilated by any natural cause, (for under all its variety of forms, matter is matter still); then what kind of a substance must Heat be, to be produced and destroyed by so many causes? Why, truly, nobody can tell: for it must have a property which matter has not. Heat is, then, probably a *quality:* for qualities we know can easily be created and annihilated. And, if Heat be a quality, it must have matter to exist in; so that, if we apply any of the causes producing Heat, no Heat is produced unless there be some matter to receive it. This, therefore, is the result of our inquiries into the nature of Heat.

We have also seen, that *Light* may be produced by particular means, the solar rays for instance: it may likewise be destroyed, as has been previously shewn. The method of reasoning just applied to Heat, may with equal propriety be used here: and this will induce us to conclude that *Light*, instead of being a *fluid per se*, as has been sometimes conjectured, is a *quality*, and can no more exist independently of matter than Heat can.

Whether these conclusions may be safely relied on, is not for us to determine: the great mysterious BEING who made and governs the universe, has set a part only of the chain of causes in our view; and we find that as HE himself is too high for our comprehension, so HIS more immediate instruments are also involved in an obscurity that our feeble endeavours are not able to dissipate.

However,

However, as Mr. *Maclaurin* has observed,— "From what we are able to understand of nature, "we may entertain the greater expectations of "what will be discovered to us, if ever we shall "be allowed to penetrate to the FIRST CAUSE "himself, and see the whole scheme of his works "as they are really derived from HIM, when our "imperfect philosophy shall be completed."

FINIS.

Ellerton and Henderson, Printers,
Johnson's Court, London.

The following Works have been lately published by the Author of these Lessons,

And may be had of J. Conder, 18, *St. Paul's Church-yard.*

COURSE OF NATURAL AND MATHEMATICAL PHILOSOPHY.

Just published, to be had, either together or in separate Parts, as follows:

1. AN ELEMENTARY TREATISE ON NATURAL PHILOSOPHY; Translated from the French of M. R. J. Haüy, with Notes, critical, illustrative, and historical, by Olinthus Gregory, L. L. D. of the Royal Military Academy, Woolwich, in two Volumes octavo, with twenty-four folding Plates, price 1*l.* 4*s.* boards.[1]

*** In this Work are treated the Subjects of Extension, Impenetrability, Divisibility, Mobility, Velocity, Inertia, Hardness, Elasticity, Ductility, Gravity, Accelerated Motion, Specific Gravity, Crystallization, Heat, Dilatations by Heat, Thermometers, Combustion, Water in the States of Liquidity, Ice, and Vapour, Capillary Attraction, Congelation of Mercury, Steam-Engines, Air, Barometers, Syphons, Pumps, Evaporation, Winds, Air Balloons, Theory of Musical Sounds, Electricity, Galvanism, Magnetism, Light and Vision, with Descriptions of Electrical, Magnetical, and Optical Instruments, &c.

Testimonies in favour of this Treatise.

"We have not yet seen a Treatise on Natural Philosophy which approached so nearly to a systematic form; no one completed with so much care, comprehending such a variety of details, finished with more philosophical accuracy." *Crit. Rev.* Series 3. vol. i. App.

"There is more originality of manner and more vigour of intellect discoverable in the Traité de Physique of M. Haüy, than in any other elementary treatise of Natural Philosophy which has for many years made its appearance in Britain. The Translator has executed his task with fidelity and skill: the public are well acquainted with his talents, and will doubtless feel much indebted to him for presenting so valuable a production to their notice: as well as for having considerably increased its utility by the frequent interspersion of copious notes." *Eclec. Rev.* vol. iv. No. 2.

"Mr. Gregory has done justice to the author in his translation, and has, we think, rendered a service to the public by giving this treatise in an English dress. He has not, however, confined himself to a bare translation, but has given many valuable notes, which add considerably to the utility of the work." *Phil. Mag.* Dec. 1807.

2. DR. GREGORY'S TREATISE ON ASTRONOMY; in which the Elements of the Science are deduced in a natural Order from the Appearances of the Heavens to an Observer on the Earth; demonstrated on Mathematical Principles, and explained by an Application to the various Phenomena: one large octavo volume, with nine folding plates, price 15s. in boards.

For testimonies in faveur of this Treatise, see Monthly Review, Aug. 1802; Phil. Mag. Feb. 1802; and Mathematical Repository and Review, Sept. 1802.

3 DR. GREGORY'S TREATISE OF MECHANICS, THEORETICAL, PRACTICAL, AND DESCRIPTIVE; in two large octavo volumes, besides a volume containing fifty-five quarto plates. The first volume is devoted to the theory of Statics, Dynamics, Hydrostatics, Hydrodynamics, and Pneumatics: the second volume contains Remarks on the Nature, Construction, and Simplification of Machinery, on Friction, and the Rigidity of Cords, First Movers, &c. with Tables, and Descriptions of nearly two hundred curious and useful Machines. Third edition, price 2*l.* 2s in boards.

Commendatory accounts of this extensive work are given in Phil. Mag. No. 95. Crit. Rev. May 1806. Brit. Crit. Aug. 1806. Month. Rev. March 1807. Annual Rev. for 1806. Eclectic Rev. Nov. 1807.

4. In conjunction with Dr. HUTTON, volume Third of A COURSE OF MATHEMATICS, composed for the Use of the Royal Military Academy, by Order of his Lordship the Master-General of the Ordnance, price 12*s.* bound.

5 In conjunction with JOHN MASON GOOD, Esq. F. R. S. and Mr. NEWTON BOSWORTH,
PANTOLOGIA: a General Dictionary of Arts, Sciences, and Words: now re-publishing in Monthly Parts, and completed in 12 vols. Royal octavo.

6. LETTERS TO A FRIEND ON THE EVIDENCES, DOCTRINES, AND DUTIES OF THE CHRISTIAN RELIGION. In 2 vols. crown 8vo. 3d edition. 14*s.* boards.

This work is intended to guard young persons of liberal education against infidelity and heterodoxy; and to evince the peculiar importance and reasonableness of Christianity, as manifested in its distinguishing doctrines, and in their powerful tendency to influence the conduct.

The following Works are likewise Sold by JOSIAH CONDER, *No.* 18, *St. Paul's Church-yard.*

1. THE COMPLETE WORKS of the Rev. ISAAC WATTS, D. D. in 9 Vols. 8vo. 4*l.* 14*s.* 6*d.* boards; fine paper, 6*l.* 6*s.*

2. The COMPLETE WORKS of the Rev. STEPHEN CHARNOCK, D. D. in 7 Vols. 8vo. price 12*s.* per Vol. Edited by the Rev. Edward Parsons, of Leeds.

3. THE ASSOCIATE MINSTRELS. The Second Edition; with additional Poems. Foolscap 8vo. price 6*s.* boards.

"The Associate Minstrels possess elevation of thought and elegance of expression. Piety, chaste morals, and the finer feelings of the heart, are always discernible, and not unfrequently sustained and ornamented by vigorous and pure diction." *European Mag. Sept.* 1810.

"That poetical taste and genius abound among us at this period, much more, perhaps, than at any former time, has long been our firm persuasion. Were the matter doubtful, this volume alone, the work apparently of six or more writers, might almost decide it." *British Critic, April,* 1811. For similar commendations, see *Literary Panorama* for *June,* 1810; *Eclectic Review, Aug.* 1810; and *Edinburgh Christian Instructor* for *Sept.* 1811.

4. GLORIA IN EXCELSIS DEO, (Glory to God in the Highest, and on Earth Peace, Good-will to Men.) A Poem in English blank verse; respectfully inscribed to the British and Foreign Bible Society. Elegantly printed in 4to. price 1*s.* 6*d.*

"This is a highly animated effusion, in blank verse, in the sentiments of which we most cordially sympathize."

"The composition will be found throughout to breathe the same noble ardour, and is evidently produced by no mean or inexperienced hand." *Britic Critic, April,* 1813.

See also the *Eclectic Review* for *Dec.* 1812.

5. OBSERVATIONS on the CHARACTER, CUSTOMS, and SUPERSTITIONS of the IRISH: and on some of the Causes which have retarded the Moral and Political Improvement of Ireland. By the Rev. Daniel Dewar, M. A. 8vo. 10*s.* 6*d.* boards.

6. MAY's FAMILY PRAYER-BOOK, Abridged; containing Forms of Prayer for every Day in the Week. A new edition, corrected. 18mo. 2s. bound.

This excellent little work has gone through eight editions. Some of the Prayers, being rather long, are, in the present edition abridged, to make them more convenient for families in general; while their simple and evangelical strain renders them peculiarly adapted for the purpose of social worship.

7. A TREATISE on RELIGIOUS EXPERIENCE; in which its Nature, Evidences, and Advantages, are considered. By Charles Buck, Fouth Edition, 12mo. 5s. boards.

8. ON THE SLAVE TRADE, and on the SLAVERY of BLACKS and of WHITES. By a Friend of Men of all Colours. Translated from the Original French of M. Gregoire, formerly Bishop of Blois. To which are annexed, Prefatory Observations and Notes, by the Translator. Price 3s. 6d. sewed.

"If you have a right to enslave others, there may be others who have a right to enslave you."—PRICE *on the American Revolution.*

9. HYMNS for INFANT MINDS. By the Authors of "Original Poems for Infant Minds," "Rhymes for the Nursery, &c. Seventh Edition. Price 1s. 6d. neatly half bound.

For very high commendations of this admirable little w· of which nearly 40,000 have been already circulated, the Public are referred to the *Christian Observer* for Nov. 1810, and the *Eclectic Review* for Aug. 1810.

10. ORIGINAL HYMNS for Sunday Schools. By the Authors of "Hymns for Infant Minds," Third Edition. Price 4d. stitched, or 3s. 6d. per dozen.

For a high character of these Original Hymns, as admirably designed to facilitate the labours of Sunday School Teachers with regard to the lowest classes, see *Eclectic Review*, Jan. 1, 1813.

11. ORIGINAL POEMS for INFANT MINDS. By several Young Persons. Tenth Edition. 2 vols. 3s. neatly half bound.

12. RHYMES for the NURSERY. By the Authors of "Original Poems," &c.