A HISTORY OF THE EARTH AND ANIMATED NATURE.

BY OLIVER GOLDSMITH.

WITH COPIOUS NOTES;

And an Appendix,

CONTAINING EXPLANATIONS OF TECHNICAL TERMS, AND AN OUTLINE OF THE CUVIERIAN AND OTHER SYSTEMS,

BY

CAPTAIN THOMAS BROWN,
F.L.S., M.W.S., M.K.S.

VOL. I.—PART I.

A. FULLARTON AND CO.,
EDINBURGH, GLASGOW, AND LONDON.

1840.

GLASGOW:
FULLARTON AND CO., PRINTERS, VILLAFIELD.

oshua Reynolds

Freeman.

Oliver Goldsmith

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TO WHICH IS SUBJOINED

AN APPENDIX,

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PRESIDENT OF THE ROYAL PHYSICAL SOCIETY

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CONTENTS OF VOLUME FIRST.

PART I.

PART II.

OF ANIMALS.

A HISTORY OF ANIMALS.

BOOK I.—ANIMALS OF THE HORSE KIND.

BOOK II.—OF RUMINATING ANIMALS.

PREFACE TO THE ORIGINAL EDITION.

NATURAL HISTORY, considered in its utmost extent, comprehends two objects. First, that of discovering, ascertaining, and naming, all the various productions of Nature. Secondly, that of describing the properties, manners, and relations, which they bear to us, and to each other. The first, which is the most difficult part of this science, is systematical, dry, mechanical, and incomplete. The second is more amusing, exhibits new pictures to the imagination, and improves our relish for existence, by widening the prospect of nature around us.

Both, however, are necessary to those who would understand this pleasing science in its utmost extent. The first care of every inquirer, no doubt, should be, to see, to visit, and examine, every object, before he pretends to inspect its habitudes or its history. From seeing and observing the thing itself, he is most naturally led to speculate upon its uses, its delights, or its inconveniences.

Numberless obstructions, however, are found in this part of his pursuit that frustrate his diligence and retard his curiosity. The objects in nature are so many, and even those of the same kind are exhibited in such a variety of forms, that the inquirer finds himself lost in the exuberance before him, and, like a man who attempts to count the stars, unassisted by art, his powers are all distracted in barren superfluity.

To remedy this embarrassment, artificial systems have been devised, which, grouping into masses those parts of nature more nearly resembling each other, refer the inquirer for the name of the single object he desires to know, to some one of those general distributions, where it is to be found by farther examination.

If, for instance, a man should, in his walks, meet with an animal, the name, and consequently the history, of which he desires to know, he is taught by systematic writers of natural history to examine its most obvious qualities, whether a quadruped, a bird, a fish, or an insect. Having determined it, for explanation' sake, to be an insect, he examines whether it has wings; if he finds it possessed of these, he is taught to examine whether it has two or four; if possessed of four, he is taught to observe, whether the two upper wings are of a shelly hardness, and serve as cases to those under them; if he finds the wings composed in this manner, he is then taught to pronounce, that this insect is one of the beetle kind: of the beetle kind, there are three different classes, distinguished from each other by their feelers; he examines the insect before him, and finds that the feelers are clavated or knobbed at the ends; of beetles, with feelers thus formed, there are ten kinds; and among those he is taught to look for the precise name of that which is before him. If, for instance, the knob be divided at the ends, and the belly be streaked with white, it is no other than the Dorr, or the May-bug; an animal, the noxious qualities of which give it a very distinguished rank in the history of the insect creation. In this manner a system of natural history may, in some measure, be compared to a dictionary of words. Both are solely intended to explain the names of things; but with this difference, that in the dictionary of words we are led from the name of the thing to its definition; whereas in the system of natural history, we are led from the definition to find out the name.

Such are the efforts of writers, who have composed their works with great labour and ingenuity, to direct the learner in his progress through nature, and to inform him of the name of every animal, plant, or fossil substance, that he happens to meet with: but it would be only deceiving the reader to conceal the truth, which is, that books alone can never teach him this art in perfection: and the solitary student can never succeed. Without a master, and a previous knowledge of many of the objects of nature, his book will only serve to confound and disgust him. Few of the individual plants or animals, that he may happen to meet with, are in that precise state of health, or that exact period of vegetation, from whence their descriptions were taken. Perhaps he meets the plant only with leaves, but the systematic writer has described it in flower. Perhaps he meets the bird before it has moulted its first feathers, while the systematic description was made in its state of full perfection. He thus ranges without an instructor, confused, and with sickening curiosity, from subject to subject, till at last he gives up the pursuit, in the multiplicity of his disappointments.

Some practice, therefore, much instruction, and diligent reading, are requisite to make a ready and expert naturalist, who shall be able, even by the help of a system, to find out the name of every object he meets with. But when this tedious, though requisite, part of study is attained, nothing but delight and variety attend the rest of his journey. Wherever he travels, like a man in a country where he has many friends, he meets with nothing but acquaintances and allurements in all the stages of his way. The mere uninformed spectator passes on in gloomy solitude; but the naturalist, in every plant, in every insect, and every pebble, finds something to entertain his curiosity, and excite his speculation.

From hence it appears, that a system may be considered as a dictionary in the study of nature. The ancients, however, who have written most delightfully on this subject, seem entirely to have rejected those humble and mechanical helps to science. They contented themselves with seizing upon the great outlines of history, and passing over what was common, as not worth the detail; they only dwelt upon what was new, great, and surprising, and sometimes even warmed the imagination at the expense of truth. Such of the moderns as revived this science in Europe, undertook the task more methodically, though not in a manner so pleasing. Aldrovandus, Gesner, and Johnson, seemed desirous of uniting the entertaining and rich descriptions of the ancients, with the dry and systematic arrangement, of which they were the first projectors. This attempt, however, was extremely imperfect, as the great variety of nature was, as yet, but very inadequately known. Nevertheless, by attempting to carry on both objects at once, first directing us to the name of a thing, and then giving the detail of its history, they drew out their works into a tedious and unreasonable length; and thus mixing incompatible aims, they have left their labours rather to be occasionally consulted, than read with delight, by posterity.

The later moderns, with that good sense which they have carried into every other part of science, have taken a different method in cultivating natural history. They have been content to give, not only the brevity, but also the dry and disgusting air of a dictionary, to their systems. Ray, Klein, Brisson, and Linnæus, have had only one aim, that of pointing out the object in nature, of discovering its name, and where it was to be found in those authors that treated of it in a more prolix and satisfactory manner. Thus natural history, at present, is carried on in two distinct and separate channels, the one serving to lead us to the thing, the other conveying the history of the thing, as supposing it already known.

The following Natural History is written with only such an attention to system as serves to remove the reader's embarrassments, and allure him to proceed. It can make no pretensions in directing him to the name of every object he meets with; that belongs to works of a different kind, and written with very different aims. It will fully answer my design, if the reader, being already possessed of the name of any animal, shall find here a short, though satisfactory, history of its habitudes, its subsistence, its manners, its friendships, and hostilities. My aim has been to carry on just as much method as was sufficient to shorten my descriptions by generalizing them, and never to follow order where the art of writing, which is but another name for good sense, informed me that it would only contribute to the reader's embarrassment.

Still, however, the reader will perceive that I have formed a kind of system in the history of every part of animated nature, directing myself by the great obvious distinctions that she herself seems to have made; which, though too few to point exactly to the name, are yet sufficient to illuminate the subject, and remove the reader's perplexity. Mr Buffon, indeed, who has brought greater talents to this part of learning than any other man, has almost entirely rejected method in classing quadrupeds. This, with great deference to such a character, appears to me running into the opposite extreme; and as some moderns have of late spent much time, great pains, and some learning, all to very little purpose, in systematic arrangement, he seems so much disgusted by their trifling but ostentatious efforts, that he describes the animals almost in the order they happen to come before him. This want of method seems to be a fault; but he can lose little by a criticism which every dull man can make, or by an error in arrangement, from which the dullest are most usually free.

In other respects, as far as this able philosopher has gone, I have taken him for my guide. The warmth of his style, and the brilliancy of his imagination, are inimitable. Leaving him, therefore, without a rival in these, and only availing myself of his information, I have been content to describe things in my own way; and though many of the materials are taken from him, yet I have added, retrenched, and altered, as I thought proper. It was my intention at one time, whenever I differed from him, to have mentioned it at the bottom of the page; but this occurred so often, that I soon found it would look like envy, and might perhaps convict me of those very errors which I was wanting to lay upon him. I have, therefore, as being every way his debtor, concealed my dissent, where my opinion was different; but wherever I borrow from him, I take care at the bottom of the page to express my obligations. But though my obligations to this writer are many, they extend to but the smallest part of the work, as he has hitherto completed only the history of quadrupeds. I was, therefore, left to my own reading alone, to make out the history of birds, fishes, and insects, of which the arrangement was so difficult, and the necessary information so widely diffused, and so obscurely related when found, that it proved by much the most laborious part of the undertaking. Thus having made use of Mr Buffon's lights in the first part of the work, I may with some share of confidence recommend it to the public. But what shall I say to that part, where I have been entirely left without his assistance? As I would affect neither modesty nor confidence, it will be sufficient to say, that my reading upon this part of the subject has been very extensive; and that I have taxed my scanty circumstances in procuring books, which are on this subject, of all others, the most expensive. In consequence of this industry, I here offer a work to the public, of a kind which has never been attempted in ours, or any other modern language, that I know of. The ancients, indeed, and Pliny in particular, have anticipated me in the present manner of treating natural history. Like those historians who describe the events of a campaign, they have not condescended to give the private particulars of every individual that formed the army; they were content with characterizing the generals, and describing their operations, while they left it to meaner hands to carry the muster-roll. I have followed their manner, rejecting the numerous fables which they adopted, and adding the improvements of the moderns, which are so numerous, that they actually make up the bulk of natural history.

The delight which I found in reading Pliny, first inspired me with the idea of a work of this nature. Having a taste rather classical than scientific, and having but little employed myself in turning over the dry labours of modern system-makers, my earliest intention was to translate this agreeable writer, and by the help of a commentary to make my work as amusing as I could. Let us dignify natural history never so much with the grave appellation of *a useful science*, yet still we must confess, that it is the occupation of the idle and the speculative, more than of the busy and the ambitious part of mankind. My intention, therefore, was to treat what I then conceived to be an idle subject in an idle manner; and not to hedge round plain and simple narratives with hard words, accumulated distinctions, ostentatious learning, and disquisitions that produced no conviction. Upon the appearance, however, of Mr Buffon's work, I dropped my former plan, and adopted the present, being convinced, by his manner, that the best imitation of the ancients was to write from our own feelings, and to imitate nature.

It will be my chief pride, therefore, if this work may be found an innocent amusement for those who have nothing else to employ them, or who require a relaxation from labour. Professed naturalists will, no doubt, find it superficial; and yet I should hope that even these will discover hints and remarks, gleaned from various reading, not wholly trite or elementary. I would wish for their approbation. But my chief ambition is to drag up the obscure and gloomy learning of the cell to open inspection, to strip it from its garb of austerity, and to show the beauties of that form, which only the industrious and the inquisitive have been hitherto permitted to approach.

ADVERTISEMENT TO THE PRESENT EDITION.

More than half a century has elapsed since Goldsmith's History of the Earth and Animated Nature was first published; and although it has gone through many editions, such is the charm of the work, that the demand for it continues little abated. The art, which Goldsmith eminently possessed, of saying every thing he had to say in a pleasing manner,—the fascinating ease and beauty of his style, and the intelligible method of arrangement which he adopted in his Natural History, secured for his work an extensive and steady patronage,—and well did the result prove the correctness of Dr Johnson's anticipation, when he said, as is recorded in Boswell's Life, "Goldsmith is now writing a Natural History, and he will make it as entertaining as a Persian tale." Goldsmith's work, indeed, did much to render Natural History a popular study in this country; for, important and interesting as the science is, it was late in the progress of knowledge, both as regards ancient and modern times, before it assumed a regular form, or began to be generally cultivated. In Greece, many of the sciences had been successfully prosecuted, and the fine arts had attained maturity, before Aristotle gave the first outline in Natural History: in Rome, taste and genius had passed their meridian, before the elder Pliny collected his singular medley of precious facts and idle fancies, which is the only valuable work in Natural History to be met with in Roman literature: and in our own times, the heroes of almost every other science had flourished before Buffon and Linnæus appeared. Goldsmith, it is true, cannot be classed with these great naturalists in the extent and originality of his researches; yet, if he added little to the science, he divested it of much of its obscurity, and by the inimitable graces of his style and manner, threw a charm over it, which was new to the English reader, and the effect of which, in rendering the science popular, has been, and to this day is, great and extensive.

With all its attractions, however, his work—owing to the imperfect state of information which obtained in the Author's time on many branches of the science—is not free from errors, and at this day cannot be held either as complete or scientific in its system. To correct its mistakes and supply its deficiencies are, therefore, leading objects of the present edition; and while the original text of the Author—which has so long delighted, and can never fail to delight the general reader—is faithfully retained, such additions are made to it in the shape of Notes as the present improved state of the science calls for. These Notes are thus distinguished: the references to them consist of an asterisk or dagger, while the references to Dr Goldsmith's own notes, or to notes not peculiar to this edition, consist of figures.

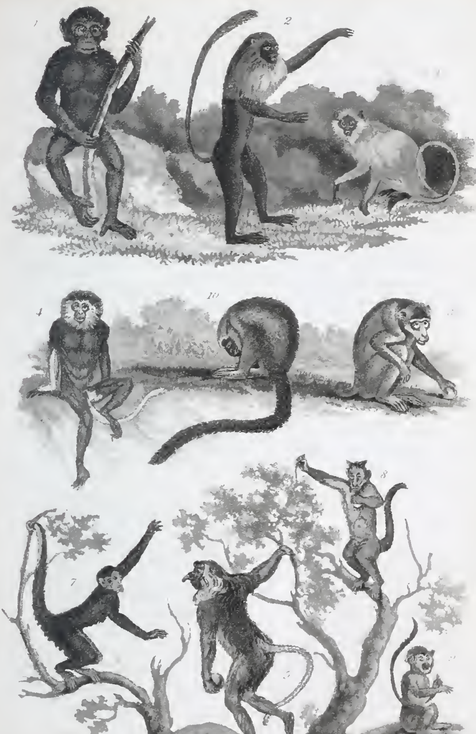
It is in scientific details that Goldsmith is chiefly deficient; and the Editor has, therefore, been careful to give as much of these within his Notes as would tend to render the work more complete as a system of natural history, without encumbering its spirit, or dimming its attractions. This necessarily left him little room for the introduction of illustrative anecdotes; and as these form not only an interesting, but a most important point of natural history, he has been led to devote a supplemental volume entirely to them. By this means, he trusts the value of the work will be increased, and it will have a claim to completeness much beyond that of any other edition.

In the prosecution of his labours, the Editor has derived great advantage from the writings of Wilson, Rennie, Knapp, Selby, Bennet, Vigors, Loudon, Jamieson, Audabon, and other popular modern naturalists. But he begs, in an especial manner, to acknowledge his obligations to the highly interesting and valuable Supplements, appended by Mr Griffith, Mr Pidgeon, and Major Smith, to the English edition of Baron Cuvier's Animal Kingdom. These gentlemen have proved themselves worthy coadjutors of the great Baron in his splendid researches; and it is from devoted leaders like these, that so great an impulse has been given in the present day to the study of natural history.

G.V

1 Caucasian 2 Mongolian 3 Negro 4 American 5 Malay 6 New Hollander.

GV*



1 Chimpanse. 2 Full Bottom Monkey. 3 Entellus Monkey. 4 Cochimiona D°
5 Proboscis D° 6 Brown Baboon. 7 Coaita 8 Horned Sapajow 9 Squirrel
Monkey. 10 Douroucouli.

1. Noctule 2 Long Eared D^o. 3 Spectre Phyllostoma. 4 Truncated Chlamyphorus. 5 Florida Neotoma 6 Raffless Gymnura. 7 Radiated Mole 8 Shrew Mole. 9 Leaf Glossophaga. 10 Tenrec.

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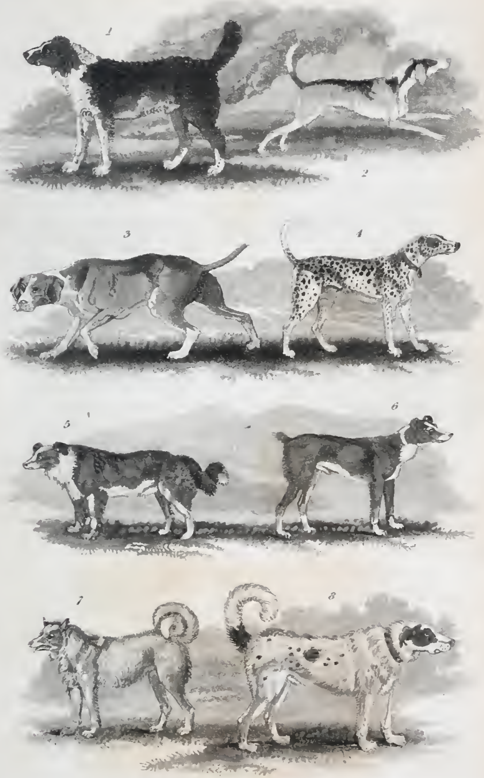

R. Scott

1 Large Water Spaniel. 2 Fox Hound 3 Spanish Pointer 4 Dalmatian D.º
5 Shepherds Dog. 6 Cur D.º 7 Greenland D.º 8 Newfoundland D.º

1

2

3

R. Scott

1 Lion . 2 Lioness . 3 Tiger

Published by Arch^d Fullarton & Co. Glasgow.

G. [illegible]

R. Scott

1 Malayan [illegible] 2 Guazupu[illegible] Deer. 3 [illegible]matra Muntjak. 4 P[illegible] 5 P[illegible]

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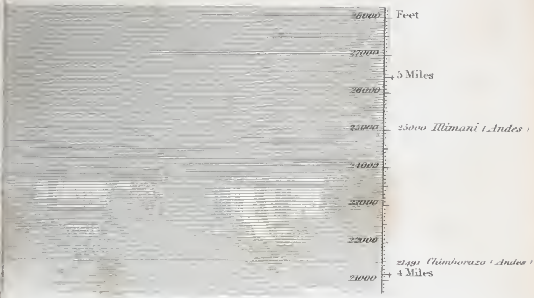
NTAINS OF THE WORLD



A

HISTORY OF THE EARTH.

CHAP. I.

A SKETCH OF THE UNIVERSE.

THE world may be considered as one vast mansion, where man has been admitted to enjoy, to admire, and to be grateful. The first desires of savage nature are merely to gratify the importunities of sensual appetite, and to neglect the contemplation of things, barely satisfied with their enjoyment: the beauties of nature, and all the wonders of creation, have but little charms for a being taken up in obviating the wants of the day, and anxious for precarious subsistence.

Philosophers, therefore, who have testified such surprise at the want of curiosity in the ignorant, seem not to consider that they are usually employed in making provisions of a more important nature; in providing rather for the necessities than the amusements of life. It is not till our more pressing wants are sufficiently supplied, that we can attend to the calls of curiosity; so that in every age scientific refinement has been the latest effort of human industry.

But human curiosity, though at first slowly excited, being at last possessed of leisure for indulging its propensity, becomes one of the greatest amusements of life, and gives higher satisfactions than what even the senses can afford. A man of this disposition turns all nature into a magnificent theatre, replete with objects of wonder and surprise, and fitted up chiefly for his happiness and entertainment: he industriously examines all things, from the minutest insect to the most finished animal; and, when his limited organs can no longer make the disquisition, he sends out his imagination upon new inquiries.

Nothing, therefore, can be more august and striking than the idea which his reason, aided by his imagination, furnishes of the universe around him. Astronomers tell us, that this earth which we inhabit, forms but a very minute part in that great assemblage of bodies of which the world is composed. It is a million of times less than the sun, by which it is enlightened. The planets also, which, like it, are subordinate to the sun's influence, exceed the earth a thousand times in magnitude. These, which were at first supposed to wander in the heavens without any fixed path, and that took their name from their apparent deviations, have long been found to perform their circuits with great exactness and strict regularity. They have been discovered as forming, with our earth, a system of bodies circulating round the sun, all obedient to one law, and impelled by one common influence.

Modern philosophy has taught us to believe, that, when the great Author of nature began the work of creation, he chose to operate by second causes; and that, suspending the constant exertion of his power, he endued matter with a quality, by which the universal economy of nature might be continued without his immediate assistance. This quality is called *attraction*; a sort of approximating influence, which all bodies, whether terrestrial or celestial, are found to possess; and which in all increases as the quantity of matter in each increases.* The sun, by far the

* Although we are indebted to Sir Isaac Newton for the complete discovery of the law of universal gravitation, and its application to the explanation of the planetary motions, yet, the existence of the law had been surmised by different philosophers, both of ancient and modern times. Copernicus, the celebrated restorer of the true system of astronomy, in speaking of the gravity of terrestrial bodies, by which they tend towards the centre of the earth, and to which the figure of the earth is owing, observes, that it is highly reasonable to suppose, that by a like principle, diffused from the sun and planets, their figures are preserved in their various motions; and Fermat, a mathematician of great eminence, who lived in the 15th century appears to have had accurate notions, to a certain extent at least, of the nature of this law; for he says, that the weight of a body is the sum of the tendencies of each particle to every particle of the earth; and among the moderns he is the first that made this remark. The justly celebrated Kepler, however, extended his views still farther; for in his *Epitome Astronomiæ Copernicanæ*, he says, that if there be supposed two bodies placed out of the reach of all external forces, and at perfect liberty to move, they would approach each other with velocities inversely proportionat to their quantities of matter; the moon, says he, and the earth mutually attract each other, and are prevented from meeting by their revolution round

greatest body in our system, is, of consequence, possessed of much the greatest share of this attracting power; and all the planets, of which our earth is one, are, of course, entirely subject to its superior influence. Were this power, therefore, left uncontrol-

their common centre of attraction; and he says, that the tides of the ocean are the effects of the moon's attraction, heaping up the waters immediately under her. Then, adopting the opinion of Dr Gilbert, that the earth is a great magnet, he explains how this mutual attraction will produce a deflection into a curvilineal path. Dr Hooke appears to have had very accurate general notions of the nature of the mutual attraction of the celestial bodies; for, at a meeting of the Royal Society in the year 1666, he expressed himself as follows: "I will explain a system of the world very different from any yet received, and it is founded on the three following positions. 1. That all the heavenly bodies have not only a gravitation of their parts towards their own proper centre, but that they mutually attract each other within their spheres of action. 2. That all bodies having a simple motion, will continue to move in a straight line, unless continually deflected from it by some extraneous force, causing them to describe a circle, an ellipse, or some other curve. 3. That this attraction is so much the greater as the bodies are nearer. As to the proportion in which those forces diminish by an increase of distance, I own," said he, "I have not discovered it, although I have made some experiments to this purpose: I leave this to others, who have time and knowledge sufficient for this task." Previous to this period, Dr Hooke had exhibited to the Society an experiment, with a view to show how a motion in a curve might be produced in consequence of a tendency in a body towards a centre. A ball suspended by a thread from the ceiling was made to revolve about another ball laid on a table immediately below the point of suspension. When the push given to the pendulous ball was properly adjusted to its deviation from the perpendicular, it described a perfect circle round the ball on the table, but when the push was very great, or very small, it described an ellipse, having the other ball in its centre. Dr Hooke showed that this was the operation of a deflecting force directly proportional to the distance from the other ball; but he added, that although this illustrated the planetary motions in some degree, yet it was not suitable to their cause; for the planets describe ellipses, having the sun not in the centre, but in one of their foci; therefore they are not retained by a force proportional to their distance from the sun. In these remarks, we have a clear and modest account of a rational theory; and it must be inferred from them, that Dr Hooke had anticipated Newton in describing the general nature of the planetary motions, although it is solely to the latter that we owe the discovery of the precise law of the force by which the very motions we observe are produced.

To this extent the true theory of the motions of the heavenly bodies had been discovered, or rather conjectured, when Sir Isaac Newton turned his attention to the subject. The circumstances under which he discovered the true theory of the planetary motions, are stated by Dr Pemberton, in his preface to this *View of Sir Isaac Newton's Philosophy.* They are in substance as follows: He had retired from Cambridge to his country house in the year 1666, on account of the plague; and one day as he sat alone in his garden, reflecting on the power by which all terrestrial bodies gravitate towards led by any other, the sun must quickly have attracted all the bodies of our celestial system to itself; but it is equally counteracted by another power of equal efficacy; namely, a progressive force, which each planet received when it was

the earth, it occurred to him, that as this power is not sensibly diminished at any distance to which we can recede from the earth's centre, there seemed reason to conclude that it extended much farther than was commonly supposed, and even might extend as far as the moon; and if this were true, he concluded that her motion would be influenced by it, and that probably it was this very force which retained her in her orbit. However, although the force of gravity be not sensibly less at the tops of the highest mountains, than at the ordinary level of the earth's surface, he conceived it to be very possible, that at so great a distance as that of the moon, it might be considerably different. To make an estimate of what might be the degree of the diminution, he considered that if the moon be retained in her orbit by the force of gravity, no doubt the primary planets are carried round the sun by a like power; and by comparing the periods of the several planets with their distances from the sun, he found that if any power like gravity kept them in their orbits, its strength must decrease in proportion, as the squares of the distances increase: but in making this conclusion, he supposed that the orbits of the planets were circles, having the sun in their centre, from which figure the greater part of them do not much differ. Supposing, therefore, the force of gravity to extend as far as the moon, and to decrease according to this ratio, he computed whether that force would be sufficient to keep the moon in her orbit; but having no books at hand, by which he might ascertain the true magnitude of the earth, he was obliged to employ in his calculation the erroneous estimate at that time commonly received among geographers and seamen, namely, that a degree of latitude on the earth's surface was 60 English miles. Now, as the degree contains in reality about 69½ miles, his computation of course did not agree with the phenomena; and on this account, he laid aside at that time all further consideration of the subject. Some years after, in consequence of a letter he received from Dr Hooke, he investigated the nature of the path which a body would describe, if it were let fall from any high place, taking into account the rotation of the earth; and on this occasion, he resumed his former train of reflections concerning the motion of the moon. He had now, however, the advantage of knowing pretty nearly the exact magnitude of the earth, in consequence of the measurement of an arc of the meridian made in France by Picard; and he had the inexpressible satisfaction of finding that his calculation agreed exactly with what it ought to be, if the opinion he had formed was correct. He therefore concluded that his conjecture was correct, and that the moon was really kept in her order by the force of gravity, which decreased according as the square of the distance increased, agreeably to what he had supposed. It is said, that as the calculation drew to a close, the mind of Newton was so much agitated by the importance of the discovery he was on the point of making, that he was obliged to desire a friend to finish them. This is not to be wondered at, when we consider the great revolution which he foresaw he was about to produce in the opinions of mankind, and the immense fabric of science that might be built on his discovery.

impelled forward by the divine Architect, upon its first formation. The heavenly bodies of our system being thus acted upon by two opposing powers; namely, by that of *attraction*, which draws them towards the sun; and that of *impulsion*, which drives them straight forward into the great void of space; they pursue a track between these contrary directions; and each, like a stone whirled about in a sling, obeying two opposite forces, circulates round its great centre of heat and motion.

In this manner, therefore, is the harmony of our planetary system preserved. The sun, in the midst, gives heat, and light, and circular motion, to the planets which surround it: Mercury, Venus, the Earth, Mars, Jupiter, and Saturn,* perform their

* Since Goldsmith's time, five other planetary bodies, (Uranus, Ceres, Pallas, Juno, Vesta,) belonging to our solar system, have been discovered. On the 13th of March, 1781, Dr Herschel discovered a new planet without the orbit of Saturn, which was first named by foreign astronomers, after its observer, *the Herschel*, but called by Herschel himself (in honour of George III.) the *Georgium Sidus*—although both these names are fast sinking, and *Uranus* is the appellation now almost universally adopted. The *Uranus* is the most remote of our planets, so far as discovered, circulating about the sun at the astonishing distance of 1800 million miles, and performing its orbicular revolution in about 80 of our years. Its diameter is 35,112 miles. It has six secondary planets or moons. The other four planets are small. Ceres was discovered situated between the orbits of Mars and Jupiter, on the 1st of January, 1801, by M. Piazzi, a Sicilian astronomer. It performs its revolution round the sun in about four years. Pallas was discovered also situated between the orbits of Mars and Jupiter, on the 28th March, 1802, by Dr Olbers of Bremen. Juno was discovered by Mr Harding, at the observatory of Lilienthal, near Bremen, on the 1st day of September, 1804. It is likewise situated between the orbits of Mars and Jupiter; and performs its revolution round the sun in 5 years and 182 days. Vesta was discovered by Dr Olbers, on the 29th of March, 1807. It is also situated between the orbits of Mars and Jupiter; and performs its revolution round the sun in 3 years and 182 days.—The diameters of these planets (which must, however, be considered as doubtful) have been given as follows:—Ceres, 1024 miles; Pallas, 2099 miles; Juno, 1425 miles; Vesta, 238 miles. It was supposed by some astronomers that a planet existed between the orbits of Jupiter and Mars. The discovery of Ceres confirmed this conjecture; but the opinion which it seemed to establish respecting the harmony of the solar system, appeared to be completely overturned by the discovery of Pallas and Juno. Dr Olbers, however, considers that these small celestial bodies are merely the fragments of a larger planet, which had been burst asunder by some internal convulsion, and that several more might yet be discovered between the orbits of Mars and Jupiter. Some writers suppose the meteoritic stones which fall upon our earth to be small portions of this dissevered planet. In Brewster's Encyclopædia a theory is started respecting the origin of Ceres and Pallas, which is plausible and

constant circuits at different distances, each taking up a time to complete its revolutions proportioned to the greatness of the circle which it is to describe. The lesser planets also, which are atten-

curious. It is thus stated: "A comet appeared in the year 1770, and was carefully observed for nearly four months by M. Messier. When Prosperin and Pingre applied themselves to calculate the elements of its orbit, they found that a parabolic path would not represent the observations of Messier, and hence they suspected that its orbit might be sensibly elliptical. M. Lexell of St Petersburgh computed its elements in an elliptical orbit, and he found that its period was five years and a half, and that its greatest distance from the sun did not much exceed that of Jupiter. This curious subject was investigated rather unsuccessfully by Slop, Sejour, and Lambert; and a few years ago it attracted the particular notice of the National Institute of France. At the request of that learned body, Dr Burckhardt repeated all the calculations with the utmost care, and the result of his investigations was a complete confirmation of Lexell's conclusions. Here then is a most singular anomaly in the motion of this comet. While all the other comets which have been observed, move in orbits stretching far beyond the limits of the solar system, and revolve in periods of long duration, the comet of 1770 never wanders beyond the orbit of Saturn, and completes its revolution in the short period of five years and a half. The return of this body, therefore, was confidently expected by astronomers; but though it must now have completed nearly eight revolutions round the sun, and though more observations have been made in the heavens during the last 40 years than perhaps during the two preceding centuries, yet the comet of 1770 has never re-appeared. We are consequently entitled to conclude, that the comet of 1770 is lost, which could happen only from its uniting with one of the planets, whose orbits it crossed. Now, if such a union took place, two consequences would obviously flow from it. The planet would suffer a sensible derangement in its motions, and its atmosphere would receive a vast accession of that nebulous matter, of which the comets are often wholly composed. Here, then, we have two distinct criteria to enable us to ascertain the individual planet by which the comet was attracted. The path of the comet intersects the orbits only of Venus, the Earth, Mars, the four new planets, and Jupiter, and therefore it must have united with one of these bodies, or with their satellites. Now, since the year 1770, neither Venus, the Earth, Mars, nor Jupiter, have suffered the smallest derangement of this kind, nor have they received any visible addition to their atmospheres. We must, therefore, look to the four new planets for some indication of the presence of a comet, and if they exhibit any phenomena that are unequivocally of this description, we must consider such a coincidence as a strong proof of the theory, or as one of the most wonderful facts in the history of science. Two of the new planets, Ceres and Pallas, exhibit, in the form and position of their orbits, evident marks of some great derangement; but as this may have arisen from that explosive force, by which they seem to have been separated from a larger planet, we are not entitled to regard it as a proof of the present theory. But though we cannot employ our first criterion either for or against the theory, the second applies with irresistible force, and we would entreat the particular attention of our readers to this single point. The two planets Ceres and Pallas, are actually surrounded with atmospheres of an immense size. The dants upon some of the greater, are subject to the same laws; they circulate with the same exactness; and are, in the same manner, influenced by their respective centres of motion.

Besides those bodies which make a part of our peculiar system, and which may be said to reside within its great circumference, there are others that frequently come among us, from the most distant tracts of space, and that seem like dangerous intruders upon the beautiful simplicity of nature. These are Comets, whose appearance was once so terrible to mankind; and the theory of which is so little understood at present: all we know is, that their number is much greater than that of the planets; and that, like these, they roll in orbits, in some measure obedient to solar influence.* Astronomers have endeavoured to

atmosphere of Ceres is 675 English miles high, while that of Pallas rises to the height of 468 miles. Now the height of any of these atmospheres is greater than the united heights of the atmospheres of all the other planets, and is above a thousand times higher than it ought to have been, according to the ratio which exists between the globes and the atmospheres of all the other bodies of the system. Astronomers were so forcibly struck with the magnitude of these atmospheres, that a dispute arose whether Ceres and Pallas should be called planets or comets, and the discussion terminated, by giving them the name of asteroids, a class of bodies which were supposed to partake of the nature both of planets and comets. But to draw this argument still closer upon the subject, let us inquire from what other source these atmospheres could be derived, if they were not imparted by the comet of 1770. If the four new planets are the fragments of a larger body, endowed with an extensive atmosphere, each fragment would obviously carry off a portion of atmosphere proportioned to its magnitude; but two of the fragments, Juno and Vesta, have no atmosphere at all, consequently the atmospheres of Ceres and Pallas could not have been derived from the original planet, but must have been communicated to them at a period posterior to the divergency of the fragments. It would have been a satisfactory addition to the preceding arguments, if we had been able to show, by direct calculation, that Ceres and Pallas were at the same instant with the comet in that part of their orbits which was crossed by its path, and that the position of the planes of the orbits was such, as to permit a near approximation. But as we have no data sufficiently correct for such a calculation, we must leave this part of the subject to some future opportunity. There is one fact, however, which in some measure supplies its place, and which is therefore worthy of particular notice. The nodes of the comet of 1770, lie exactly between the nodes of Ceres and Pallas, an arrangement which is absolutely indispensable to the truth of the preceding theory."

* When examined through a good telescope, a comet resembles a mass of aqueous vapours encircling an opaque nucleus of different degrees of darkness in different comets, though sometimes, as in the case of several discovered by Dr Herschel, no nucleus can be seen. As the comet advances

calculate the returning periods of many of them; but experience has not, as yet, confirmed the veracity of their investigations. Indeed, who can tell, when those wanderers have made their excursions into other worlds and distant systems, what obstacles may be found to oppose their progress, to accelerate their motions, or retard their return?

towards the sun, its faint and nebulous light becomes more brilliant, and its luminous train gradually increases in length. When it reaches its perihelion, the intensity of its light, and the length of its tail, reach their maximum, and sometimes it shines with all the splendour of Venus. During its retreat from the perihelion, it is shorn of its splendour, it gradually resumes its nebulous appearance, and its tail decreases in magnitude till it reaches such a distance from the earth, that the attenuated light of the sun, which it reflects, ceases to make an impression on the organ of sight. Traversing unseen the remote portion of its orbit, the comet wheels its ethereal course far beyond the limits of our system. What region it there visits, or upon what destination it is sent, the limited powers of man are unable to discover. After the lapse of years, we perceive it again returning to our system, and tracing a portion of the same orbit round the sun, which it had formerly described. It would be a waste of time to detail the various wild and extravagant opinions which have been entertained respecting these interesting stars. During the ages of barbarism and superstition, they were regarded as the harbingers of awful convulsions, both in the political and in the physical world. Wars, pestilence, and famine, the dethronement of kings, the fall of nations, and the more alarming convulsions of the globe, were the dreadful evils which they presented to the diseased and terrified imaginations of men. As the light of knowledge dissipated these gloomy apprehensions, the absurdities of licentious speculation supplied their place, and all the ingenuity of conjecture was exhausted in assigning some rational office to these wandering planets. Even at the beginning of the 18th century, the friend and companion of Newton regarded them as the abode of the damned. Anxious to know more than what is revealed, the fancy of speculative theologians strove to discover the frightful regions in which vice was to suffer its merited punishment; and the interior caverns of the earth had, in general, been regarded as the awful prison-house in which the Almighty was to dispense the severities of justice. Mr Whiston, however, outstripped all his predecessors in fertility of invention. He pretended not only to fix the residence of the damned, but also the nature of their punishment. Wheeled from the remotest limits of the system, the chilling regions of darkness and cold, the comet wafted them into the very vicinity of the sun; and thus alternately hurried its wretched tenants to the terrifying extremes of chilling cold and devouring fire. By other astronomers, comets were destined for more scientific purposes. They were supposed to convey back to the planets the electric fluid which is constantly dissipating, or to supply the sun with the fuel which it perpetually consumes. They have been regarded also as the cause of the deluge; and we must confess, that if a natural cause is to be sought for that great event, we can explain it only by the shock of some celestial body. The transient effect of a comet passing near the earth, could

But what we have hitherto attempted to sketch, is but a small part of that great fabric in which the Deity has thought proper to manifest his wisdom and omnipotence. There are multitudes of other bodies, dispersed over the face of the heavens, that lie too remote for examination: these have no motion, such as the planets are found to possess, and are, therefore, called *fixed*

scarcely amount to any great convulsion; but if the earth were actually to receive a direct impulse from one of these bodies, the consequences would be awful. A new direction would be given to its rotatory motion, and the globe would revolve round a new axis. The seas, forsaking their ancient beds, would be hurried by their centrifugal force, to the new equatorial regions; islands and continents, the abodes of men and animals, would be covered by the universal rush of the waters to the new equator, and every vestige of human industry and genius at once destroyed. The chances against such an event, however, are so very numerous, that there is no dread of its occurrence. Various opinions have been entertained by astronomers respecting the tails of comets. They were supposed by Appian, Cardan, and Tycho Brahe, to be the light of the sun transmitted through the nucleus of the comet, which they believed to be transparent like a lens. Kepler thought, that the impulsion of the solar rays drove away the denser parts of the comet's atmosphere, and thus formed the tail. Descartes ascribes the tail to the refraction of light by the nucleus. Newton maintained, that it is a thin vapour raised by the heat of the sun from the comet. Euler asserts, that the tail is occasioned by the impulsion of the solar rays driving off the atmosphere of the comet; and that the curvature observed in the tail is the joint effect of this impulsive force, and the gravitation of the atmospherical particles to the solid nucleus. Mairan imagines that comets' tails are portions of the sun's atmosphere. Dr Hamilton of Dublin supposes them to be streams of electric matter; and Biot supposes with Newton, that the tails are vapours produced by the excessive heat of the sun; and also, that the comets are solid bodies before they reach their perihelion; but that they are afterwards either partly or totally converted into vapour by the intensity of the solar heat. Of all these theories, that of Euler seems to be most philosophical. Since the comets are composed chiefly of nebulous matter, and have very large atmospheres, the external atmospheric strata must be drawn towards the comet by very slight powers of attraction, and will therefore yield to the smallest impulse. From the great density of the planets, on the contrary, and the small size of their atmospheres, the external strata are attracted towards them with a very great force, and therefore cannot yield, like those of the comets, to a slight impulse. Hence we see the reason why the comets have tails, while none of the planetary bodies exhibit such a phenomenon. Whatever opinion may be entertained of this explanation, it must, at least, be admitted, that if light is a material substance, the atmospherical particles of a comet may have their gravity diminished to such a degree, either by their distance from its centre, or by the rarity of the nucleus, as to yield to the impulse of the solar rays, and be forced behind the nucleus, in the same manner as smoke yields to the impulse of the gentlest breeze.

stars; and from their extreme brilliancy, and their immense distance, philosophers have been induced to suppose them to be suns, resembling that which enlivens our system. As the imagination also, once excited, is seldom content to stop, it has furnished each with an attendant system of planets belonging to itself; and has even induced some to deplore the fate of those systems, whose imagined suns, which sometimes happens, have become no longer visible.

But conjectures of this kind, which no reasoning can ascertain, nor experiment reach, are rather amusing than useful. Though we see the greatness and wisdom of the Deity in all the seeming worlds that surround us, it is our chief concern to trace him in that which we inhabit. The examination of the earth, the wonders of its contrivance, the history of its advantages, or of the seeming defects in its formation, are the proper business of the *natural historian*. A description of this *earth*, its *animals*, *vegetables*, and *minerals*, is the most delightful entertainment the mind can be furnished with, as it is the most interesting and useful. I would beg leave, therefore, to conclude these common-place speculations, with an observation which, I hope, is not entirely so.

A use, hitherto not much insisted upon, that may result from the contemplation of celestial magnificence, is, that it will teach us to make an allowance for the apparent irregularities we find below. Whenever we can examine the works of the Deity at a proper point of distance, so as to take in the whole of his design, we see nothing but uniformity, beauty, and precision. The heavens present us with a plan, which, though inexpressibly magnificent, is yet regular beyond the power of invention. Whenever, therefore, we find any apparent defects in the Earth, which we are about to consider, instead of attempting to reason ourselves into an opinion that they are beautiful, it will be wiser to say, that we do not behold them at the proper point of distance, and that our eye is laid too close to the objects, to take in the regularity of their connection. In short, we may conclude, that God, who is regular in his GREAT productions, acts with equal uniformity in the LITTLE.

CHAP. II.

A SHORT SURVEY OF THE GLOBE, FROM THE LIGHT OF ASTRONOMY AND GEOGRAPHY.

All the sciences are, in some measure, linked with each other, and before the one is ended, the other begins. In a natural history, therefore, of the earth, we must begin with a short account of its situation and form, as given us by astronomers and geographers: it will be sufficient, however, upon this occasion, just to hint to the imagination, what they, by the most abstract reasonings, have forced upon the understanding. The earth which we inhabit is, as has been said before, one of those bodies which circulate in our solar system; it is placed at a happy middle distance from the centre; and even seems, in this respect, privileged beyond all other planets that depend upon our great luminary for their support. Less distant from the sun than [Uranus,] Saturn, Jupiter, and Mars, and yet less parched up than Venus and Mercury, that are situate too near the violence of its power, the Earth seems in a peculiar manner to share the bounty of the Creator: it is not, therefore, without reason, that mankind consider themselves as the peculiar objects of his providence and regard.

Besides that motion which the earth has round the sun, the circuit of which is performed in a year, it has another upon its own axis, which it performs in twenty-four hours. Thus, like a chariot-wheel, in has a compound motion; for while it goes forward on its journey, it is all the while turning upon itself. From the first of these two arises the grateful vicissitude of the seasons; from the second, that of day and night.

It may be also readily conceived, that a body thus wheeling in ir cles will most probably be itself a sphere. The earth, beyond all possibility of doubt, is found to be so. Whenever its shadow happens to fall upon the moon, in an eclipse, it appears to be always circular, in whatever position it is projected; and it is easy to prove, that a body which in every position makes a circular shadow, must itself be round. The rotundity of the earth may be also proved from the meeting of two ships at sea: the topmasts of each are the first parts that are discovered by both, the under parts being hidden by the convexity of the globe which rises between them. The ships, in this instance, may be resembled to two men who approach each other on the opposite sides of a hill; their heads will first be seen, and gradually as they come nearer they will come entirely into view.*

However, though the earth's figure is said to be spherical, we ought only to conceive it as being nearly so. It has been found in the last age to be rather flatted at both poles, so that its form is commonly resembled to that of a turnip. The cause of this swelling of the equator is ascribed to the greater rapidity of the motion with which the parts of the earth are there carried round; and which, consequently, endeavouring to fly off, act in opposition to central attraction. The twirling of a mop may serve as a homely illustration; which, as every one has seen, spreads and grows broader in the middle as it continues to be turned round.

As the earth receives light and motion from the sun, so it derives much of its warmth and power of vegetation from the same beneficent source. However, the different parts of the globe participate of these advantages in very different proportions, and accordingly put on very different appearances; a polar prospect, and a landscape at the equator, are as opposite in their appearances as in their situation.

The polar regions, that receive the solar beams in a very oblique direction, and continue for one half of the year in night, receive but few of the genial comforts which other parts of the world enjoy. Nothing can be more mournful or hideous than the picture which travellers present of those wretched regions. The ground,[1] which is rocky and barren, rears itself in every place in lofty mountains and inaccessible cliffs, and meets the mariner's eye at even forty leagues from shore. These precipices, frightful in themselves, receive an additional horror from being constantly covered with ice and snow, which daily seem to accumulate, and fill all the valleys with increasing desolation. The few rocks and cliffs that are bare of snow, look at a distance of

* Other proofs of the earth's rotundity might be adduced, the most practical of which is that derived from the many voyages performed around it—navigators pursuing a due course east or west having returned to the same place whence they set out, which could not have happened were the earth a plane.

1 Crantz's History of Greenland. p. 3.

a dark brown colour, and quite naked. Upon a nearer approach, however, they are found replete with many different veins of coloured stone, here and there spread over a little earth, and a scanty portion of grass and heath. The internal parts of the country are still more desolate and deterring. In wandering through these solitudes, some plains appear covered with ice, that at first glance, seem to promise the traveller an easy journey.[1] But these are even more formidable and more unpassable than the mountains themselves, being cleft with dreadful chasms, and every where abounding with pits that threaten certain destruction. The seas that surround these inhospitable coasts are still more astonishing, being covered with flakes of floating ice, that spread like extensive fields, or that rise out of the water like enormous mountains. These, which are composed of materials as clear and transparent as glass,[2] assume many strange and fantastic appearances. Some of them look like churches or castles, with pointed turrets; some like ships in full sail; and people have often given themselves the fruitless toil to attempt piloting the imaginary vessels into harbour. There are still others that appear like large islands, with plains, valleys, and hills, which often rear their heads two hundred yards above the level of the sea; and although the height of these be amazing, yet their depth beneath is still more so; some of them being found to sink three hundred fathom under water.

The earth presents a very different appearance at the equator, where the sunbeams, darting directly downwards, burn up the lighter soils into extensive sandy deserts, or quicken all the moister tracts with incredible vegetation. In these regions, almost all the same inconveniences are felt from the proximity of the sun, that in the former were endured from its absence. The deserts are entirely barren, except where they are found to produce serpents, and that in such quantities, that some extensive plains seem almost entirely covered with them.[3]

It not unfrequently happens also, that this dry soil, which is so parched and comminuted by the force of the sun, rises with the smallest breeze of wind; and the sands, being composed of parts almost as small as those of water, they assume a similar

1 Crantz's History of Greenland, p. 22.
2 Ibid. p. 27. 3 Adanson's Description of Senegal.

appearance, rolling onward in waves like those of a troubled sea, and overwhelming all they meet with inevitable destruction. On the other hand those tracts which are fertile, teem with vegetation even to a noxious degree. The grass rises to such a height as often to require burning; the forests are impassable from underwoods, and so matted above, that even the sun, fierce as it is, can seldom penetrate.[1] These are so thick as scarcely to be extirpated; for the tops being so bound together by the climbing plants that grow round them, though a hundred should be cut at the bottom, yet not one would fall, as they mutually support each other. In these dark and tangled forests, beasts of various kinds, insects in astonishing abundance, and serpents of surprising magnitude, find a quiet retreat from man, and are seldom disturbed except by each other.

In this manner the extremes of our globe seem equally unfitted for the comforts and conveniences of life; and although the imagination may find an awful pleasure in contemplating the frightful precipices of Greenland, or the luxurious verdure of Africa, yet true happiness can only be found in the more moderate climates, where the gifts of nature may be enjoyed, without incurring danger in obtaining them.

It is in the temperate zone, therefore, that all the arts of improving nature, and refining upon happiness, have been invented: and this part of the earth is, more properly speaking, the theatre of natural history. Although there be millions of animals and vegetables in the unexeplored forests under the line, yet most of these may for ever continue unknown, as curiosity is there repressed by surrounding danger. But it is otherwise in these delightful regions which we inhabit, and where this art has had its beginning. Among us there is scarce a shrub, a flower, or an insect, without its particular history; scarce a plant that could be useful, which has not been propagated; nor a weed that could be noxious, which has not been pointed out.

CHAP. III.

A VIEW OF THE SURFACE OF THE EARTH.

When we take a slight survey of the surface of our globe, a thousand objects offer themselves, which, though long known,

1 Linnæi Amænit. vol. vi. p. 67.

yet still demand our curiosity. The most obvious beauty that every where strikes the eye is the verdant covering of the earth, which is formed by a happy mixture of herbs and trees of various magnitudes and uses. It has been often remarked, that no colour refreshes the sight so much as green: and it may be added, as a further proof of the assertion, that the inhabitants of those places where the fields are continually white with snow, generally become blind long before the usual course of nature.

This advantage, which arises from the verdure of the fields, is not a little improved by their agreeable inequalities. There are scarcely two natural landscapes that offer prospects entirely resembling each other; their risings and depressions, their hills and valleys, are never entirely the same, but always offer something new to entertain and refresh the imagination.

But to increase the beauties of the face of nature, the landscape is enlivened by springs and lakes, and intersected by rivulets. These lend a brightness to the prospect; give motion and coolness to the air; and, what is much more important, furnish health and subsistence to animated nature.

Such are the most obvious and tranquil objects that every where offer: but there are objects of a more awful and magnificent kind; the *Mountain* rising above the clouds, and topped with snow; the *River* pouring down its sides, increasing as it runs, and losing itself, at last, in the ocean; the *Ocean* spreading its immense sheet of waters over one half of the globe, swelling and subsiding at well-known intervals, and forming a communication between the most distant parts of the earth.

If we leave those objects that seem to be natural to our earth, and keep the same constant tenor, we are presented with the great irregularities of nature: the burning mountain; the abrupt precipice; the unfathomable cavern; the headlong cataract; and the rapid whirlpool.

If we carry our curiosity a little further, and descend to the objects immediately below the surface of the globe, we shall there find wonders still as amazing. We first perceive the earth, for the most part, lying in regular beds or layers, every bed growing thicker in proportion as it lies deeper, and its contents more compact and heavy. We shall find, almost wherever we make our subterranean inquiry, an amazing number of shells that once belonged to aquatic animals. Here and there, at a distance from the sea, beds of oyster-shells, several yards thick, and many miles over; sometimes testaceous substances of various kinds on the tops of mountains, and often in the heart of the hardest marble. These, which are dug up by the peasants in every country, are regarded with little curiosity; for being so very common, they are considered as substances entirely terrene. But it is otherwise with the inquirer after nature, who finds them, not only in shape, but in substance, every way resembling those that are found in the sea; and he, therefore, is at a loss to account for their removal.

Yet not one part of nature alone, but all her productions and varieties, become the object of the speculative man's inquiry; he takes different views of nature from the inattentive spectator; and scarcely an appearance, how common soever, but affords matter of his contemplation; he inquires how and why the surface of the earth has those risings and depressions which most men call natural; he demands in what manner the mountains were formed, and in what consists their uses; he asks from whence springs arise, and how rivers flow round the convexity of the globe; he enters into an examination of the ebbings and flowings, and the other wonders of the deep; he acquaints himself with the irregularities of nature, and endeavours to investigate their causes; by which, at least, he will become better versed in their history. The internal structure of the globe becomes an object of his curiosity; and although his inquiries can fathom but a very little way, yet, if possessed with a spirit of theory, his imagination will supply the rest. He will endeavour to account for the situation of the marine fossils that are found in the earth, and for the appearance of the different beds of which it is composed. These have been the inquiries that have splendidly employed many of the philosophers of the last and present age,[1] and, to a certain degree, they must be serviceable But the worst of it is, that, as speculations amuse the writer more than facts, they may be often carried to an extravagant length; and that time may be spent in reasoning upon nature, which might be more usefully employed in writing her history.

Too much speculation in natural history is certainly wrong; but there is a defect of an opposite nature that does much more

1 Buffon, Woodward, Burnet, Whiston, Kircher, Bourquat, Leibnitz, Steno, Ray, &c.

prejudice; namely, that of silencing all inquiry, by alleging the benefits we receive from a thing, instead of investigating the cause of its production. If I inquire how a mountain came to be formed; such a reasoner, enumerating its benefits, answers, because God knew it would be useful. If I demand the cause of an earthquake, he finds some good produced by it, and alleges that as the cause of its explosion. Thus such an inquirer has constantly some ready reason for every appearance in nature, which serves to swell his periods, and give splendour to his declamation; every thing about him is, on some account or other, declared to be good; and he thinks it presumption to scrutinize into its defects, or to endeavour to imagine how it might be better. Such writers, and there are many such, add very little to the advancement of knowledge. It is finely remarked by Bacon, that the investigation of final causes[2] is a barren study; and like a virgin dedicated to the Deity, brings forth nothing. In fact, those men who want to compel every appearance and every irregularity in nature into our service, and expatiate on their benefits, combat that very morality which they would seem to promote. God has permitted thousands of natural evils to exist in the world, because it is by their intervention that man is capable of moral evil; and he has permitted that we should be subject to moral evil, that we might do something to deserve eternal happiness, by showing that we had rectitude to avoid it

CHAP. IV.

A REVIEW OF THE DIFFERENT THEORIES OF THE EARTH.

Human invention has been exercised for several ages to account for the various irregularities of the earth. While those philosophers, mentioned in the last chapter, see nothing but beauty, symmetry, and order; there are others, who look upon the gloomy side of nature, enlarge on its defects, and seem to consider the earth, on which they tread, as one scene of extensive desolation.[3] Beneath its surface they observe minerals and waters confusedly jumbled together; its different beds of earth

2 Investigatio causarum finalium sterilis est, et veluti virgo Deo dedicata nil parit.

3 Buffon's second discourse.

irregularly lying upon each other; mountains rising from places that once were level;[1] and hills sinking into valleys; whole regions swallowed by the sea, and others again rising out of its bosom. All these they suppose to be but a few of the changes that have been wrought in our globe; and they send out the imagination to describe its primeval state of beauty.

Of those who have written theories describing the manner of the original formation of the earth, or accounting for its present appearances, the most celebrated are Burnet, Whiston, Woodward, and Buffon. As speculation is endless, so it is not to be wondered that all these differ from each other, and give opposite accounts of the several changes, which they suppose our earth to have undergone. As the systems of each have had their admirers, it is, in some measure, incumbent upon the natural historian to be acquainted, at least, with their outlines; and, indeed, to know what others have even dreamed in matters of science, is very useful, as it may often prevent us from indulging similar delusions ourselves, which we should never have adopted, but because we take them to be wholly our own. However, as entering into a detail of these theories is rather furnishing a history of opinions than things, I will endeavour to be as concise as I can.

The first who formed this amusement of earth-making into system, was the celebrated Thomas Burnet, a man of polite learning and rapid imagination. His *Sacred Theory*, as he calls it, describing the changes which the earth has undergone, or shall hereafter undergo, is well known for the warmth with which it is imagined, and the weakness with which it is reasoned; for the elegance of its style, and the meanness of its philosophy. "The earth," says he, "before the deluge, was very differently formed from what it is at present: it was at first a fluid mass; a chaos composed of various substances, differing both in density and figure: those which were most heavy, sunk to the centre, and formed in the middle of our globe a hard solid body; those of a lighter nature remained next; and the waters, which were lighter still, swam upon its surface, and covered the earth on every side. The air, and all those fluids which were lighter than water, floated upon this also; and in the same manner encompassed the globe; so that between the surrounding

1 Senec. Quæst. lib. vi. cap. 21.

body of waters, and the circumambient air, there was formed a coat of oil, and other unctuous substances, lighter than water. However, as the air was still extremely impure, and must have carried up with it many of those earthy particles with which it once was intimately blended, it soon began to defecate, and to depose these particles upon the oily surface already mentioned, which soon uniting, the earth and oil formed that crust, which soon became a habitable surface, giving life to vegetation, and dwelling to animals.

" This imaginary antediluvian abode was very different from what we see it at present. The earth was light and rich ; and formed of a substance entirely adapted to the feeble state of incipient vegetation ; it was a uniform plain, every where covered with verdure; without mountains, without seas, or the smallest inequalities. It had no difference of seasons, for its equator was in the plane of the ecliptic, or, in other words, it turned directly opposite to the sun, so that it enjoyed one perpetual and luxuriant spring. However, this delightful face of nature did not long continue in the same state; for, after a time, it began to crack and open in fissures; a circumstance which always succeeds when the sun exhales the moisture from rich or marshy situations. The crimes of mankind had been for some time preparing to draw down the wrath of Heaven; and they, at length, induced the Deity to defer repairing these breaches in nature. Thus the chasms of the earth every day became wider, and, at length, they penetrated to the great abyss of waters; and the whole earth, in a manner, fell in. Then ensued a total disorder in the uniform beauty of the first creation, the terrene surface of the globe being broken down : as it sunk the waters gushed out in its place; the deluge became universal ; all mankind, except eight persons, were destroyed, and their posterity condemned to toil upon the ruins of desolated nature."

It only remains to mention the manner in which he relieves the earth from this universal wreck, which would seem to be as difficult as even its first formation : " These great masses of earth falling into the abyss, drew down with them vast quantities also of air; and, by dashing against each other, and breaking into small parts by the repeated violence of the shock, they, at length, left between them large cavities, filled with nothing but air. These cavities naturally offered a bed to receive the influent waters; and in proportion as they filled, the face of the earth became once more visible. The higher parts of its broken surface, now become the tops of mountains, were the first that appeared; the plains soon after came forward, and, at length, the whole globe was delivered from the waters, except the places in the lowest situations; so that the ocean and the seas are still a part of the ancient abyss, that have not had a place to return Islands and rocks are fragments of the earth's former crust; kingdoms and continents are larger masses of its broken substance; and all the inequalities that are to be found on the surface of the present earth, are owing to the accidental confusion into which both earth and waters were then thrown."

The next theorist was Woodward, who, in his Essay towards a Natural History of the Earth, which was only designed to precede a greater work, has endeavoured to give a more rational account of its appearances; and was, in fact, much better furnished for such an undertaking than any of his predecessors, being one of the most assiduous naturalists of his time. His little book, therefore, contains many important facts, relative to natural history, although his system may be weak and groundless.

He begins by asserting that all terrene substances are disposed in beds of various natures, lying horizontally one over the other, somewhat like the coats of an onion; that they are replete with shells, and other productions of the sea; these shells being found in the deepest cavities, and on the tops of the highest mountains. From these observations, which are warranted by experience, he proceeds to observe, that these shells and extraneous fossils are not productions of the earth, but are all actual remains of those animals which they are known to resemble; that all the beds of the earth lie under each other, in the order of their specific gravity; and that they are disposed as if they had been left there by subsiding waters. All these assertions he affirms with much earnestness, although daily experience contradicts him in some of them; particularly we find layers of stone often over the lightest soils, and the softest earth under the hardest bodies. However, having taken it for granted, that all the layers of the earth are found in the order of their specific gravity, the lightest at the top, and the heaviest next the centre, he consequently asserts, and it will not improbably follow, that all the substances of which the earth is composed, were once in an actual state of dissolution. This universal dissolution he takes to have happened at the time of the flood. He supposes, that at that time a body of water which was then in the centre of the earth, uniting with that which was found on the surface, so far separated the terrene parts as to mix all together in one fluid mass; the contents of which afterwards sinking according to their respective gravities, produced the present appearances of the earth. Being aware, however, of an objection, that fossil substances are not found dissolved, he exempts them from this universal dissolution, and, for that purpose, endeavours to show that the parts of animals have a stronger cohesion than those of minerals; and that, while even the hardest rocks may be dissolved, bones and shells may still continue entire.

So much for Woodward; but of all the systems which were published respecting the earth's formation, that of Whiston was most applauded, and most opposed. Nor need we wonder: for being supported with all the parade of deep calculation, it awed the ignorant, and produced the approbation of such as would be thought otherwise; as it implied a knowledge of abstruse learning, to be even thought capable of comprehending what the writer aimed at. In fact, it is not easy to divest this theory of its mathematical garb: but those who have had leisure, have found the result of our philosopher's reasoning to be thus: He supposes the earth to have been originally a comet; and he considers the history of the creation, as given us in scripture, to have its commencement just when it was, by the hand of the Creator, more regularly placed as a planet in our solar system. Before that time he supposes it to have been a globe without beauty or proportion; a world in disorder; subject to all the vicissitudes which comets endure; some of which have been found, at different times, a thousand times hotter than melted iron; at others, a thousand times colder than ice. These alterations of heat and cold, continually melting and freezing the surface of the earth, he supposes to have produced, to a certain depth, a chaos entirely resembling that described by the poets, surrounding the solid contents of the earth, which still continued unchanged in the midst, making a great burning globe of more than two thousand leagues in diameter. This surrounding chaos, however was far from being solid: he resembles it to a dense, though fluid atmosphere, composed of substances mingled, agitated, and shocked against each other ; and in this disorder he describes the earth to have been just at the eve of creation.

But upon its orbit being then changed, when it was more regularly wheeled round the sun, every thing took its proper place ; every part of the surrounding fluid then fell into a situation, in proportion as it was light or heavy. The middle, or central part, which always remained unchanged, still continued so, retaining a part of that heat which it received in its primeval approaches towards the sun ; which heat, he calculates, may continue for about six thousand years. Next to this fell the heavier parts of the chaotic atmosphere, which serve to sustain the lighter : but as in descending they could not entirely be separated from many watery parts, with which they were intimately mixed, they drew down a part of these also with them ; and these could not mount again after the surface of the earth was consolidated : they, therefore, surrounded the heavy first-descending parts in the same manner as these surround the central globe. Thus the entire body of the earth is composed internally of a great burning globe : next which is placed a heavy terrene substance, that encompasses it ; round which is also circumfused a body of water. Upon this body of water, the crust of earth, which we inhabit, is placed : so that, according to him, the globe is composed of a number of coats, or shells, one within the other, all of different densities. The body of the earth being thus formed, the air, which is the lightest substance of all, surrounded its surface ; and the beams of the sun, darting through, produced that light which, we are told, first obeyed the Creator's command.

The whole economy of the creation being thus adjusted, it only remained to account for the risings and depressions on the surface of the earth, with the other seeming irregularities of its present appearance. The hills and valleys are considered by him as formed by their pressing upon the internal fluid, which sustains the outward shell of earth, with greater or less weight : those parts of the earth which are heaviest sink into the subjacent fluid more deeply, and become valleys : those that are lighter rise higher upon the earth's surface, and are called mountains.

Such was the face of nature before the deluge : the earth was then more fertile and populous than it is at present ; the life of man and animals was extended to ten times its present duration ;

ana all these advantages arose from the superior heat of the central globe, which ever since has been cooling. As its heat was then in full power, the genial principle was also much greater than at present; vegetation and animal increase were carried on with more vigour; and all nature seemed teeming with the seeds of life. But these physical advantages were only productive of moral evil; the warmth which invigorated the body increased the passions and appetites of the mind; and, as man became more powerful, he grew less innocent. It was found necessary to punish this depravity; and all living creatures were overwhelmed by the deluge in universal destruction.

This deluge, which simple believers are willing to ascribe to a miracle, philosophers have long been desirous to account for by natural causes; they have proved that the earth could never supply from any reservoir towards its centre, nor the atmosphere by any discharge from above, such a quantity of water as would cover the surface of the globe to a certain depth over the tops of our highest mountains. Where, therefore, was all this water to be found? Whiston has found enough, and more than a sufficiency, in the tail of a comet; for he seems to allot comets a very active part in the great operations of nature.

He calculates, with great seeming precision, the year, the month, and the day of the week, on which this comet (which has paid the earth some visits since, though at a kinder distance,) involved our globe in its tail. The tail he supposed to be a vaporous fluid substance, exhaled from the body of the comet by the extreme heat of the sun, and increasing in proportion as it approached that great luminary. It was in this that our globe was involved at the time of the deluge; and, as the earth still acted by its natural attraction, it drew to itself all the watery vapours which were in the comet's tail; and the internal waters being also at the same time let loose, in a very short space the tops of the highest mountains were laid under the deep.

The punishment of the deluge being thus completed, and all the guilty destroyed, the earth, which had been broken by the eruption of the internal waters, was also enlarged by it; so that, upon the comet's recess, there was found room sufficient in the internal abyss for the recess of the superfluous waters; whither they all retired, and left the earth uncovered, but in some respects changed, particularly in its figure, which, from being round, was now become oblate. In this universal wreck of nature, Noah survived, by a variety of happy causes, to re-people the earth, and to give birth to a race of men slow in believing ill-imagined theories of the earth.

After so many theories of the earth which have been published, applauded, answered, and forgotten, Mr Buffon ventured to add one more to the number. This philosopher was, in every respect, better qualified than any of his predecessors for such an attempt, being furnished with more materials, having a brighter imagination to find new proofs, and a better style to clothe them in. However, if one so ill qualified as I am may judge, this seems the weakest part of his admirable work; and I could wish that he had been content with giving us facts instead of systems; that, instead of being a reasoner, he had contented himself with being merely an historian.

He begins his system by making a distinction between the first part of it and the last; the one being founded only on conjecture, the other depending entirely upon actual observation. The latter part of his theory may, therefore, be true, though the former should be found erroneous.

"The planets," says he, "and the earth among the number, might have been formerly (he only offers this as conjecture) a part of the body of the sun, and adherent to its substance. In this situation, a comet falling in upon that great body, might have given it such a shock, and so shaken its whole frame, that some of its particles might have been driven off like streaming sparkles from red-hot iron; and each of these streams of fire, small as they were in comparison of the sun, might have been large enough to have made an earth as great, nay, many times greater, than ours. So that in this manner the planets, together with the globe which we inhabit, might have been driven off from the body of the sun by an impulsive force: in this manner also they would continue to recede from it for ever, were they not drawn back by its superior power of attraction; and thus, by the combination of the two motions, they are wheeled round in circles.

"Being in this manner detached at a distance from the body of the sun, the planets, from having been at first globes of liquid fire, gradually became cool. The earth also, having been impelled obliquely forward, received a rotatory motion upon its axis at the very instant of its formation; and this motion being greatest at the equator, the parts there acting against the force of gravity, they must have swollen out, and given the earth an oblate or flatted figure.

"As to its internal substance, our globe, having once belonged to the sun, it continues to be an uniform mass of melted matter, very probably vitrified in its primeval fusion. But its surface is very differently composed. Having been in the beginning heated to a degree equal to, if not greater, than what comets are found to sustain; like them it had an atmosphere of vapours floating round it, and which, cooling by degrees, condensed and subsided upon its surface. Those vapours formed, according to their different densities, the earth, the water, and the air; the heavier parts falling first, and the lighter remaining still suspended."

Thus far our philosopher is, at least, as much a system maker as Whiston or Burnet; and, indeed, he fights his way with great perseverance and ingenuity, through a thousand objections that naturally arise. Having, at last, got upon the earth, he supposes himself on firmer ground, and goes forward with greater security. Turning his attention to the present appearance of things upon this globe, he pronounces from the view, that the whole earth was at first under water. This water he supposes to have been the lighter parts of its former evaporation, which, while the earthy particles sunk downwards by their natural gravity, floated on the surface, and covered it for a considerable space of time.

"The surface of the earth," says he,[1] "must have been in the beginning much less solid than it is at present; and, consequently, the same causes which at this day produce but very slight changes, must then, upon so complying a substance, have had very considerable effects. We have no reason to doubt but that it was then covered with the waters of the sea; and that those waters were above the tops of our highest mountains; since, even in such elevated situations, we find shells and other marine productions in very great abundance. It appears also that the sea continued for a considerable time upon the face of the earth: for as these layers of shells are found so very frequent at such

1 Theorie de la Terre, vol. i. p. 111.

great depths, and in such prodigious quantities, it seems impossible for such numbers to have been supported all alive at one time; so that they must have been brought there by successive depositions. These shells also are found in the bodies of the hardest rocks, where they could not have been deposited, all at once, at the time of the deluge, or at any such instant revolution; since that would be to suppose, that all the rocks in which they are found, were, at that instant, in a state of dissolution, which would be absurd to assert. The sea, therefore, deposited them wheresoever they are now to be found, and that by slow and successive degrees.

"It will appear also, that the sea covered the whole earth, from the appearance of its layers, which lying regularly one above the other, seem all to resemble the sediment formed at different times by the ocean. Hence, by the irregular force of its waves, and its currents driving the bottom into sand banks, mountains must have been gradually formed within this universal covering of waters; and these successively raising their heads above its surface, must, in time, have formed the highest ridges of mountains upon land, together with continents, islands, and low grounds, all in their turns. This opinion will receive additional weight by considering, that in those parts of the earth where the power of the ocean is greatest, the inequalities on the surface of the earth are highest. The ocean's power is greatest at the equator, where its winds and tides are most constant; and, in fact, the mountains at the equator are found to be higher than in any other part of the world. The sea, therefore, has produced the principal changes in our earth; rivers, volcanoes, earthquakes, storms, and rain, having made but slight alterations, and only such as have affected the globe to very inconsiderable depths."

This is but a very slight sketch of Mr Buffon's theory of the earth; a theory which he has much more powerfully supported, than happily invented; and it would be needless to take up the reader's time from the pursuit of truth in the discussion of plausibilities. In fact, a thousand questions might be asked this most ingenious philosopher, which he would not find it easy to answer; but such is the lot of humanity, that a single Goth can in one day destroy the fabric which Cæsars were employed an age in erecting. We might ask, How mountains, which are composed of the most compact and ponderous substances, should be the first whose parts the sea began to remove. We might ask, How fossil-wood is found deeper even than shells? which argues, that trees grew upon the places he supposes once to have been covered with the ocean. But we hope this excellent man is better employed than to think of gratifying the petulance of incredulity, by answering endless objections. *

* Since Goldsmith wrote, various other theories of the earth have been advanced, the most important of which are the Huttonian and Wernerian. Dr Hutton supposes this globe to be regulated by a system of decay and renovation, and that these are effected by certain processes which bear a uniform relation to each other. The solid matter of the earth, especially the rocks and high lands, he supposes to be perpetually separating, by the reiterated action of air and water, and when thus detached, carried down by the streams and rivers and deposited in the beds of the ocean. From these deposites, the various strata of our earth are supposed to be formed, obtaining their consolidation from the action of submarine fires; which being placed at immense depths, must operate on these stratified depositions under the circumstance of vast pressure, by which volatilization must be prevented, and such changes produced as would not otherwise be effected by the power of heat. The expansive power of subterraneous fire is also called in to explain, by the elevation of strata, their various positions. Thus, whilst the ocean is in one part removed by the accumulation and the elevation of strata, fresh receptacles are forming for it in other spots, where new strata will be deposited, consolidated, and elevated. According to this system, therefore, in the present world—which is made up of the fragments of those which preceded it—the materials are arranging for the formation of a new surface; new worlds are rising at the bottom of the present oceans; and imagination pictures successive lands overwhelmed by successive oceans, and these in turn producing new kingdoms, to be peopled by new nations; the system manifesting, as its author avowed, neither vestige of a beginning, nor prospect of an end.

According to Werner the earth is supposed to have existed originally in a state of aqueous fluidity, which is inferred from its spheroidical form, and from the highest mountains being composed of rocks, possessing a structure exactly resembling that of those fossils, which have, as it were, been formed under the eye by water. From this circumstance it also follows, that the ocean must have formerly stood very high over these mountains; and as these appear to have been formed during the same period of time, it follows, that the ocean must have formerly covered the whole earth at the same time. Contemplating the formation of the mountains themselves, Werner discovered the strongest proofs of the diminution of the original waters of the globe. He ascertained, 1*st*, That the *outgoings*—that is, the upper extremities as they appear at the surface of the earth—of the newer strata are generally lower than the outgoings of the older, from granite downwards to the alluvial deposite—and that not in particular spots, but around the whole globe. 2*d*. That the primitive part of the earth is entirely composed of chemical precipitations, and that the mechanical depositions only appear in those of a later period, that is, in the transition class; and continue increasing

CHAP. V.

OF FOSSIL-SHELLS, AND OTHER EXTRANEOUS FOSSILS.

We may affirm of Mr Buffon, that which has been said of the chemists of old; though he may have failed in attaining his

through all the succeeding classes of rocks. This evidence of the vast dimi nution of the volume of water which stood so high over the whole earth, is assumed to be perfectly satisfactory, although we can form no correct idea of what has become of it. By the earliest separations from the chaotic mass, which are discoverable in the crust of the globe, was formed a class of rocks, which are therefore termed *primitive rocks.* The circumstances which mark the high antiquity of these rocks are, that they form the fundamental rock of the other classes. Having been formed in the uninhabitable state of the globe, they contain no petrifactions, and, excepting the small portion which sometimes accompany those which will be next mentioned, they contain no mechanical deposites, but are, throughout, pure chemical productions. Small portions of carbonaceous matter, occur only in the newer members of the class. Before the summits of the mountains appeared above the level of the ocean, and before the creation of vegetables and animals, a rising of the waters is supposed to have taken place, during which, that class of rocks which are said to be of the *second formation* was deposited. The rocks of this formation are clay, porphyry, pearl stone porphyry, obsidian porphyry, seinite, and pitchstone; they exhibit very few mechanical depositions, are of complete chemical formation, and contain little or no carbonaceous matter, and never any petrifactions. On the appearance of land, or during the transition of the earth from its chaotic to its habitable state, rocks which from this circumstance are denominated *transition rocks* were formed. In these rocks, the first slight traces of petrifaction, and of mechanical depositions, are to be found. As the former class of rocks were purely of chemical formation, so the contents of these are chiefly chemical productions, mingled with a small proportion of mechanical depositions; to explain the cause of the mixture, we are referred to the period of their formation, tha at which the summits of the primitive mountains just appeared above the waters, when, by the attraction excited by the motion of the waves, and which we are reminded extended to no great depth, particles of the original mountains were worn off and deposited. As the height of the level of the ocean diminished, so would the surface on which its waves acted increase, and of course the number of mechanical depositions. Hence, these are much more abundant in the rocks of the next formation, which are denominated *floetz rocks*, on account of their being generally disposed in horizontal or flat strata. In these, petrifactions are very abundantly found, having been formed whilst vegetables and animals existed in great numbers. These rocks are generally of very wide extent, and commonly placed at the foot of primitive mountains; they are seldom of a very great height, from whence it may be inferred, that the water had considerably subsided at the time of their formation, and did not then cover the whole face of the earth. Countries composed of these rocks are not so rugged in their appearance, nor so marked principal aim, of establishing a theory, yet he has brought together such a multitude of facts relative to the history of the earth, and the nature of its fossil productions, that curiosity finds ample compensation, even while it feels the want of conviction.

Before, therefore, I enter upon the description of those parts

by sudden inequalities, as those in which the primitive and transition rocks prevail. Most of the rocks which have been just enumerated, are covered by a great formation, which is named the *newest floetz trap*. This formation also covers many of the highest primitive mountains; it has but little continuity, but is very widely distributed. It contains considerable quantities of mechanical deposites, such as clay, sand, and gravel. The remains both of vegetables and animals also occur very abundantly in these deposites. Heaps of trees, and parts of plants, and an abundance of shells and other marine productions, with the horns of stags, and great beds of bituminous fossils, point out the lateness of the period when this formation was deposited. In this formation several rocks occur which are also met with in other floetz formations; but the following are supposed to be peculiar to this class: basalt, wacke, greystone, porphyry, slate, and trap tuff. These rocks are said to have been formed during the settling of the water consequent upon a vast deluge, which is supposed to have taken place when the surface of the earth was covered with animals and vegetables, and when much dry land existed. From various appearances observed in these rocks, it is concluded, that the waters in which they were formed, had risen with great rapidity, and had afterwards settled into a state of considerable calmness. The collections and deposites derived from the materials of pre-existing masses, worn down by the powerful agency of air and water, and afterwards deposited on the land, or on the sea-coast, are termed *alluvial*, and are of course, of much later formation than any of the preceding classes. These deposites may be divided into: 1*st*, Those which are formed in mountainous countries, and are found in valleys, being composed of rolled masses, gravel, sand, and sometimes loam, fragments of ores, and different kinds of precious stones. 2*d*, Those which occur in low and flat countries, being peat, sand, loam, bog, iron ore, nagelflech, calc-tuff and calc-sinter; the three latter being better known by the names breccia, tufa, and stalactite.

Every part of the surface of this globe, M. Cuvier maintains, exhibits such phenomena, as unavoidably lead to the conclusion that the sea, at one period or another, has covered the whole, and remained for a long time in a state of tranquillity so as to form those regular and extensive horizontal deposites in which many of the marine exuviæ are contained. But there are also inclined or vertical strata of the same nature, situated under the horizontal strata, which having been necessarily formed in a horizontal position, have been subsequently lifted up and shifted into their inclined or vertical situation, and that too before the horizontal strata were deposited above them. Now amid these changes it was hardly possible that the same species of animals should continue to live. There must have been a succession of changes in animal natures corresponding to that in the chemical properties of the fluid which they inhabited. It is also conceivable that the change of element might of the earth which seem more naturally to fall within the subject, it will not be improper to give a short history of those animal productions that are found in such quantites, either upon its surface, or at different depths below it. They demand our curiosity; and, indeed, there is nothing in natural history that has afforded more scope for doubt, conjecture, and speculation. Whatever depths of the earth we examine, or at whatever distance within land we seek, we most commonly find a number of fossil-shells, which being compared with others from the sea, of known kinds, are found to be exactly of a similar shape and nature.[1] They are found at the very bottom of quarries and mines, in the retired and inmost parts of the most firm and solid rocks, upon the tops of even the highest hills and mountains, as well as in the valleys and plains; and this not in one country alone, but in all places where there is any digging for marble, chalk, or any other terrestrial matters, that are so compact as to fence off the external injuries of the air, and thus preserve these shells from decay.

These marine substances, so commonly diffused, and so generally to be met with, were for a long time considered by phi-

be so great as to cause the entire destruction of all existing genera. Accordingly, not only the species, but even the genera change with the strata; and when the sea last receded from our continent, its inhabitants were not very different from those which it continues to support. The strata around us, therefore, may serve the double purpose of recording the great revolutions which have taken place both in the animal kingdom and upon the surface of the globe. Neither physical nor astronomical causes of revolution on the earth's surface are sufficient to explain these changes. The irruption of the sea and its retreat have neither been slow nor gradual; the catastrophes have been sudden, and the present surface of the world is by no means of very ancient formation. This theory approximates more nearly to the Mosaical record than many others which we have noticed. In fact, modern geologists are all eager to bear testimony to the actual occurrence of the deluge; neither are they, generally speaking, guilty of disowning the act of creation, though some of them have uttered incredible nonsense on this subject. M. Cuvier, indeed, by his catastrophes and epochs, agrees with many scientific men in assigning a far higher antiquity to our globe, than is consistent with the Mosaic account of the origin of things; but no Christian will hesitate which to prefer; and Granville Penn has abundantly demonstrated, what indeed there could be no good reason to doubt, that the objections to the Christain Revelation, founded on the facts of Geology, are as unphilosophical as they are impious.

1 Woodward's Essay towards a Natural History, p. 16.

losophers as productions, not of the sea, but of the earth. "As we find that spars," said they, "always shoot into peculiar shapes, so these seeming snails, cockles, and mussel-shells, are only sportive forms that nature assumes amongst others of its mineral varieties: they have the shape of fish, indeed, but they have always been terrestrial substances."[2]

With this plausible solution mankind were for a long time content; but upon closer inquiry, they were obliged to alter their opinion. It was found that these shells had in every respect the properties of animal, and not of mineral nature. They were found exactly of the same weight with their fellow shells upon shore. They answered all the chemical trials in the same manner as sea-shells do. Their parts, when dissolved, had the same appearance to view, the same smell and taste. They had the same effects in medicine, when inwardly administered; and, in a word, were so exactly conformable to marine bodies, that they had all the accidental concretions growing to them, (such as pearls, corals, and smaller shells,) which are found in shells just gathered on the shore. They were, therefore, from these considerations, given back to the sea; but the wonder was, how to account for their coming so far from their own natural element upon land.[3]

As this naturally gave rise to many conjectures, it is not to be wondered that some among them have been very extraordinary. An Italian, quoted by Mr Buffon, supposes them to have been deposited in the earth at the time of the crusades, by the pilgrims who returned from Jerusalem; who gathering them upon the sea-shore, in their return carried them to their different places of habitation. But this conjecturer seems to have but a very inadequate idea of their numbers. At Touraine, in France, more than a hundred miles from the sea, there is a plain of about nine leagues long, and as many broad, whence the peasants of the country supply themselves with marl for manuring their lands. They seldom dig deeper than twenty feet; and the whole plain is composed of the same materials, which are shells of various kinds, without the smallest portion of earth between them. Here then is a large space, in which are deposited millions of tons of shells, that pilgrims could not have collected,

2 Lowthorp's Abridgment, Phil. Trans. vol. ii. p. 426.
3 Woodward, p. 45.

though their whole employment had been nothing else. England is furnished with its beds, which, though not quite so extensive, yet are equally wonderful. "Near Reading, in Berkshire, for many succeeding generations, a continued body of oyster-shell has been found through the whole circumference of five or six acres of ground. The foundation of these shells is a hard rocky chalk; and above this chalk, the oyster-shells lie in a bed of green sand, upon a level, as nigh as can possibly be judged, and about two feet thickness."[1] These shells are in their natural state, but they were found also petrified, and almost in equal abundance[2] in all the Alpine rocks, in the Pyrenees, on the hills of France, England, and Flanders. Even in all quarries from whence marble is dug, if the rocks be split perpendicularly downwards, petrified shells and other marine substances will be plainly discerned.

"About a quarter of a mile from the river Medway, in the county of Kent, after the taking off the coping of a piece of ground there, the workmen came to a blue marble, which continued for three feet and a half deep, or more, and then beneath appeared a hard floor, or pavement, composed of petrified shells crowded closely together. This layer was about an inch deep, and several yards over; and it could be walked upon as upon a beach. These stones, of which it was composed, (the describer supposes them to have always been stones,) were either wreathed as snails, or bivalvular like cockles. The wreathed kinds were about the size of a hazel-nut, and were filled with a stony substance of the colour of marl; and they themselves, also, till they were washed, were of the same colour; but when cleaned, they appeared of the colour of bezoar, and of the same polish. After boiling in water they became whitish, and left a chalkiness upon the fingers."[3]

In several parts of Asia nd Africa, travellers have observed these shells in great abundance. In the mountains of Castravan, which lie above the city Barut, they quarry out a white stone, every part of which contains petrified fishes in great numbers, and of surprising diversity. They also seem to continue in such preservation, that their fins, scales, and all the minutest distinctions of their make, can be perfectly discerned.[4]

1 Phil. Trans. vol. ii. p. 427. 2 Buffon, vol. i. p. 407.
3 Phil. Trans. p. 426. 4 Buffon, vol. i. p. 408.

From all these instances we may conclude, that fossils are very numerous: and, indeed, independent of their situation, they afford no small entertainment to observe them as preserved in the cabinets of the curious. The varieties of their kinds are astonishing. Most of the sea-shells which are known, and many others to which we are entirely strangers, are to be seen either in their natural state, or in various degrees of petrifaction.[1] In the place of some we have mere spar, or stone, exactly expressing all the lineaments of animals, as having been wholly formed from them. For it has happened, that the shells dissolving by very slow degrees, and the matter having nicely and exactly filled all the cavities within, this matter, after the shells have perished, has preserved exactly and regularly the whole print of their internal surface. Of these there are various kinds found in our pits; many of them resembling those of our own shores; and many others that are only to be found on the coasts of other countries. There are some shells resembling those that are never stranded upon our coasts;[2] but always remain in the deep:[3] and many more there are which we can assimilate with no shells that are known amongst us. But we find not only shells in our pits, but also fishes and corals in great abundance; together with almost every sort of marine production.

It is extraordinary enough, however, that the common red coral, though so very frequent at sea, is scarcely seen in the fossil world; nor is there any account of its having ever been met with. But to compensate for this, there are all the kinds of the white coral now known, and many other kinds of that substance with which we are unacquainted. Of animals there are various parts: the vertebræ of whales, and the mouths of lesser fishes; these, with teeth also of various kinds, are found in the cabinets of the curious; where they receive long Greek names, which it is neither the intention nor the province of this work to enumerate. Indeed, few readers would think themselves much improved, should I proceed with enumerating the various classes of the Conicthyodontes, Polyleptoginglimi, or the Orthoceratites. These names, which mean no great matter when they are explained, may serve to guide in the furnishing a cabinet; but they are of very little service in furnishing the page of instructive history.

1 Hill, p. 646. 2 Littorales. 3 Pelagii.

From all these instances we see in what abundance petrifactions are to be found; and, indeed, Mr Buffon, to whose accounts we have added some, has not been sparing in the variety of his quotations, concerning the places where they are mostly to be found.* However, I am surprised that he should have

* Mr Kirwan remarks, that petrifactions are most commonly found in strata of marle, chalk, limestone, or clay; seldom in sand-stone, still more rarely in gypsum, &c. They sometimes occur among ores, and almost always consist of the species of earth, stone, or other mineral, which immediately surrounds them. Those of shells are generally found nearest the surface of the earth, those of fish deeper, and those of wood deepest. A very remarkable circumstance is, that petrifactions are found in climates where their originals could not have existed. From the gradual and insensible concretion of this kind of matter from dropping waters, are found the large pendulous columns, hanging like icicles from the roofs and sides of caves. The most remarkable are in the Peak of Derbyshire. Sometimes they are found in the arches of old bridges, and arise from water oozing through, and carrying particles of lime with it. Petrifactions occur in three states; sometimes they are a little altered; sometimes they are converted into stone; and sometimes only the impressions of them, or the moulds in which they have been enclosed, remain. Wood occurs in great abundance in many parts of England, buried at various depths under the surface, and very little altered either in its texture or properties. Pit-coal is supposed to be of vegetable origin. One circumstance confirms this opinion, namely, the existence of vast depositions of matter, half-way, as it were, between perfect wood and perfect pit-coal; betraying obviously its vegetable nature, and yet so nearly approximating to pit-coal in several respects, that it has been generally distinguished by the name of coal.

No complete treatise on geological botany has hitherto appeared in this country. Mr Parkinson's first volume, it is true, is dedicated to the consideration of the vegetable kingdom. It contains descriptions and beautiful figures of many varieties of fossil wood, plants, flowers, seeds, and fruits, from various parts of Europe, and treats of the mineral and petrifying processes to which they have been subjected. But at the pèriod this writer commenced his labours, no systematic classification or nomenclature had been formed, nor was it known that this class of fossils was so numerous. The great source whence our geologists have hitherto drawn their knowledge of antediluvian plants, is the splendid work, the *Flora der Vorwelt* of Count Sternberg. In England the coal formations are particularly rich in beautifully preserved plants. So far as they admit of comparison, they approach those tribes of plants which now exist in warm climates, and luxuriate in moist situations. They consist chiefly of palms and arborescent ferns, (*See Plate* I, *fig.* 1,) succulent plants, cacti, euphorbiæ, canes, reeds, and gramina The trunks or stems thus discovered, belong principally to arundinaceous plants, approximating to those now known, partly to the palmaceous order, and partly to anomalous forms, constituting a transition between these and the coniferous plants. From the few comparisons which have been hitherto instituted between the plants of various distant coal fields, there is reason to conclude that they have a general resemblance in all parts of the world: and, omitted the mention of one, which, in some measure, more than any of the rest, would have served to strengthen his theory. We are informed, by almost every traveller[2] that has described the pyramids of Egypt, that one of them is entirely built of a

If so, it contributes to establish a fact, on which much speculation has been employed, of the original uniformity of climate at those remote points on the earth's surface. In plate I, other representations of fossils may be seen. *Fig.* 2 represents the impression of leaves, on sand-stone, of a pale yellow colour. In this specimen a circumstance is observable which is highly deserving observation. Lhwydd and others remark, that sometimes, though rarely, the leaf will be found so well preserved, that even the colour may be discerned: and in this specimen the leaves are evidently of a very dark olive green. *Fig.* 3 represents an asterial fossil from America, apparently of the nature of the Encrinus. *Fig.* 4 represents the Lily Encrinite, with part of its vertebral column attached to it.

Accumulations of trees, called "subterranean forests," may be traced a intervals, along our eastern coasts. Some of them, apparently, are the remains of forests which clothed the surface of our soil prior to the last grea geological epoch. Most of the trees of this class, although broken off, overwhelmed by tremendous violence, and often flattened by the pressure of diluvial and alluvial deposits, appear to occupy their original sites; their stumps still remain rooted in the soil on which they evidently once flourished. These lignites have been much confounded with others of obvious postdiluvian lacustrine origin. *Mosses*, *confervæ*, and other equally delicate vegetable substances, preserved in agate and chalcedony, have been examined by Dr MacCulloch, who is inclined to refer their origin to a period nearly coeval with the earliest existence of organic matter. Naturalists have often failed in their endeavours to identify the antediluvian plants with those now existing. They evidently flourished under a warm climate; but botanists hesitate to pronounce upon the species, or even the genera. In one instance, lately, a fossil plant has been determined with unusual precision. Under the name Trichomanes rotundatus, Mr Lindley has described a vegetable, discovered within a nodule of argillaceous ironstone, which plant he does not hesitate to identify closely with one which is now only known recent in the deep forests of New Zealand.

Zoophytes, which form the link between vegetables and shellfish, are little less obscure than the plants; and we are again struck with the want of agreement between the organic productions of the ancient and of the present world. As far as the investigation has been pursued, it would seem that the zoophytes of those remote and mysterious times were not less numerous and beautiful than those of our own days. Mr Parkinson examined 170 fossil corals, and found nearly the whole differed from any that are now known. "In my attempt," says this able observer, "to preserve a parallel between the recent and the fossil species, I have been most completely foiled. Indeed, so little could this parallel be preserved, that I am under the necessity of acknowledging I am not certain of the existence of the recent analogue of any one mineralised coral."

When the shellfish that inhabit our ocean are compared with the foss

2 Hasselquist, Sandys.

kind of free-stone, in which these petrified shells are found in great abundance. This being the case, it may be conjectured, as we have accounts of these pyramids among the earliest records of mankind, and of their being built so long before the age of

tribes, essential specific differences are perceived; and these differences become more striking as we recede from the latest formations. In our crag and fresh-water beds some species may be discovered which possess a strong similarity, if not absolute identity, with those living in our lakes and seas. Even here, the identity is maintained but by a limited number, which are intermixed with numerous others that have no recent analogues. Investigations in fossil conchology lead, therefore, to one result; that, with the inconsiderable exceptions that have been stated, the species have not been perpetuated to our times.

One of the most remarkable facts elicited is, that certain Testacea, whose genera were abundantly preserved and prolonged through so many formations, should now exist so sparingly, or be entirely lost. We might instance the Terebratulæ, which abound no less in the mountain limestone than in the chalk, and in almost every intermediate rock, which are absent in nearly every one of our tertiary beds, and re-appear in the most recent. Not less than 100 fossil species of Terebratulæ, and myriads of individuals, are known to us; but the recent shells of this genus are comparatively few. Of Trigonia, also, 25 species are found in our strata, often abundantly, and terminating, like the Ammonites, with the chalk. Until lately, this genus was considered to be extinct; but one species has been discovered on the shores of New Holland. Of Ammonites, so profusely distributed, whose species amount, it is said, to no less than 200, and of which about 175 are known in the English formations, none now remain. 29 species of Producta, 3 of Pentamerus, and 19 of Spirifer, inhabited the waters that produced the transition and mountain limestone, and contiguous shales; but these genera are altogether extinct. Indeed, almost the whole series of antediluvian multilocular shells seem to have shared a similar fate. On the other hand, instances are no less abundant and striking, where the recent species comprehended under certain genera do greatly outnumber the fossils. Thus, under the Linnean genus Conus are comprised 155 species existing; but only 3 occur fossil in our London clay. The genus Cypræa contains about 110 living species, and only four fossil in the tertiary beds. Thus, during the revolutions of ages, some races have been extinguished, and have given place to others which may still be traced in our seas. In the great tertiary deposits of the Sub-Apennines, Brocchi conceived he could point out some marine shells, which are now very widely dispersed, in the Indian and American Oceans, the Atlantic, the Red Sea, the Persian Gulf, and the coasts of Africa and Jamacia.

When we consider the enormous proportion of insects to the rest of the animated beings in the present world,—being, according to Baron Humboldt, no less than 44,000 out of 51,700,—we might expect to discover more frequent traces of these tribes in the fossil world. Whether they did not prevail in such numbers during the former period of the globe, or whether, as is most probable, the extreme delicacy of their structure was unfavourable to their preservation, we have only the fact, that but scanty traces of their former existence, particularly in the elder beds, do now appear.

Herodotus, who lived but fifteen hundred years after the flood, that even the Egyptian priests could tell neither the time nor the cause of their erection; I say, it may be conjectured that they were erected but a short time after the flood. It is not

Of *Birds* the remains also are of rare occurrence; and the same remark might be applied to them, with respect to proportion, as to the preceding order. It does seem a singular circumstance, that more birds have not been found fossil, when we consider that they now are, as regards species, five times as numerous as the Mammalia.

Of *Fishes*, the most common form in which they are found is compressed between the laminæ of sandstones, schists, calcareous slates, and Purbeck marble. Their teeth, scales, and vertebræ are abundant in many formations between the lias and London clay, particularly in the latter, and are even yet more plentiful in the Suffolk crag beds. These teeth are commonly ascribed to varieties of sharks. Palates, or "dentes molares," are found in the oolites, and are beautifully preserved in chalk. A vast collection of impressions of fish have long been known to exist in the calcareous schist of Monte Bolca, many of which have been identified with living species. In M. Bozza's collection, out of 100 known fishes, 4 were ascertained to be similar to those living in the seas of Otaheite. In the Paris museum, containing 62 species, 28 are said to be common to European seas; 14 to Indian seas; 2 to African; 13 to South American; and 5 to North American. In another collection, of 105 species, from the same place, M. Saussure decided that 34 resemble those of European seas; 39 Asiatic; 3 African; 18 South American; 11 North American.

Of *oviparous quadrupeds* (amphibia,) several genera are now known in different formations; but it does not appear that the fossil skeletons of these animals assimilate precisely to living species. By far the greater number are of extraordinary conformation. Thus, the Plesiosaurus (*See Plate* II. *fig.* 1.) approaches to the genus Crocodile, but possesses double the number of vertebræ; a neck resembling the body of a serpent; the head of a lizard; instead of feet, it has swimmers like a whale, or paddles like those of turtles and in other respects its proportions present some approach to those animals The Ichthyosaurus (*fig.* 2.) recedes from the form of the lizard family, and in the structure of its vertebræ it approaches that of fishes. It has forty-one cervical and dorsal vertebræ, and is also furnished with paddles, intermediate between feet and fins. This genus exhibits the snout of a dolphin, the teeth of a crocodile, the head and sternum of a lizard, the swimmers of a whale, and the vertebræ of a fish. Found in the lias, Stonesfield slate, Oxford clay, Kimmeridge clay, coral rag or Malton oolite, and probably in other formations. The Megalosaurus, or gigantic lizard of Stonesfield and Tilgate Forest, is computed by Dr Buckland to be 40 ft. long. It possesses resemblances both to the monitors and the crocodiles. Mr Mantell estimates the Iguanodon, the great herbivorus reptile of the Tilgate stone, to have far exceeded the last in magnitude, and to have attained the extraordinary length of 60 ft. This appears to have been an inhabitant of fresh-water lakes and rivers. Vertebræ of another saurian animal have lately been discovered in the Portland series at Thame, near Oxford, of still more extraordinary dimensions. They are twice as large as those of the Iguanodon, and four times the size of very likely, therefore, that the marine substances found in one of them, had time to be formed into a part of the solid stone, either during the deluge, or immediately after it; and, consequently, their petrifaction must have been before that period.

the vertebræ of the Mastodon. The Stonesfield slate contains perhaps one of the most remarkable assemblages of organic remains that are known to geologists. Here are marine, amphibious, and terrestrial animals, associated with terrestrial, fluviatile or lacustrine, and marine plants, and with birds and insects; *all collected in a bed whose greatest thickness does not exceed* 6 *ft.* Pterodactylus, or winged lizard, one of the most extraordinary productions of the fossil world, is an animal which forms the intermediate link, hitherto deemed to exist only in fable, between birds and reptiles. This creature, previously known in two formations upon the continent, has been recently recognised in the lias of Dorsetshire. Traces of tortoises (Trionyx) are observed in the bituminous schist of the north of Scotland, the geological situation of which is probably similar to that of the coal-measures of England. Impressions, resembling the footsteps made by tortoises, were not long since noticed on the surface of beds of new red sandstone in Dumfriesshire. Bones of several cetaceous animals occur in marine diluvium, particularly in Norfolk. They have been traced much earlier in the Stonesfield slate, in the Tilgate stone, the Kimmeridge clay, and in limestone near Bath. Their occurrence is somewhat rare with us, but less so on some parts of the Continent. In Italy, entire skeletons, at 1200 ft. elevation. Baron Cuvier enumerates 10 fossil species. One is like a species native of the Ganges; a second has no close affinity with any known species; while the remaining eight bear a resemblance to the species at present natives of the British seas.

With regard to the geological distribution of fossil quadrupeds, Baron Cuvier observed that mammiferous sea animals are in more ancient strata than mammiferous land animals; oviparous quadrupeds than viviparous quadrupeds. The oviparous quadrupeds apparently began to exist at the same time with the fishes; the land quadrupeds not until long after, and after the period when most of the shells were deposited.

On comparing the antediluvian animals with those existing, it is seen that the principal loss has fallen upon the Carnivora, while the Ruminants are preserved. Another singular fact has been elicited through the labours of the baron. The fossil ruminants appertain precisely to the genera and sub-genera at present most common in the northern climates: to the aurochs, the musk-ox, the elk, and the rein-deer; while the fossil Pachydermata, the elephant, the rhinoceros, the hippopotamus, and the tapir, are limited at present to the torrid zone. Remains of carnivorous animals are frequently found in our island. The supposed antediluvian fissures of rocks, chiefly in the mountain limestone, red sandstone, and oolite, are their principal receptacles. They are derived from several extinct species of hyænas, wolf, tiger, bear, and weasel. *Plate* II. *fig.* 3 represents molar tooth of wolf; *fig.* 4 molar tooth of tiger; *fig.* 5 molar tooth of hyæna, found in Kirkdale cave. In Yorkshire, an interesting discovery has recently been communicated by Mr Vernon, of the bones of the lion and wolf mixed with those of large herbivorous animals, in lacustrine marl, beneath diluvial gravel. Baron

And this is the opinion Mr Buffon has so strenuously endeavoured to maintain; having given specious reasons to prove, that such shells were laid in the beds where they are now found, not only before the deluge, but even antecedent to the formation of

Cuvier describes 20 or more species of fossil Carnivora, including several mall species from the quarries of Mont-martre.

Herbivorous Quadrupeds occupy the same geological position with the foregoing fossil Mammalia. The larger animals of this class are found to possess anatomical differences from those now existing. They are subdivided into the following orders: —*Pachydermata*, thick-skinned herbivorous quadrupeds, having more than two toes to the foot, and incisive teeth in both aws. The Kirkdale cave has furnished bones of the elephant, rhinoceros, hippopotamus, and horse. Bones of the elephant or mammoth are among the most abundant in every part of the globe. We have derived numerous specimens from Suffolk and Norfolk. The Mastodon, although figured in some works on English geology, does not appear to have been authenticated as a British fossil animal. The peculiar structure of the teeth and bones of these animals has been fully illustrated in various scientific publications. An extinct quadruped of this order, named by Cuvier Anoplotherium, found in the plaster quarries of Paris, appears in a single instance to have been traced in the lower fresh-water beds of the Isle of Wight. See Plate III. for supposed outlines of this extinct quadruped; also for skeleton figure of the great Mastodon. *Plate* II. *fig.* 7 represents molar tooth of Rhinoceros, one third size; *fig.* 8 worn molar tooth of Hippopotamus. Nearly forty species of extinct Pachydermata are found in the upper deposits of the Paris environs. Among them are numerous skeletons resembling tapirs and camels, some other species of rhinoceroses and the new genus Palæotheria, and three or four others. Bones of the horse are found in similar situations to the foregoing, and were therefore contemporaneous with those extinct Pachydermata. Remains of the ox, the aurochs or bison, and several species of deer, were observed in the cave of Kirkdale, and they occur, more or less, in all the great diluvial deposits of this country, and in the valleys through which our great rivers pass. Skulls of the Bos Urus at Walton Naze, Woolwich, Ilford, &c. The great fossil elk of Ireland is found in peat bogs and gravel beds. Some of these skeletons have been met with, although rarely, in England, at Walton and in Holderness. Cervus Elaphus, or red deer; common in diluvial gravel of the eastern counties. Cervus Dama, or fallow deer; traced occasionally in similar situations. Cervus Capreolus, or antelope; near Ipswich, and at Roydon, Norfolk.—*Rodentia* or *Gnawers:* Of this order the Kirkdale cave alone yielded to the researches of Dr Buckland the genera hare, rabbit, rat, water-rat, and mouse. Of *Quadrumanous* animals there exist no known traces in this or any other part of the globe, either of the ape, monkey, or the *human species*. In alluvial deposits, calcareous incrustations, peat formations, mines, and volcanic debris, human bones and their accompaniments have frequently been discovered, bearing evidence of very high antiquity; but they are all referable to more recent times than the deluge, and may be explained by similar events of ordinary occurrence.

No works of art, or other indications of the former existence of man, occur man, at the time when the whole earth, as he supposes, was buried beneath a covering of waters.

But while there are many reasons to persuade us that these extraneous fossils have been deposited by the sea, there is one fact that will abundantly serve to convince us, that the earth was habitable, if not inhabited, before these marine substances came to be thus deposited. For we find fossil-trees, which no doubt once grew upon the earth, as deep, and as much in the body of solid rocks, as these shells are found to be. Some of these fallen trees also have lain at least as long, if not longer, in the earth, than the shells, as they have been found sunk deep in a marly substance, composed of decayed shells and other marine productions. Mr Buffon has proved, that fossil-shells could not have been deposited in such quantities all at once by the flood; and I think, from the above instance, it is pretty plain, that, howsoever they were deposited, the earth was covered with trees before the deposition; and, consequently, that the sea could not have made a very permanent stay. How then shall we account for these extraordinary appearances in nature? A suspension of all assent is certainly the first, although the most mortifying conduct. For my own part, were I to offer a conjecture, and all that has been said upon this subject is but conjecture, instead of supposing them to be the remains of animals belonging to the sea, I would consider them rather as bred in the numerous fresh-water lakes, that in primeval times covered the face of uncultivated nature. Some of these shells we know to belong to fresh waters; some can be assimilated to none of the marine shells now known;[1] why, therefore, may we not as well ascribe the production of all to fresh waters, where we do not find them as we do that of the latter to the sea only, where we

in diluvial or tertiary beds. We are therefore led to unite in the opinion that he is among "the most recent tenants of the globe," coincident with the oldest records and traditions of his race; and that the time in which he has inhabited the earth forms but a trifling portion of its absolute duration. Whether man was coeval with the mastodons, the mammoths, and other mighty animals that once ranged the earth, and left their traces on so large a part of its surface, is an inquiry which there seems little probability will ever be solved. At present we have only the negative fact, that no human remains have been discovered of equal antiquity with those extinct races of animals of which we have made brief mention in this imperfect sketch.

1 Hill's Fossils, p. 41.

never find them? We know that lakes, and lands also, have produced animals that are now no longer existing; why, therefore, might not these fossil productions be among the number? I grant that this is making a very harsh supposition; but I cannot avoid thinking that it is not attended with so many embarrassments as some of the former, and that it is much easier to believe that these shells were bred in fresh water, than that the sea had for a long time covered the tops of the highest mountains.

CHAP. VI.

OF THE INTERNAL STRUCTURE OF THE EARTH.

Having, in some measure, got free from the regions of conjecture, let us now proceed to a description of the earth as we find it by examination, and observe its internal composition, as far as it has been the subject of experience, or exposed to human inquiry. These inquiries, indeed, have been carried but to a very little depth below its surface, and even in that disquisition men have been conducted more by motives of avarice than of curiosity. The deepest mine, which is that at Cotteberg in Hungary,[2] reaches not more than three thousand feet deep; but what proportion does that bear to the depth of the terrestrial globe, down to the centre, which is above four thousand miles? All, therefore, that has been said of the earth, to a deeper degree, is merely fabulous or conjectural: we may suppose, with one, that it is a globe of glass;[3] with another, a sphere of heated iron;[4] with a third, a great mass of waters;[5] and with a fourth, one dreadful volcano:[6] but let us at the same time show our consciousness, that all these are but suppositions.

Upon examining the earth, where it has been opened to any depth, the first thing that occurs, is the different layers or beds of which it is composed; these all lying horizontally one over the other, like the leaves of a book, and each of them composed

2 Boyle, vol. iii p. 210. 3 Buffon. 4 Whiston.
5 Burnet. 6 Kircher.

of materials that increase in weight, in proportion as they lie deeper. This is, in general, the disposition of the different materials, where the earth seems to have remained unmolested; but this order is frequently inverted; and we cannot tell whether from its original formation, or from accidental causes. Of different substances, thus disposed, the far greatest part of our globe consists, from its surface downwards to the greatest depths we ever dig or mine.[1]

The first layer most commonly found at the surface, is that light coat of blackish mould, which is called by some *garden earth.* With this the earth is every where invested, unless it be washed off by rains, or removed by some other external violence. This seems to have been formed from animal and vegetable bodies decaying, and thus turning into its substance. It also serves again as a storehouse, from whence animal and vegetable nature are renewed: and thus are all vital blessings continued with unceasing circulation. This earth, however, is not to be supposed entirely pure, but is mixed with much stony and gravelly matter, from the layers lying immediately beneath it. It generally happens, that the soil is fertile in proportion to the quantity that this putrified mould bears to the gravelly mixture; and as the former predominates, so far is the vegetation upon it more luxuriant. It is this external covering that supplies man with all the true riches he enjoys. He may bring up gold and jewels from greater depths; but they are merely the toys of a capricious being, things upon which he has placed an imaginary value, and for which fools alone part with the more substantial blessings of life. "It is this earth," says Pliny,[2] "that, like a kind mother, receives us at our birth, and sustains us when born." It is this alone of all the elements around us, that is never found an enemy to man. The body of waters deluge him with rains, oppress him with hail, and drown him with inundations. The air rushes in storms, prepares the tempest, or lights up the volcano; but the earth, gentle and indulgent, ever subservient to the wants of man, spreads his walks with flowers, and his table with plenty; returns with interest every good committed to her care; and though she produces the poison, she still supplies the antidote; though constantly teased more to furnish the

1 Woodward, p. 9. 2 Plinii Historia Naturalis, lib. ii. cap. 63.

luxuries of man than his necessities, yet even to the last, she continues her kind indulgence, and when life is over, she piously covers his remains in her bosom.

This external and fruitful layer which covers the earth, is, as was said, in a state of continual change. Vegetables, which are naturally fixed and rooted to the same place, receive their adventitious nourishment from the surrounding earth and water; animals, which change from place to place, are supported by these, or by each other. Both, however, having for a time enjoyed a life adapted to their nature, give back to the earth those spoils, which they had borrowed for a very short space, yet still to be quickened again into fresh existence. But the deposits they make are of very dissimilar kinds, and the earth is very differently enriched by their continuance: those countries that have for a long time supported men and other animals, having been observed to become every day more barren; while, on the contrary, those desolate places, in which vegetables only are abundantly produced, are known to be possessed of amazing fertility. "In regions which are uninhabited,"[3] says Mr Buffon, "where the forests are not cut down, and where animals do not feed upon the plants, the bed of vegetable earth is constantly increasing. In all woods, and even in those which are often cut, there is a layer of earth of six or eight inches thick, which has been formed by the leaves, branches, and bark, which fall and rot upon the ground. I have frequently observed on a Roman way, which crosses Burgundy, for a long extent, that there is a bed of black earth, of more than a foot thick, gathered over the stony pavement, on which several trees, of a very considerable size, are supported. This I have found to be nothing else than an earth formed by decayed leaves and branches, which have been converted by time into a black soil. Now as vegetables draw much more of their nourishment from the air and water than they do from the earth, it must follow that in rotting upon the ground, they must give more to the soil than they have taken from it. Hence, therefore, in woods kept a long time without cutting, the soil below increases to a considerable depth; and such we actually find the soil in those American wilds, where the forests have been undisturbed for ages. But

3 Buffon, vol. i. p. 353.

it is otherwise where men and animals have long subsisted: for as they make a considerable consumption of wood and plants, both for firing and other uses, they take more from the earth than they return to it; it follows, therefore, that the bed of vegetable earth, in an inhabited country, must be always diminishing; and must at length resemble the soil of Arabia Petrea, and other provinces of the East, which having been long inhabited, are now become plains of salt and sand; the fixed salt always remaining, while the other volatile parts have flown away."

If from this external surface we descend deeper, and view the earth cut perpendicularly downwards, either in the banks of great rivers, or steepy sea shores, or going still deeper, if we observe it in quarries or mines, we shall find its layers regularly disposed in their proper order. We must not expect, however, to find them of the same kind or thickness in every place, as they differ in different soils or situations. Sometimes marl is seen to be over sand, and sometimes under it. The most common disposition is, that under the first earth is found gravel or sand, then clay or marl, then chalk or coal, marbles, ores, sands, gravels; and thus an alteration of these substances, each growing more dense as it sinks deeper. The clay, for instance, found at the depth of a hundred feet, is usually more heavy than that found not far from the surface. In a well which was dug at Amsterdam, to the depth of two hundred and thirty feet, the following substances wer ound in succession:[1] seven feet of vegetable earth, nine of turf, nine of soft clay, eight of sand, four of earth, ten of clay, four of earth, ten of sand, two of clay, four of white sand, one of soft earth, fourteen of sand, eight of clay mixed with sand, four of sea-sand mixed with shells, then a hundred and two feet of soft clay, and then thirty-one feet of sand.

In a well dug at Marly, to the depth of a hundred feet, Mr Buffon gives us a still more exact enumeration of its layers of earth. "Thirteen of a reddish gravel, two of gravel mingled with a vitrifiable sand, three of mud or slime, two of marl, four of marly stone, five of marl in dust mixed with vitrifiable sand, six of very fine vitrifiable sand, three of earthy marl, three of hard marl, one of gravel, one of eglantine, a stone of the hard-

1 Varenius, as quoted by Mr Buffon, p. 350.

ness and grain of marble, one of gravelly marl, one of stony marl, one of a coarser kind of stony marl, two of a coarser kind still, one of vitrifiable sand mixed with fossil-shells, two of fine gravel, three of stony marl, one of coarse powdered marl, one of stone calcinable like marble, three of gray sand, two of white sand. one of red sand streaked with white, eight of gray sand with shells, three of very fine sand, three of a hard gray stone, four of red sand streaked with white, three of white sand, and fifteen of reddish vitrifiable sand."

In this manner the earth is every where found in beds over beds; and, what is still remarkable, each of them, as far as it extends, always maintains exactly the same thickness. It is found also, that as we proceed to considerable depths, every layer grows thicker. Thus in the adduced instances we might have observed, that the last layer was fifteen feet thick, while most of the others were not above eight; and this might have gone much deeper, for aught we can tell, as before they got through it the workmen ceased digging.

These layers are sometimes very extensive, and often are found to spread over a space of some leagues in circumference. But it must not be supposed that they are uniformly continued over the whole globe without any interruption; on the contrary, they are ever at small intervals, cracked through as it were by perpendicular fissures: the earth resembling, in this respect, the muddy bottom of a pond, from whence the water has been dried off by the sun, and thus gaping in several chinks, which descend in a direction perpendicular to its surface. These fissures are many times found empty, but oftener closed up with adventitious substances, that the rain, or some other accidental causes, have conveyed to fill their cavities. Their openings are not less different than their contents, some being not above half an inch wide, some a foot, and some several hundred yards asunder. Which last form those dreadful chasms that are to be found in the Alps, at the edge of which the traveller stands dreading to look down at the immeasurable gulph below. These amazing clefts are well known to such as have passed these mountains, where a chasm frequently presents itself several hundred feet deep, and as many over, at the edge of which the way lies. It often happens also, that the road leads along the bottom, and then the spectator observes on each side frightful precipices several hundred yards above him; the sides of which correspond so exactly with each other, they evidently seem torn asunder.

But these chasms, to be found in the Alps, are nothing to what Ovale tells us are to be seen in the Andes. These amazing mountains, in comparison of which the former are but little hills, have their fissures in proportion to their greatness. In some places they are a mile wide, and deep in proportion; and there are some others, that, running under ground, in extent resemble a province.

Of this kind also is that cavern called *Eldenhole,* in Derbyshire, which Dr Plott tells us, was sounded by a line of eight and twenty hundred feet, without finding the bottom or meeting with water: and yet the mouth at the top is not above forty yards over.[1] This immeasurable cavern runs perpendicularly downward; and the sides of it seem to tally so plainly as to show that they were once united. Those who come to visit the place, generally procure stones to be thrown into its mouth; and these are heard for several minutes, falling and striking against the sides of the cavern, producing a sound that resembles distant thunder, dying away as the stone goes deeper.*

Of this kind also is that dreadful cavern described by Elian; his account of which the reader may not have met with.[2] "In the country of the Arrian Indians, is to be seen an amazing chasm, which is called, *The Gulph of Pluto.* The depth and the recesses of this horrid place are as extensive as they are unknown. Neither the natives, nor the curious who visit it, are able to tell how it was first made, or to what depths it descends. The Indians continually drive thither great multitudes of animals, more than three thousand at a time, of different kinds, sheep, horses, and goats; and, with an absurd superstition, force them into the cavity, from whence they never return. Their several sounds, however, are heard as they descend; the bleating of sheep, the lowing of oxen, and the neighing of horses, issuing

1 Phil. Trans. vol. ii. 370.

* Dr Plott has exaggerated the width and depth of this fearful cavern. Mr Lloyd, who descended into it, found its depth to be 186 feet. Its mouth is 20 feet wide one way, and fifty another. He found it to consist of two compartments, the first was in shape like an oven, the other resembled the dome of a glass-house furnace. Mr Lloyd says, from its roof were hanging stalactites, from which circumstance we may conclude, that it occurs in a lime-stone rock.

2 Æliani Var. Hist. lib. xvi. cap. 16.

up to the mouth of the cavern. Nor do these sounds cease, as the place is continually furnished with a fresh supply."

There are many more of these dreadful perpendicular fissures in different parts of the earth; with accounts of which, Kircher, Gaffarellus, and others who have given histories of the wonders of the subterranean world, abundantly supply us. The generality of readers, however, will consider them with less astonishment when they are informed of their being common all over the earth; that in every field, and every quarry, these perpendicular fissures are to be found, either still gaping, or filled with matter that has accidently closed their interstices. The inattentive spectator neglects the inquiry, but their being common is partly the cause that excites the philosopher's attention to them: the irregularities of nature he is often content to let pass unexamined; but when a constant and a common appearance presents itself, every return of the object is a fresh call to his curiosity; and the chink in the next quarry becomes as great a matter of wonder as the chasm in Eldenhole. Philosophers have long, therefore, endeavoured to find out the cause of these perpendicular fissures, which our own countrymen, Woodward and Ray, were the first that found to be so common and universal. Mr Buffon supposes them to be cracks made by the sun, in drying up the earth, immediately after its immersion from the deep. The heat of the sun is very probably a principal cause; but it is not right to ascribe to one only, what we find may be the result of many. Earthquakes, severe frosts, bursting waters, and storms tearing up the roots of trees, have, in our own times, produced them; and to this variety of causes we must, at present, be content to assign those that have happened before we had opportunities for observation.

CHAP. VII.

OF CAVES AND SUBTERRANEOUS PASSAGES THAT SINK, BUT NOT PERPENDICULARLY, INTO THE EARTH.

In surveying the subterranean wonders of the globe, besides those fissures that descend perpendicularly, we frequently find others that descend but a little way, and then spread themselves often to a great extent below the surface. Many of these caverns, it must be confessed, may be the production of art and human industry; retreats made to protect the oppressed, or shelter the spoiler. The famous labyrinth of Candia, for instance, is supposed to be entirely the work of art. Mr Tournefort assures us, that it bears the impression of human industry and that great pains have been bestowed upon its formation. The stone-quarry of Maestricht is evidently made by labour: carts enter at its mouth, and load within, then return, and discharge their freight into boats that lie on the brink of the river Maese. This quarry is so large, that forty thousand people may take shelter in it: and it in general serves for this purpose, when armies march that way; becoming then an impregnable retreat to the people that live thereabout Nothing can be more beautiful than this cavern, when lighted up with torches: for there are thousands of square pillars, in large level walks, about twenty feet high; and all wrought with much neatness and regularity. In this vast grotto there is very little rubbish; which shows both the goodness of the stone and the carefulness of the workmen. To add to its beauty, there also are in various parts of it, little pools of water, for the convenience of the men and cattle. It is remarkable also, that no droppings are seen to fall from the roof, nor are the walks any way wet under foot, except in cases of great rains, where the water gets in by the air shafts. The salt mines in Poland are still more spacious than these. Some of the catacombs, both in Egypt and Italy, are said to be very extensive. But no part of the world has a greater number of artificial caverns than Spain, which were made to serve as retreats to the Christians against the fury of the Moors, when the latter conquered that country. However, an account of the works of art does not properly belong to a natural history. It will be enough to observe, that though caverns be found in every country, far the greatest part of them have been fashioned by the hand of nature only. Their size is found beyond the power of man to have effected, and their forms but ill adapted to the conveniences of a human habitation. In some places indeed, we find mankind still make use of them

1 Phil. Trans. vol. ii. p. 363.

as houses; particularly in those countries where the climate is very severe;[2] but in general they are deserted by every race of meaner animals, except the bat: these nocturnal solitary creatures are usually the only inhabitants; and these only in such whose descent is sloping, or, at least, not directly perpendicular.

There is scarcely a country in the world without its natural caverns; and many new ones are discovered every day. Of those in England, Oakey-hole, the Devil's-hole, and Penpark-hole, have been often described. The former, which lies on the south side of Mendip-hills,[3] within a mile of the town of Wells, is much resorted to by travellers. To conceive a just idea of this, we must imagine a precipice of more than a hundred yards high, on the side of a mountain which shelves away a mile above it. In this is an opening not very large, into which you enter, going along upon a rocky uneven pavement, sometimes ascending, and sometimes descending. The roof of it, as you advance, grows higher; and in some places is fifty feet from the floor. In some places, however, it is so low that a man must stoop to pass. It extends itself, in length, about two hundred yards: and from every part of the roof and the floor, there are formed sparry concretions of various figures, that by strong imaginations have been likened to men, lions, and organs. At the farthest part of this cavern rises a stream of water, well stored with fish, large enough to turn a mill, and which discharges itself near the entrance.

Penpark-hole, in Gloucestershire, is almost as remarkable as the former. Captain Sturmy descended into this by a rope, twenty-five fathoms perpendicular, and at the bottom found a very large vault in the shape of a horse-shoe. The floors consisted of a kind of white stone enamelled with lead ore, and the pendant rocks were glazed with spar. Walking forward on this stony pavement, for some time, he came to a great river, twenty fathoms broad, and eight fathoms deep; and having been informed that it ebbed and flowed with the sea, he remained in this gloomy abode for five hours to make an exact observation. He did not find, however, any alteration whatsoever in its appearance. But his curiosity was ill requited; for it cost this unfortunate gentleman his life; immediately after his return he

2 Phil. Trans. vol. ii. p. 368. 3 Ibid.

was seized with an unusual and violent head-ache, which threw him into a fever, of which he died soon after.*

But of all the subterranean caverns now known, the grotto of Antiparos is the most remarkable, as well for its extent as fo

* There are other caves in Great Britain, fully as remarkable as those above described.—*Donnald Mill-hole*, five miles N. E. from Lancaster, is a cavern in the middle of a large common: the traveller is led to it by a large brook, nearly as big as the New River of London, which, after turning a corn-mill, just at the entrance of the cave, runs in at its mouth by several cascades, continuing its course two miles under a large mountain; and at last makes its appearance again near Cranford, a village in the road to Kendal. The entrance of this subterraneous channel has something most pleasantly horrible in it: from the mill at the top you descend for about ten yards perpendicular, by means of chinks in the rocks, and shrubs or trees; the road is then almost parallel to the horizon, leading to the right a little winding, till you have some hundreds of yards thick of rocks and minerals above you. In this manner we proceed, sometimes through vaults so capacious that we cannot see either roof or sides, and sometimes we have to crawl on our hands and feet, from its narrowness; still following the brook, which has a continued murmuring harmony well suited to the place; for the different heights of its falls are so many keys of music, which is all conveyed to the ear by the amazing echo, and adds greatly to the majestic horror which surrounds us. The beautiful lakes formed by the brook, in the hollow parts of the cavern, realize the fabulous river Styx, so famous in heathen mythology. The falls from one rock to another break the rays of the candles of those who explore this cavern, in such a way, that they form most curious vibrations and appearances upon the variegated roof. The sides, too, are not less remarkable for fine colouring; the damps, the creeping vegetables, and the seams in the marble and limestone part of the rocks, make as many tints as are seen in the rainbow, and are covered with a perpetual varnish from the just weeping springs that trickle from the roof. The curious in grottos and cascades will be much gratified by exploring this wonderful place.

Poole's-hole is within a mile of Buxton: the entrance into this hole is so narrow, that you most stoop to get in: but it soon widens to a broad and lofty cavity, which extends in height upwards of a quarter of a mile. Water drops from the roof every where, and by the reflection of the candles, which the guides carry, exhibit a thousand imaginary figures, as lions, fonts, lanterns, organs, flitches of bacon, &c. At the farther end of this cavity is Mary queen of Scots' pillar, so named after her paying this place a visit; and this is the boundary of most people's curiosity who visit this place. A stream of water runs through the middle of this cavern, with a hideous noise re-echoed from all sides. On the left hand side, you see, after creeping through a passage of ten yards long, a chamber, where they say Poole, a famous robber, lived, from which circumstance the place is named.

The Dropping Cave at Slains, on the east coast of Buchan, in Aberdeenshire, extends upwards of 200 feet under ground; numerous drops of water ooze through the roof, passing through a bed of lime, with which they are impregnated, and form fantastic incrustations or stalactites. Great quantithe beauty of its sparry incrustations. This celebrated cavern was first discovered by one Magni, an Italian traveller, about a hundred years ago, at Antiparos, an inconsiderable island of the Archipelago.[1] The account he gives of it is long and in-

ties of these have been cut out, and burnt for lime; in consequence of which the cave is disfigured and nearly destroyed.

In the island of Staffa, one of the Hebrides, on the north west coast of Scotland, is another striking object of natural history, perhaps the most magnificent of the kind in existence. It is thus described by Sir Joseph Banks, in a communication to Mr Pennant. "We were no sooner arrived," says Sir Joseph, "than we were struck with a scene of magnificence which exceeded our expectations, though founded, as we thought, on the most sanguine foundations. The whole of that island, a mile in length, and half a mile in breadth, supported by ranges of natural pillars, mostly above fifty feet high, every stone being formed into a certain number of sides and angles, standing in natural colonnades, according as the bays or points of land formed themselves: upon a firm basis of solid unformed rock, above these the stratum which reaches to the soil or surface of the island, varied in thickness as the island itself is formed into hills or valleys; each hill, which hung over the columns below, forming an ample pediment; some of these above sixty feet in thickness, from the base to the point, formed by the sloping of the hill on one side almost in the shape of those used in architecture. Compared with this, what are the cathedrals or palaces built by man? Mere models or playthings: imitations as diminutive as his works will always be, when compared to those of nature. Where is now the boast of the architect? Regularity, the only part in which he fancied himself to exceed his mistress, Nature, is here found in her possession; and here it has been for ages undescribed. Is not this the school where the art was originally studied? and what has been added to this by the whole *Grecian* school? A capital to ornament the column of nature, of which they could expect only a model; and for that very capital they were obliged to a bush of *Acanthus*: how amply does nature repay those who study her wonderful works! With our minds full of such reflections, we proceeded along the shore, treading upon another *Giant's Causeway*, every stone being regularly formed into a certain number of sides and angles, till in a short time we arrive at the mouth of a cave, the most magnificent, I suppose, that has ever been described by travellers. The mind can hardly form an idea more magnificent than such a space supported on each side by ranges of columns, and roofed by the bottoms of those which have been broke off in order to form it; between the angles of which a yellow stalagmitic matter has been exuded, which serves to define the angles precisely, and at the same time vary the colour with a great deal of elegance; and to render it still more agreeable, the whole is lighted from without, so that the farthest extremity is very plainly seen from without; and the air, being agitated by the flux and reflux of the tides, is perfectly dry and wholesome, free entirely from the damp vapour with which natural caverns in general abound. We asked the name of it. Said our guide, "The cave of

1 Kircher Mund. sub. 112. I have translated a part of Kircher's description rather than Tournefort's, as the latter was written to support an hypothesis

flated, but upon the whole amusing. "Having been informed," says he, "by the natives of Paros, that in the little island of Antiparos, which lies about two miles from the former, of a gigantic statue that was to be seen at the mouth of a cavern in that place, it was resolved that we (the French consul and himself) should pay it a visit. In pursuance of this resolution, after we had landed on the island, and walked about four miles through the midst of beautiful plains and sloping woodlands, we at length came to a little hill, on the side of which yawned a most horrid cavern, that with its gloom at first struck us with terror, and almost repressed curiosity. Recovering the first surprise, however, we entered boldly; and had not proceeded above twenty paces, when the supposed statue of the giant presented itself to our view. We quickly perceived, that what the ignorant natives had been terrified at as a giant was nothing more than a sparry concretion, formed by the water dropping from

Fhinn." "What is *Fhinn?*" said we. "*Fhinn Mac Coul*, whom the translator of *Ossian's* work has called Fingal." How fortunate, that in this case we should meet with the remembrance of that chief, whose existence, as well as that of the whole *Epic* poem, is almost doubted in England.

The following are the dimensions of the cave.

Length of the cave from the arch without,	371 feet
From the pitch of the arch,	250
Breadth of the arch at the mouth,	53
At the farther end,	20
Height of the arch at the mouth,	117
Height of the arch at the end,	79
Height of an outside pillar,	39
Of one at the north-west corner,	54
Depth of the water at the mouth,	18
At the bottom,	9

In volcanic regions there are many caves, formed by the blisters of the lava which flows during the eruption of volcanic mountains. The following is a description of one of that kind by Sir George M'Kenzie, which he met with during his travels in Iceland, in the year 1810, in a valley near Havnefoird. "We proceeded to a cave (says Sir George,) about two miles to the eastward. It was nothing more than an extensive hollow, formed by one of those blisters or bubbles, hundreds of which we have walked over. Many of these are of considerable depth and great length. The bottom of this was covered with ice, and numerous icicles hung from the roof. Having lighted our lamps, we went to the end of the cave, the distance of which, from the entrance, we found to be fifty-five yards, the height not being in general more than seven or eight feet. The inside was lined with melted matter, disposed in various singular forms."

the roof of the cave, and by degrees hardening into a figure that their fears had formed into a monster. Incited by this extraordinary appearance, we were induced to proceed still farther, in quest of new adventures in this subterranean abode. As we proceeded, new wonders offered themselves: the spars, formed into trees and shrubs, presented a kind of petrified grove; some white, some green; and all receding in due perspective. They struck us with the more amazement, as we knew them to be mere productions of nature, who, hitherto in solitude, had, in her playful moments, dressed the scene, as if for her own amusement.

"But we had as yet seen but a few of the wonders of the place; and were introduced only into the portico of this amazing temple. In one corner of this half-illumined recess there appeared an opening of about three feet wide, which seemed to lead to a place totally dark, and that, one of the natives assured us, contained nothing more than a reservoir of water. Upon this we tried, by throwing down some stones, which rumbling along the sides of the descent for some time, the sound seemed at last quashed in a bed of water. In order, however, to be more certain, we sent in a Leventine mariner, who, by the promise of a good reward, with a flambeaux in his hand, ventured into this narrow aperture. After continuing within it for about a quarter of an hour, he returned, carrying some beautiful pieces of white spar in his hand, which art could neither imitate nor equal. Upon being informed by him that the place was full of these beautiful incrustations, I ventured in once more with him for about fifty paces, anxiously and cautiously descending by a steep and dangerous way. Finding, however, that we came to a precipice which led into a spacious amphitheatre, if I may so call it, still deeper than any other part, we returned, and being provided with a ladder, flambeaux, and other things to expedite our descent, our whole company, man by man, ventured into the same opening, and descending one after another we at last saw ourselves altogether in the most magnificent part of the cavern.

"Our candles being now all lighted up, and the whole place completely illuminated, never could the eye be presented with a more glittering, or a more magnificent scene. The roof all hung with solid icicles, transparent as glass, yet solid as marble. The eye could scarcely reach the lofty and noble ceiling; the sides were regularly formed with spars; and the whole presented the idea of a magnificent theatre, illuminated with an immense profusion of lights. The floor consisted of solid marble; and in several places magnificent columns, thrones, altars, and other objects appeared, as if nature had designed to mock the curiosities of art. Our voices, upon speaking or singing, were redoubled to an astonishing loudness, and upon the firing of a gun, the noise and reverberations were almost deafening. In the midst of this grand amphitheatre rose a concretion of about fifteen feet high, that in some measure resembled an altar; from which, taking the hint, we caused mass to be celebrated there. The beautiful columns that shot up round the altar, appeared like candlesticks; and many other natural objects represented the customary ornaments of this sacrament.

"Below even this spacious grotto there seemed another cavern; down which I ventured with my former mariner, and descended about fifty paces by means of a rope. I at last arrived at a small spot of level ground, where the bottom appeared different from that of the amphitheatre, being composed of a soft clay yielding to the pressure, and in which I thrust a stick to about six feet deep. In this, however, as above, numbers of the most beautiful crystals were formed, one of which particularly resembled a table. Upon our egress from this amazing cavern, we perceived a Greek inscription upon a rock at the mouth, but so obliterated by time that we could not read it. It seemed to import that one Antipater, in the time of Alexander, had come thither, but whether he had penetrated into the depths of the cavern, he does not think fit to inform us."

Such is the account of this beautiful scene as communicated in a letter to Kircher. We have another, and a more copious description of it by Tournefort, which is in every body's hands; but I have given the above, both because it was communicated by the first discoverer, and because it is a simple narrative of facts, without any reasoning upon them. According to Tournefort's account, indeed, we might conclude from the rapid growth of the spars in this grotto that it must every year be growing narrower, and that it must in time be choked up with them entirely; but no such thing has happened hitherto, and the grotto at this day continues as spacious as we ever knew it.

This is not a place for an inquiry into the seeming vegetation of those stony substances, with which this and almost every cavern are incrusted; it is enough to observe, in general, that they are formed by an accumulation of that little gritty matter which is carried thither by the waters, and which in time acquires the hardness of marble. What in this place more imports us to know, is, how these amazing hallows in the earth came to be formed. And I think, in the three instances above mentioned, it is pretty evident, that their excavation has been owing to water. These finding subterraneous passages under the earth, and by long degrees hollowing the beds in which they flowed, the ground above them has slipt down closer to their surface, leaving the upper layers of the earth or stone still suspended: the ground that sinks upon the face of the waters forming the floor of the cavern; the ground or rock, that keeps suspended, forming the roof: and indeed, there are but few of these caverns found without water, either within them, or near enough to point out their formation.

CHAP. VIII.

OF MINES, DAMPS, AND MINERAL VAPOURS.

The caverns which we have been describing, generally carry us but a very little way below the surface of the earth. Two hundred feet, at the utmost, is as much as the lowest of them is found to sink. The perpendicular fissures run much deeper; but few persons have been bold enough to venture down to their deepest recesses; and some few who have tried, have been able to bring back no tidings of the place, for unfortunately they left their lives below. The excavations of art have conducted us much farther into the bowels of the globe. Some mines in Hungary are known to be a thousand yards perpendicular downwards; and I have been informed, by good authority, of a coal mine in the north of England, a hundred yards deeper still.

It is beside our present purpose to inquire into the peculiar contrivance and construction of these, which more properly belongs to the history of fossils. It will be sufficient to observe in this place, that as we descend into the mines, the various layers of earth are seen as we have already described them ; and in some of these are always found the metals or minerals for which the mine has been dug. Thus frequently gold is found dispersed and mixed with clay and gravel ;[1] sometimes it is mingled with other metallic bodies, stones, or bitumens ;[2] and sometimes united with that most obstinate of all substances, platina, from which scarce any art can separate it. Silver is sometimes found quite pure,[3] sometimes mixed with other substances and minerals. Copper is found in beds mixed with various substances, marbles, sulphurs, and pyrites. Tin, the ore of which is heavier than that of any other metal, is generally found mixed with every kind of matter :[4] lead is also equally common ; and iron, we well know, can be extracted from all the substances upon earth.

The variety of substances which are thus found in the bowels of the earth, in their native state, have a very different appearance from what they are afterwards taught to assume by human industry. The richest metals are very often less glittering and splendid than the most useless marcasites ; and the basest ores are generally the most beautiful to the eye.

This variety of substances, which compose the internal parts of our globe, is productive of equal varieties, both above and below its surface. The combination of the different minerals with each other, the heats which arise from their mixture, the vapours they diffuse, the fires which they generate, or the colds which they sometimes produce, are all either noxious or salutary to man ; so that in this great elaboratory of nature, a thousand benefits and calamities are forging, of which we are wholly unconscious ; and it is happy for us that we are so.

Upon our descent into mines of considerable depth, the cold seems to increase from the mouth as we descend ;[5] but after passing very low down, we begin by degrees to come into a warmer air, which sensibly grows hotter as we go deeper, till at last, the labourers can scarcely bear any covering as they continue working.

This difference in the air was supposed by Boyle to proceed

1 Ulloa, vol ii. p. 470 2 Ulloa, ibid. 3 Macquer's Chymistry, vol. i. p. 316. 4 Hill's Fossils, p. 628. 5 Boyle, vol. iii. p. 232.

from magazines of fire that lay nearer the centre, and that diffused their heat to the adjacent regions. But we now know that it may be ascribed to more obvious causes. In some mines, the composition of the earth all around is of such a nature, that upon the admission of water or air, it frequently becomes hot, and often bursts out into eruptions. Besides this, as the external air cannot readily reach the bottom, or be renewed there, an observable heat is perceived below, without the necessity of recurring to the central heat for an explanation.

Hence, therefore, there are two principal causes of the warmth at the bottom of mines: the heat of the substances of which the sides are composed; and the want of renovation in the air below. Any sulphureous substance, mixed with iron, produces a very great heat, by the admission of water. If, for instance, a quantity of sulphur be mixed with a proportionable share of iron filings, and both kneaded together into a soft paste, with water, they will soon grow hot, and at last produce a flame. This experiment, produced by art, is very commonly effected within the bowels of the earth by nature. Sulphurs and irons are intimately blended together, and want only the mixture of water or air to excite their heat; and this, when once raised, is communicated to all bodies that lie within the sphere of their operation. Those beautiful minerals called *marcasites* and *pyrites*, are often of this composition; and wherever they are found, either by imbibing the moisture of the air, or having been by any means combined with water, they render the mine considerably hot.[6]

The want of fresh air also, at these depths, is, as we have said, another reason for their being found much hotter. Indeed, without the assistance of art, the bottom of most mines would, from this cause be insupportable. To remedy this inconvenience, the miners are often obliged to sink, at some convenient distance from the mouth of the pit where they are at work, another pit, which joins the former below, and which, in Derbyshire, is called an *air-shaft*. Through this the air circulates; and thus the workmen are enabled to breathe freely at the bottom of the place; which becomes, as Mr Boyle affirms, very commodious for respiration, and also very temperate as to heat and cold.[7] Mr Locke, however, who has left us an account of

6 Kircher Mund. Subt. vol. ii. p. 216.

7 Boyle, vol. iii. p. 238.

the Mendip mines, seems to present a different picture. "The descent into these is exceedingly difficult and dangerous; for they are not sunk like wells, perpendicularly, but as the crannies of the rocks happen to run. The constant method is to swing down by a rope placed under the arms, and clamber along by applying both feet and hands to the sides of the narrow passage. The air is conveyed into them through a little passage that runs along the sides from the top, where they set up some turfs, on the lee-side of the hole, to catch and force it down. These turfs being removed to the windy side, or laid over the mouth of the hole, the miners below presently want breath, and faint; and if sweet-smelling flowers chance to be placed there, they immediately lose their fragrancy, and stink like carrion." An air so putrefying can never be very commodious for respiration.

Indeed, if we examine the complexion of most miners, we shall be very well able to form a judgment of the unwholesomeness of the place where they are confined. Their pale and sallow looks show how much the air is damaged by passing through those deep and winding ways, that are rendered humid by damps, or warmed with noxious exhalations. But although every mine is unwholesome, all are not equally so. Coal-mines are generally less noxious than those of tin; tin than those of copper; but none are so dreadfully destructive as those of quicksilver. At the mines near the village of Idra, nothing can adequately describe the deplorable infirmities of such as fill the hospital there; emaciated and crippled, every limb contracted or convulsed, and some in a manner transpiring quicksilver at every pore. There was one man, says Dr Pope,[1] who was not in the mines above half a year, and yet whose body was so impregnated with this mineral, that putting a piece of brass money in his mouth, or rubbing it between his fingers, it immediately became as white as if it had been washed over with quicksilver. In this manner all the workmen are killed sooner or later; first becoming paralytic, and then dying consumptive: and all this they sustain for the trifling reward of sevenpence a-day.

But these metallic mines are not so noxious from their own vapours, as from those of the substances with which the ores are

1 Phil. Trans. vol. ii. p. 578.

usually united, such as arsenic, cinnabar, bitumen, or vitriol. From the fumes of these, variously combined, and kept inclosed, are produced those various damps, that put on so many dreadful forms, and are usually so fatal. Sometimes these noxious vapours are perceived by the delightful fragrance of their smell,[1] somewhat resembling the pea-blossom in bloom, from whence one kind of damp has its name. The miners are not deceived, however, by its flattering appearances; but as they have thus timely notice of its coming, they avoid it while it continues, which is generally during the whole summer season. Another shows its approach by the burning of the candles, which seem to collect their flame into a globe of light, and thus gradually lessen, till they are quite extinguished. From this, also, the miners frequently escape; however, such as have the misfortune to be caught in it, either swoon away, and are suffocated, or slowly recover in excessive agonies. Here also is a third, called *the fulminating damp*, much more dangerous than either of the former, as it strikes down all before it like a flash of gunpowder, without giving any warning of its approach. But there is another, more deadly than all the rest, which is found in those places where the vapour has been long confined, and has been, by some accident, set free. The air rushing out from thence, always goes upon deadly errands: and scarce any escape to describe the symptoms of its operations.

Some colliers in Scotland, working near an old mine that had been long closed up, happened, inadvertently, to open a hole into it, from the pit where they were then employed. By great good fortune, they at that time perceived their error, and instantly fled for their lives. The next day, however, they were resolved to renew their work in the same pit, and eight of them ventured down, without any great apprehensions; but they had scarcely got to the bottom of the stairs that led to the pit, but, coming within the vapour, they all instantly dropped down dead, as if they had been shot. Amongst these unfortunate poor men, there was one whose wife was informed he was stifled in the mine: and, as he happened to be next the entrance, she so far ventured down as to see where he lay. As she approached the place, the sight of her husband inspired her with a desire to res-

1 Phil. Trans. vol. ii. p. 375.

cue him if possible, from that dreadful situation; though a little reflection might have shown her it was then too late. But nothing could deter her; she ventured forward, and had scarce touched him with her hand, when the damp prevailed, and the misguided, but faithful creature, fell dead by his side.*

* The coal-mines of Great Britain were wrought on a very limited scale, and with comparatively little system, till after the beginning of the eighteenth century. It was not till the introduction of the steam-engine, for drawing water in the first place, and coals afterwards, that the coal mines began to be wrought on an extensive scale; even to this period the ventilation of mines was conducted in a very rude, uncertain, and irregular manner, and for many years afterwards. Every bed of coal abounds less or more with deleterious air, which is of two kinds; the one is specifically heavier, the other lighter, than common air; the natural consequence of which is, that the one rests in the deepest or lowest places, the other, from its levity, ascends to the highest places of the mine. The first is known by the common provincial names of choak damp, black damp, styth, or bad air; the other is known by the name of foul air, fire damp, or inflammable air. The one is the carbonic acid, the other the carburetted hydrogen gas of the chemist. The precise qualities of the carbonic acid of coal mines, have been comparatively little attended to, as its destroying powers have not operated extensively. The nature and composition of the carburetted hydrogen have closely engaged the attention of philosophers for the last ten years. According to the best authorities these gases are of the following specific gravity and weight.

	Spec. Grav.	Weight of 100 Cubic inches.
Carbonic acid	1.518	46.313
Carburetted hydrogen	0.555	16.99
Hydrogen	0.074	2.230

The common air being reckoned unity, the temperature at 60, and barometer at 30 inches. According to Dr Thomson, the component parts of carburetted hydrogen are,

Carbon	72
Hydrogen	28
	100

In which there is always a mixture of carbonic acid.

Various theories have been brought forward regarding the formation of these gases, but more particularly of the carburetted hydrogen: both of them flow or exude from the cutters, fissures, and minute pores of the coal; and when in small quantity in the forehead of a mine in solid coal, they make a hissing noise. The carbonic acid seldom comes off very suddenly in large quantities. From its weight it is not liable to a sudden change of place, and though it is invisible, its line of division from the common atmospheric air is most distinctly found by approaching it with a lighted candle or lamp; for though the candle burns with its ordinary brightness at the distance of three inches from the carbonic acid, the instant it is placed within this air, it is suddenly extinguished: it produces the same instant effect upon the strong-

Thus, the vapours found beneath the surface of the earth are very various in their effects upon the constitution: and they are not less in their appearances. There are many kinds that seemingly are no way prejudicial to health, but in which the workmen

est flame of coals; sometimes the upper part of the mine next the roof has the air perfectly good, while the pavement has a stratum of carbonic acid, of a foot or two in thickness, resting upon it.

As the flame of a candle is a correct index of the presence of this air, the miners have instant warning, and stop their advancing any farther, till means are used to drive it away. Comparatively few lives have been lost by this gas. Those who have perished from its effects, had generally gone amongst it without a candle, and of course were insensible of its presence, till they dropped down from its deleterious effects on the constitution. When men are rendered senseless by inhaling this air, they can be recovered if brought quickly into good air, but if they remain any time in it, all attempts to recover them are ineffectual. It must be remarked, however, that as the air of these coal mines which abound with carbonic acid, has always a very considerable mixture of it through the whole of the works, the air in this state is reckoned very salubrious, though mixed with a great proportion of moisture. The workmen who breathe it every day are generally healthy, and it is reckoned a specific in some complaints, it being a common practice to send down children affected with the hooping cough to breathe in it.

The carburetted hydrogen is not found in all coal mines, and is seldom seen where the carbonic acid abounds. In Scotland there are extensive districts where the inflammable air was never seen, and others where it is very abundant. In the numerous collieries situated upon the north banks of the river Forth, it is only found in one very limited district, and in only two districts upon the south banks of the Forth. In the very extensive coal-fields in the Lothians, south from the city of Edinburgh, it is unknown: whereas in the coal-fields around the city of Glasgow, and along the coast of Ayr, it is found very abundant; at the same time there are coal-fields in that very extensive range, where it never was seen; but where it is not seen, the carbonic acid abounds.

The production of these gases, renders the system of the ventilation of coal mines a chief point in the system of mining, particularly where the inflammable air abounds, by which the lives of the workmen and the prosperity of the mining concern may be instantly destroyed. It would require a long dissertation, and the most minute detail, to give a clear view of the almost infinite variety of cases connected with the accumulation of inflammable air in the mines of a colliery, and of the plans and methods which have to be employed and varied for the ventilation, corresponding to each particular situation of the mines.

With daily misfortunes of a lesser or greater degree were the collieries of Great Britain carried on from year to year, every one struggling against the direful ravages of the inflammable air: but it baffled the skill of the most experienced engineers, and all the precautions of their most unwearied diligence and anxious attention. The general question and anxious inquiries were, Can no remedy be devised to avert these awful calamities, to deliver an industrious class of society from such desolating catastrophes? Many plans were proposed, but they were altogether inapplicable.

breathe freely; and yet in these, if a lighted candle be introduced, they immediately take fire, and the whole cavern at once becomes one furnace of flame. In mines, therefore, subject to damps of this kind, they are obliged to have recourse to a very peculiar

In some instances, fish, which, in the incipient stage of putrefaction, give a strong phosphoric light, had been tried to give light to the miner in very dangerous cases; and the light produced by the collision of flint and steel was universally employed when candles could not be used without producing an explosion. The machine for producing this light is named a steel mill. Philosophers proposed the various kinds of phosphorus, but these were altogether insufficient for the purpose. When tried in the mines they only produced a most melancholy light, and rather tended to render "the darkness visible." In the meantime the mines were extended, and the melancholy catastrophes constantly increased. At last an explosion and catastrophe took place at Felling colliery, near Gateshead, in the county of Durham, about a mile and a half distant from Newcastle, more dreadful and melancholy in their consequence than any which had ever taken place in the collieries of Great Britain. This colliery was working with great vigour and under a most regular system both as to the mining operations and ventilation; the latter was effected by a furnace and air-tube placed upon a rise-pit on elevated ground south from the turnpike road leading to Sunderland. The depth of the winning was above 100 fathoms; twenty-five acres of coal had been excavated, and such was the execution of work, that from one pit they were drawing at the rate of 1700 tons of coal weekly. Upon the 25th May, 1812, the night-shift was relieved by the day-shift of miners at eleven o'clock forenoon, one hundred and twenty-one persons were in the mine, and had taken their several places, when at half past eleven o'clock the gas fired, and produced a most tremendous explosion, which alarmed all the neighbouring villages. The subterraneous fire broke forth with two heavy discharges from the dip-pit, and these were instantly followed by one from the rise-pit. A slight trembling, as from an earthquake, was felt for about half a mile around the colliery, and the noise of the explosion, though dull, was heard at from three to four miles distance. Immense quantities of dust and small coal accompanied these blasts, and rose high into the air, in the form of an inverted cone. The heaviest part of the ejected matter, such as corves, wood, and small coal, fell near the pits, but the dust, borne away by a strong west wind, fell in a continued shower to the distance of a mile and a half from the pit. In the adjoining village of Heworth it caused a darkness like that of early twilight, and covered the roads so thickly, that the footsteps of passengers were imprinted in it. The heads of both shaft-frames were blown off, their sides set on fire, and their pulleys shattered in pieces. The coal dust ejected from the rise-pit into the horizontal part of the ventilating tube was about three inches thick, and soon burnt to a cinder; pieces of burning coal driven off the solid stratum of the mine were also blown up this shaft. Of the 121 persons in the mine, at the time of the explosion, only 32 were drawn up the pit alive; and of these, three died within a few hours after the accident. Thus were no less than 92 persons killed in an instant by this desolating pestilence. The scene at the pit-mouth cannot be described.

This fatal misfortune at Felling roused the minds of every one connected with contrivance to supply sufficient light for their operations. This is by a great wheel, the circumference of which is beset with flints, which striking against steels placed for that purpose at the extremity, a stream of fire is produced, which affords light enough, and yet which does not set fire to the mineral vapour.

coal-mines, in order to find, if possible, a remedy for preventing such catastrophes.

Dr William Reid Clanny, of Sunderland, had, in the year 1813, turned his attention to the construction of a lamp which would burn amongst inflammable air, and, though an explosion might take place in the lamp, would not communicate flame to the external surrounding air. This he accomplished by means of an air-tight lamp with a glass front, the flame of which was supported by blowing air from a pair of small bellows through a stratum of water in the bottom of the lamp, while the heated air passed through water by a recurved tube at the top. By this process, the air within the lamp was completely insulated from the external air, and it appears that this was the first lamp that ever was taken into a body of inflammable air in a coal-mine at the exploding point, without producing an explosion of the surrounding gas. Dr Clanny made another lamp upon an improved plan, by introducing into it the steam of water produced from a small vessel at the top of the lamp, heated by the flame. For these inventions the Doctor twice received the thanks of "The Society for preventing accidents in Coal-Mines;" and he also received the silver and afterwards the gold medal from the Society of Arts in London. Although these lamps, invented by Dr Clanny, were upon philosophical principles, displayed much ingenuity, and were absolutely safety-lamps for mines, yet their construction prevented them from being generally used. It appears that nothing farther was attempted in this important matter, until the accident at Felling colliery, as before noticed, when Sir Humphrey Davy, Mr James Stevenson, engineer, Killingworth colliery, Newcastle, and Dr John Murray of Edinburgh, brought forward safety-lamps, in the year 1816, each constructed upon different principles. Sir Humphrey Davy's lamp was made of fine iron wire gauze, without any glass; that of Mr Stevenson was made of a strong glass cylinder having a metal plate at top, and another at bottom, perforated with very small holes to permit the air to pass to and from the lamp; and that of Dr Murray was a glass lamp, or rather lanthorn, to which good atmospheric air was brought by means of a long leather pipe from the air-course. Of these Dr Murray's lamp was not applicable but in a very few cases; the lamps of Sir Humphrey Davy and Mr Stevenson were both complete safety-lamps in their principle, and are applied in practice; but that of Sir Humphrey Davy is decidedly the best, and is generally used in Great Britain. Having no glass it is not easily injured, and sufficient light for the miner passes through the wire gauze. To each of these gentlemen the world is highly indebted, and in particular the mining interest of Great Britain for their individual exertions. The safety-lamp of Sir Humphrey Davy was instantly tried, and approved of by Mr Buddle, and the principal mining engineers at Newcastle. No one was more zealous to prove its safety and introduce it into the mines, than the Rev. John Hodgson, of Heworth. He descended the mines, entered amongst the inflammable air, and fully satisfied

Of this kind are the vapours of the mines about Bristol: on the contrary, in other mines, a single spark struck out from the collision of flint and steel, would set the whole shaft in a flame. In such, therefore, every precaution is used to avoid a collision; the workmen making use of wooden instruments in digging; and being cautious, before they enter the mine, to take out even the nails from their shoes. Whence this strange difference should arise, that the vapours of some mines catch fire with a spark, and others only with a flame, is a question that we must be content to leave in obscurity, till we know more of the nature both of mineral vapour and of fire. This we only may observe, that gunpowder will readily fire with a spark, but not with the flame of a candle; on the other hand, spirits of wine will flame with a candle, but not with a spark: but even here the cause of this difference as yet remains a secret.

As from this account of mines, it appears that the internal parts of the globe are filled with vapours of various kinds, it is not surprising that they should, at different times, reach the surface, and there put on various appearances. In fact, much of the salubrity, and much of the unwholesomeness, of climates and soils, is to be ascribed to these vapours, which make their way from the bowels of the earth upwards, and refresh or taint the air with their exhalations. Salt mines, being naturally cold,[1] send forth a degree of coldness to the external air, to comfort and refresh it: on the contrary, metallic mines are known not only to warm it with their exhalations, but often to destroy all kinds of vegetation by their volatile corrosive fumes. In some mines, dense vapours are plainly perceived issuing from their mouths, and sensibly warm to the touch. In some places neither snow nor ice will continue on the ground that covers a mine;

himself of its absolute safety, in order that he might induce the miners of his parish to use it, half of whom he had seen so lately swept away by the dreadful explosion before narrated.

The invention of this lamp has produced a new era in the coal mining of Great Britain. The steel mills were very expensive, and in certain cases produced explosions, whereas the safety-lamp can be carried without danger amongst inflammable gas ready to explode: and although the wire become red-hot, an explosion of the gas will take place inside of the lamp, without communicating inflammation to the external gas.

1 Phil. Trans. vol. ii. p. 523.

and over others the fields are found destitute of verdure.[2] The inhabitants, also, are rendered dreadfully sensible of these subterraneous exhalations, being affected with such a variety of evils proceeding entirely from this cause, that books have been professedly written upon this class of disorders.

Nor are these vapours, which thus escape to the surface of the earth, entirely unconfined; for they are frequently, in a manner, circumscribed to a spot. The grotto Del Cane, near Naples, is an instance of this; the noxious effects of which have made that cavern so very famous. This grotto, which has so much employed the attention of travellers, lies within four miles of Naples, and is situated near a large lake of clear wholesome water.[3] Nothing can exceed the beauty of the landscape which this lake affords; being surrounded with hills covered with forests of the most beautiful verdure, and the whole bearing a kind of amphitheatrical appearance. However, this region, beautiful as it appears, is almost entirely uninhabited; the few peasants that necessity compels to reside there, looking quite consumptive and ghastly, from the poisonous exhalations that rise from the earth. The famous grotto lies on the side of a hill, near which place a peasant resides, who keeps a number of dogs for the purpose of showing the experiment to the curious. These poor animals always seem perfectly sensible of the approach of a stranger, and endeavour to get out of the way. However, their attempts being perceived, they are taken and brought to the grotto; the noxious effects of which they have so frequently experienced. Upon entering this place, which is a little cave, or hole rather, dug into the hill, about eight feet high, and twelve feet long, the observer can see no visible mark of its pestilential vapour; only to about a foot from the bottom, the wall seems to be tinged with a colour resembling that which is given by stagnant waters. When the dog, this poor philosophical martyr, as some have called him, is held above this mark, he does not seem to feel the smallest inconvenience; but when his head is thrust down lower he struggles to get free for a little; but in the space of four or five minutes he seems to lose all sensation, and is taken out seemingly without life. Being plunged in the neighbouring lake, he quickly recovers, and

2 Boyle, vol. iii. p. 238. 3 Kircher, Mund. Subt. vol. i. p. 191.

is permitted to run home, seemingly without the smallest injury.

This vapour, which thus for a time suffocates, is of the humid kind, as it extinguishes a torch, and sullies a looking-glass; but there are other vapours perfectly inflammable, and that only require the approach of a candle to set them blazing. Of this kind was the burning well at Brosely, which is now stopped up; the vapour of which, when a candle was brought within about a foot of the surface of the water, caught flame like spirits of wine, and continued blazing several hours after. Of this kind, also, are the perpetual fires in the kingdom of Persia. In that province, where the worshippers of fire hold their chief mysteries, the whole surface of the earth, for some extent, seems impregnated with inflammable vapours. A reed stuck into the ground continues to burn like a flambeau; a hole made beneath the surface of the earth, instantly becomes a furnace, answering all the purposes of a culinary fire. There they make lime by merely burying the stones in the earth; and watch with veneration the appearances of a flame that has not been extinguished for times immemorial. How different are men in various climates! This deluded people worship these vapours as a deity, which in other parts of the world are considered as one of the greatest evils.

CHAP. IX.

OF VOLCANOES AND EARTHQUAKES.

Mines and caverns, as we have said, reach but a very little way under the surface of the earth, and we have hitherto had no opportunities of exploring further. Without all doubt the wonders that are still unknown surpass those that have been represented, as there are depths of thousands of miles which are hidden from our inquiry. The only tidings we have from those unfathomable regions are by means of volcanoes, those burning mountains that seem to discharge their materials from the lowest abysses of the earth.[1] A volcano may be considered as a cannon of immense size, the mouth of which is often near two miles in circumference. From this dreadful aperture are discharged torrents of flame and sulphur, and rivers of melted metal. Whole clouds of smoke and ashes, with rocks of enormous size, are discharged to many miles' distance; so that the force of the most powerful artillery, is but as a breeze agitating a feather in comparison. In the deluge of fire and melted matter which runs down the sides of the mountain, whole cities are sometimes swallowed up and consumed. Those rivers of liquid fire are sometimes two hundred feet deep; and when they harden, frequently form considerable hills. Nor is the danger of these confined to the eruption only: but the force of the internal fire struggling for vent, frequently produces earthquakes through the whole region where the volcano is situated. So dreadful have been these appearances, that men's terrors have added new horrors to the scene, and they have regarded as prodigies, what we know to be the result of natural causes. Some philosophers have considered them as vents communicating with the fires of the centre; and the ignorant as the mouths of hell itself. Astonishment produces fear, and fear superstition: the inhabitants of Iceland believe the bellowings of Hecla are nothing else but the cries of the damned, and that its eruptions are contrived to increase their tortures.

But if we regard this astonishing scene of terror with a more tranquil and inquisitive eye, we shall find that these conflagrations are produced by very obvious and natural causes. We have already been apprised of the various mineral substances in the bosom of the earth, and their aptness to burst out into flames. Marcasites and pyrites, in particular, by being humified with water or air, contract this heat, and often endeavour to expand with irresistible explosion. These, therefore, being lodged in the depths of the earth, or in the bosom of mountains, and being either washed by the accidental influx of waters below, or fanned by air, insinuating itself through perpendicular fissures from above, take fire at first by only heaving in earthquakes, but at length by bursting through every obstacle, and making their dreadful discharge in a volcano.

1 Buffon, vol. i. p. 291.

These volcanoes are found in all parts of the earth:* In Europe there are three that are very remarkable; Ætna in Sicily, Vesuvius in Italy, and Hecla in Iceland. Ætna has been a volcano for ages immemorial. Its eruptions are very violent,

* A great chain of ignivomous mountains stretches around the great ocean. Terra del Fuego, Chili, Peru, all the chain of the Andes, are full of volcanoes. We distinguish in Peru, those of Arequipa and of Pitchinca; and that of Coto Paxi, whose flames in 1738, rose higher than 2000 feet, and whose explosion was heard at the distance of 120 leagues, if we may give credit to the Spaniards. Chimboraco, the highest mountain of the globe, is an extinguished volcano; and there are a great many others. Humboldt has seen the smoke of Antisand rise 18,000 feet. If we pass the isthmus of Panama, we find the volcannoes of Nicaragua and of Guatimala. Their number is infinite: there are some which are covered with perpetual snow, and which consequently are elevated to a great height.—Then come those of Mexico, properly so called; namely, Orizaba, Popocateipetl, 16,626 feet high; Jorullo, which first broke out in 1759, and several others, all situate under the 19th parallel of latitude. California contains five volcanoes, that are now burning. There can be no doubt, according to the accounts of Cook, la Perouse, and Malaspina, that there is a number of very considerable volcanoes on the northwest of America. Mount Saint Elie is nearly 16,800 in height; these volcanoes form the intermediate link between those of Mexico and those in the Aleutian islands, and the peninsula of Alaschka. These last, which are very numerous, both extinct and burning, serve to continue the chain towards Kamschatka, where there are three of great violence. Japan has eight; and the island of Tormoso has several. The volcanic belt now becomes immensely wide, and embraces the Philippine islands, the Marian or Ladrones, the Moluccas, Java, Sumatra, the isles of Queen Charlotte, the new Hebrides, and, in short, all that vast Archipelago which forms the fifth part of the globe. The other volcanic chains are far from being of so great extent. There is perhaps one in the Indian Sea. The islands of Saint Paul and Amsterdam, the formidable volcano in the island of Bourbon, and the jets of hot water in the island of Madagascar, are the only known links of this chain. The gulf of Arabia flows at the base of the volcano of *Gebel-Tar*. The neighbourhood of the Dead Sea, and the whole chain of mountains which runs through Syria, have been the theatre of volcanic eruptions. We may be allowed to connect these two facts. A vast volcanic zone surrounds Greece, Italy, Germany, and France. The celebrated revolutions of the Grecian Archipelago, and those new islands produced by submarine explosions, are well known. The summits of Mount Ætna are next descried; this mountain has burnt for 3300 years, and it is surrounded by extinguished volcanoes which appear much more ancient. The islands of Lipari seem to owe their origin to the volcanoes which they contain. Vesuvius has not always been the only ignivomous mountain in the kingdom of Naples, another still larger, but extinguished, has been discovered near Rocca Fina. The Solfatara is ranked under the same class. The Ponce islands, or island of Ponza, are of volcanic origin; the catacombs of Rome are excavations from the lava. Tuscany abounds in hot and sulphureous springs, and other indications of volcanoes. Arduini observed in the envi-

and its discharge has been known to cover, for a certain space around, eighty-six feet deep. In the year 1537, an eruption of this mountain produced an earthquake through the whole island for twelve days, overturned many houses, and at last formed a new aperture, which overwhelmed all within five leagues round. The cinders thrown up were driven even into Italy, and its burnings were seen at Malta, at the distance of sixty leagues. "There is nothing more awful," says Kircher, "than the eruptions of this mountain, nor nothing more dangerous than attempting to examine its appearances, even long after the eruption has ceased. As we attempt to clamber up its steepy sides, every step we take upwards, the feet sink back half way. Upon arriving near the summit, ashes and snow, with an ill-assorted conjunction, present nothing but objects of desolation. Nor is

rons of Padua, Verona, and Vicenza, a great number of extinguished volcanoes. Dalmatia has several. It was long suspected that a district in Hungary nourished subterraneous fires in its bosom; the eruption of a volcano has recently evinced the truth of the conjecture. Germany contains a great number of extinguished volcanoes; the best known of which are those of Kamberg in Bohemia, Transberg near Gottingen, and those near Bonn and Andernach, upon the borders of the Rhine. The southern part of France is full of extinguished volcanoes, amongst which Mount Cantal, the Puy-de-Dome, and Mount d'Or in Auvergne, are the most conspicuous.

The Western is not like the Great Ocean, encircled by a chain of ignivomous mountains, but it contains in its bosom several groupes. If the principality of Wales, the island of Staffa, and some parts of Scotland and Ireland, exhibit only equivocal proofs of the existence of extinguished volcanoes, Iceland presents to our view its Hecla, its Kotlouguia, and several other volcanoes, which rise from the midst of perpetual snow. This volcanic focus is one of the most active in the globe; the very bottom of the ocean is, in these regions, agitated, and the waves often heave up whole fields of pumice stone, or with convulsive throes give birth to permanently new islands. Several circumstances lead us to suppose, that there are some volcanoes in the interior of Greenland. That frozen country experiences the shocks of earthquakes. The middle of the Atlantic Ocean conceals another volcanic focus, of which the Azores and Canary islands have felt the effects. The Peak of Teneriffe, which is 11,400 feet, is the most elevated volcano in the old world. It is very probable that Lisbon has in its vicinity a submarine volcano. The Antilles probably contain a whole system of volcanoes, parts of which are recognised in Jamaica, Guadaloupe, and Grenada. We may also mention some volcanoes, which are detached, or which belong to groupes little known. Such are Mount Elburtz in Persia, the extinguished volcanoes of Daourie, discovered by Patriu; perhaps some volcanoes to the north of China. That which is seen in Fuego, one of the Cape Verd islands, and those which the Portuguese authors point out in Guinea, Congo, and Monomotapa.

this the worst, for, as all places are covered over, many caverns are entirely hidden from the sight, into which, if the inquirer happens to fall, he sinks to the bottom, and meets inevitable destruction. Upon coming to the edge of the great crater, nothing can sufficiently represent the tremendous magnificence of the scene. A gulf two miles over, and so deep that no bottom can be seen; on the sides pyramidical rocks starting out between apertures that emit smoke and flame; all this accompanied with a sound that never ceases, louder than thunder, strikes the bold with horror, and the religious with veneration for HIM that has power to control its burnings."

In the descriptions of Vesuvius or Hecla, we shall find scarcely any thing but a repetition of the same terrible objects, but rather lessened, as these mountains are not so large as the former. The crater of Vesuvius is but a mile across, according to the same author; whereas that of Ætna is two. On this particular, however, we must place no dependence, as these caverns every day alter; being lessened by the mountain's sinking in at one eruption, and enlarged by the fury of another. It is not one of the least remarkable particulars respecting Vesuvius, that Pliny the naturalist was suffocated in one of its eruptions; for his curiosity impelling him too near, he found himself involved in smoke and cinders when it was too late to retire; and his companions hardly escaped to give an account of the misfortune. It was in that dreadful eruption that the city of Herculaneum was overwhelmed; the ruins of which have lately been discovered at sixty feet distance below the surface, and, what is still more remarkable, forty feet below the bed of the sea. One of the most remarkable eruptions of this mountain was in the year 1707, which is finely described by Valetta; a part of whose description I shall beg leave to translate.

"Towards the latter end of summer, in the year 1707, the mount Vesuvius, that had for a long time been silent, now began to give some signs of commotion. Little more than internal murmurs at first were heard, that seemed to contend within the lowest depths of the mountain; no flame, nor even any smoke, was as yet seen. Soon after some smoke appeared by day, and a flame by night, which seemed to brighten all the campania. At intervals, also, it shot off substances with a sound very like that of artillery, but which, even at so great a distance as we were at, infinitely exceeded them in greatness. Soon after, it began to throw up ashes, which, becoming the sport of the winds, fell at great distances, and some many miles. To this succeeded showers of stones, which killed many of the inhabitants of the valley, but made a dreadful ravage among the cattle. Soon after, a torrent of burning matter began to roll down the sides of the mountain, at first with a slow and gentle motion, but soon with increased celerity. The matter thus poured out, when cold, seemed upon inspection to be of vitrified earth, the whole united into a mass of more than stony hardness. But what was particularly observable was, that upon the whole surface of these melted materials, a light spongy stone seemed to float, while the lower body was of the hardest substance of which our roads are usually made. Hitherto there were no appearances but what had been often remarked before; but on the third or fourth day, seeming flashes of lightning were shot forth from the mouth of the mountain, with a noise far exceeding the loudest thunder. These flashes, in colour and brightness, resembled what we usually see in tempests, but they assumed a more twisted and serpentine form. After this followed such clouds of smoke and ashes, that the whole city of Naples, in the midst of the day, was involved in nocturnal darkness, and the nearest friends were unable to distinguish each other in this frightful gloom. If any person attempted to stir out without torch-light, he was obliged to return, and every part of the city was filled with supplications and terror. At length, after a continuance of some hours, about one o'clock at midnight, the wind blowing from the north, the stars began to be seen; the heavens, though it was night, began to grow brighter; and the eruptions, after a continuance of fifteen days, to lessen. The torrent of melted matter was seen to extend from the mountain down to the shore the people began to return to their former dwellings, and the whole face of nature to resume its former appearance."

The famous Bishop Berkeley gives an account of one of these eruptions in a manner something different from the former.[1] "In the year 1717, and the middle of April, with much difficulty I reached the top of Mount Vesuvius, in which I saw a vast aperture full of smoke, which hindered me from seeing its depth

1 Phil. Trans. vol. ii p. 209.

and figure. I heard within that horrid gulf certain extraordinary sounds, which seemed to proceed from the bowels of the mountain, a sort of murmuring, sighing, dashing sound; and, between whiles, a noise like that of thunder or cannon, with a clattering like that of tiles falling from the tops of houses into the streets. Sometimes, as the wind changed, the smoke grew thinner, discovering a very ruddy flame, and the circumference of the crater streaked with red and several shades of yellow. After an hour's stay, the smoke, being moved by the wind, gave us short and partial prospects of the great hollow; in the flat bottom of which I could discern two furnaces almost contiguous; that on the left seeming about three yards over, glowing with ruddy flame, and throwing up red-hot stones with a hideous noise, which, as they fell back, caused the clattering already taken notice of.—May 8, in the morning, I ascended the top of Vesuvius a second time, and found a different face of things. The smoke ascending upright, gave a full prospect of the crater, which, as I could judge, was about a mile in circumference, and a hundred yards deep. A conical mount had been formed, since my last visit, in the middle of the bottom, which I could see was made by the stones, thrown up and fallen back again into the crater. In this new hill remained the two furnaces already mentioned. The one was seen to throw up every three or four minutes, with a dreadful sound, a vast number of red-hot stones, at least three hundred feet higher than my head, as I stood upon the brink; but as there was no wind, they fell perpendicularly back from whence they had been discharged. The other was filled with red-hot liquid matter, like that in the furnace of a glass-house, raging and working like the waves of the sea, with a short abrupt noise. This matter would sometimes boil over, and run down the side of the conical hill, appearing at first red hot, but changing colour as it hardened and cooled. Had the wind driven in our faces, we had been in no small danger of stifling by the sulphureous smoke, or being killed by the masses of melted minerals that were shot from the bottom. But as the wind was favourable, I had an opportunity of surveying this amazing scene for above an hour and a half together. On the fifth of June, after a horrid noise, the mountain was seen at Naples to work over; and, about three days after, its thunders were renewed so, that not only the windows in the city, but all the houses, shook.

From that time it continued to overflow, and sometimes at night were seen columns of fire shooting upward from its summit. On the tenth, when all was thought to be over, the mountain again renewed its terrors, roaring and raging most violently. One cannot form a juster idea of the noise, in the most violent fits of it, than by imagining a mixed sound made up of the raging of a tempest, the murmur of a troubled sea, and the roaring of thunder and artillery, confused all together. Though we heard this at a distance of twelve miles, yet it was very terrible. I therefore resolved to approach nearer to the mountain; and, accordingly, three or four of us got into a boat, and were set ashore at a little town situated at the foot of the mountain. From thence we rode about four or five miles, before we came to the torrent of fire that was descending from the side of the volcano; and here the roaring grew exceedingly loud and terrible as we approached. I observed a mixture of colours in the cloud, above the crater, green, yellow, red, and blue. There was likewise a ruddy dismal light in the air, over that tract where the burning river flowed. These circumstances, set off and augmented by the horror of the night, made a scene the most uncommon and astonishing I ever saw; which still increased as we approached the burning river. Imagine a vast torrent of liquid fire, rolling from the top down the side of the mountain, and with irresistible fury bearing down and consuming vines, olives, and houses; and divided into different channels, according to the inequalities of the mountain. The largest stream seemed half a mile broad at least, and five miles long. I walked so far before my companions up the mountain, along the side of the river of fire, that I was obliged to retire in great haste, the sulphureous stream having surprised me, and almost taken away my breath. During our return, which was about three o'clock in the morning, the roaring of the mountain was heard all the way, while we observed it throwing up huge spouts of fire and burning stones, which, falling, resembled the stars in a rocket. Sometimes I observed two or three distinct columns of flame, and sometimes one only, that was large enough to fill the whole crater. These burning columns, and fiery stones, seemed to be shot a thousand feet perpendicular above the summit of the volcano; and in this manner the mountain continued raging for six or eight days after. On the 18th of the same month, the whole appearance ended, and the mountain remained perfectly quiet without any visible smoke or flame."

The matter which is found to roll down from the mouth of all volcanoes in general, resembles the dross that is thrown from a smith's forge. But it is different, perhaps, in various parts of the globe; for, as we have already said, there is not a quarter of the world that has not its volcanoes. In Asia, particularly in the islands of the Indian Ocean, there are many.* One of the

* Various burning chasms and volcanoes are to be seen in the Sandwich Islands. Mr Ellis, in his Missionary Tour, thus describes a great volcano in Hawaii or Owyhee, which he visited. "About two P. M. the CRATER OF KIRAUEA suddenly burst upon our view. We expected to have seen a mountain with a broad base and rough indented sides, composed of loose slags or hardened streams of lava, and whose summit would have presented a rugged wall of scoria, forming the rim of a mighty caldron. But instead of this, we found ourselves on the edge of a steep precipice, with a vast plain before us, fifteen or sixteen miles in circumference, and sunk from 200 to 400 feet below its original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks, and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing. Our guides led us round towards the north end of the ridge, in order to find a place by which we might descend to the plain below.

We walked on to the north end of the ridge, where, the precipice being less steep, a descent to the plain below seemed practicable. It required, however, the greatest caution, as the stones and fragments of rock frequently gave way under our feet, and rolled down from above; but with all our care, we did not reach the bottom without several falls and slight bruises. The steep which we had descended was formed of volcanic matter, apparently a light red and gray kind of lava, vesicular, and lying in horizontal strata, varying in thickness from one to forty feet. In a small number of places the different strata of lava were also rent in perpendicular or oblique directions, from the top to the bottom, either by earthquakes, or other violent convulsions of the ground connected with the action of the adjacent volcano. After walking some distance over the sunken plain, which in several places sounded hollow under our feet, we at length came to the edge of the great crater, where a spectacle, sublime and even appalling, presented itself before us—

"We stopped and trembled"

Astonishment and awe for some moments rendered us mute, and, like statues, we stood fixed to the spot, with our eyes rivetted on the abyss below. Immediately before us yawned an immense gulf, in the form of a crescent, about two miles in length, from north-east to south-west, nearly a mile in width, and apparently 800 feet deep. The bottom was covered with lava, and the south-west and northern parts of it were one vast flood of burning matter, in a state of terrific ebullition, rolling to and fro its "fiery surge" and flaming billows. Fifty-one conical islands, of varied form and size, containing so many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted columns of gray smoke, or pyramids of brilliant flame; and several of these at the same time vomited most famous is that of Albouras, near Mount Taurus, the summit of which is continually on fire, and covers the whole adjacent country with ashes. In the island of Ternate there is a volcano, which, some travellers assert, burns most furiously in the times of the equinoxes, because of the winds which then contribute to increase the flames. In the Molucco islands, there are many burning mountains; they are also seen in Japan and the islands adjacent; and in Java and Sumatra, as well as in other of the Philippine Islands. In Africa there is a cavern, near Fez, which continually sends forth either smoke or flames, In the Cape de Verde islands, one of them, called *the Island de Fuego,* continually burns; and the Portuguese, who frequently

from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below. The existence of these conical craters led us to conclude, that the boiling caldron of lava before us did not form the focus of the volcano; that this mass of melted lava was comparatively shallow; and that the basin in which it was contained was separated, by a stratum of solid matter, from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. We were further inclined to this opinion, from the vast columns of vapour continually ascending from the chasms in the vicinity of the sulphur banks and pools of water, for they must have been produced by other fire than that which caused the ebullition in the lava at the bottom of the great crater; and also by noticing a number of small craters, in vigorous action, situated high up the sides of the great gulf, and apparently quite detached from it. The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass there, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different strata of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava of irregular breadth, but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, 300 or 400 feet lower. It was evident that the large crater had been recently filled with liquid lava up to this black ledge, and had, by some subterranean canal, emptied itself into the sea, or upon the low land on the shore; and in all probability this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The gray, and in some places apparently calcined, sides of the great crater before us; the fissures which intersected the surface of the plain on which we were standing; the long banks of sulphur on the opposite side of the abyss; the vigorous action of the numerous small craters on its borders; the dense columns of vapour and smoke that rose at the north and south end of the plain; together with the ridge of steep rocks by which it was surrounded, rising probably in some places 300 or 400 feet in perpendicular height, presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below."

attempted a settlement there, have as often been obliged to desist. The Peak of Teneriffe is, as every body knows, a volcano, that seldom desists from eruptions. But of all parts of the earth, America is the place where those dreadful irregularities of nature are the most conspicuous. Vesuvius, and Etna itself, are but mere fire-works in comparison to the burning mountains of the Andes; which, as they are the highest mountains of the world, so also are they the most formidable for their eruptions. The mountain of Arequipa, in Peru, is one of the most celebrated; Carassa and Malahallo are very considerable; but that of Cotopaxi, in the province of Quito, exceeds any thing we have hitherto read or heard of. The mountain of Cotopaxi, as described by Ulloa,[1] is more than three miles perpendicular from the sea; and it became a volcano at the time of the Spaniards' first arrival in that country. A new eruption of it happened in the year 1743, having been some days preceded by a continual roaring in its bowels. The sound of one of these mountains is not, like that of the volcanoes in Europe, confined to a province, but is heard at a hundred and fifty miles distance.[2] "An aperture was made in the summit of this immense mountain; and three more about equal heights near the middle of its declivity, which was at that time buried under prodigious masses of snow. The ignited substances ejected on that occasion, mixed with a prodigious quantity of ice and snow, melting amidst the flames, were carried down with such astonishing rapidity, that in an instant the valley from Callo to Latucunga was overflowed; and besides its ravages in bearing down the houses of the Indians, and other poor inhabitants, great numbers of people lost their lives. The river of Latucunga was the channel of this terrible flood; till being too small for receiving such a prodigious current, it overflowed the adjacent country, like a vast lake, near the town, and carried away all the buildings within its reach. The inhabitants retired into a spot of higher ground behind the town, of which those parts which stood within the limits of the current were totally destroyed. The dread of still greater devastations did not subside for three days; during which the volcano ejected cinders, while torrents of melted ice and snow poured down its sides. The eruption lasted several days,

1 Ulloa vol. i p. 442. 2 Ibid.

and was accompanied with terrible roarings of the wind, rushing through the volcano, still louder than the former rumblings in its bowels. At last all was quiet, neither fire nor smoke to be seen, nor noise to be heard; till in the ensuing year, the flames again appeared with recruited violence, forcing their passage through several other parts of the mountain, so that in clear nights the flames being reflected by the transparent ice, formed an awfully magnificent illumination."

Such is the appearance and the effect of those fires which proceed from the more inward recesses of the earth: for that they generally come from deeper regions than man has hitherto explored, I cannot avoid thinking, contrary to the opinion of Mr Buffon, who supposes them rooted but a very little way below the bed of the mountain. "We can never suppose," says this great naturalist, "that these substances are ejected from any great distance below, if we only consider the great force already required to fling them up to such vast heights above the mouth of the mountain; if we consider the substances thrown up, which we shall find upon inspection to be the same with those of the mountain below; if we take into our consideration, that air is always necessary to keep up the flame; but, most of all, if we attend to one circumstance, which is, that if these substances were exploded from a vast depth below, the same force required to shoot them up so high, would act against the sides of the volcano, and tear the whole mountain in pieces." To all this specious reasoning, particular answers might be easily given; as, that the length of the funnel increases the force of the explosion; that the sides of the funnel are actually often burst with the great violence of the flame; that air may be supposed at depths at least as far as the perpendicular fissures descend. But the best answer is a well known fact; namely, that the quantity of matter discharged from Ætna alone, is supposed, upon a moderate computation, to exceed twenty times the original bulk of the mountain.[3] The greatest part of Sicily seems covered with its eruptions. The inhabitants of Catanea have found, at the distance of several miles, streets and houses sixty feet deep, overwhelmed by the lava or matter it has discharged. But what is still more remarkable, the walls of these very houses have been

3 Kircher, Mund. Subt. vol. i. p. 202.

built of materials evidently thrown up by the mountain. The inference from all this is very obvious ; that the matter thus exploded cannot belong to the mountain itself, otherwise it would have been quickly consumed ; it cannot be derived from moderate depths, since its amazing quantity evinces, that all the places near the bottom must have long since been exhausted ; nor can it have an extensive, and, if I may so call it, a superficial spread, for then the country round would be quickly undermined ; it must, therefore, be supplied from the deeper regions of the earth ; those undiscovered tracts where the Deity performs his wonders in solitude, satisfied with self-approbation !

CHAP. X.

OF EARTHQUAKES.

Having given the theory of volcanoes, we have in some measure given also that of earthquakes. They both seem to proceed from the same cause, only with this difference, that the fury of the volcano is spent in the eruption ; that of an earthquake spreads wider, and acts more fatally by being confined. The volcano only affrights a province ; earthquakes have laid whole kingdoms in ruin.

Philosophers [1] have taken some pains to distinguish between the various kinds of earthquakes, such as the tremulous, the pulsative, the perpendicular, and the inclined ; but these are rather the distinctions of art than of nature, mere accidental differences arising from the situation of the country or of the cause. If, for instance, the confined fire acts directly under a province or town, it will heave the earth perpendicularly upward, and produce a *perpendicular* earthquake. If it acts at a distance, it will raise that tract obliquely, and thus the inhabitants will perceive an *inclined* one.

Nor does it seem to me that there is much greater reason for Mr Buffon's distinction of earthquakes ; one kind of which he

1 Aristotle, Agricola, Buffon.

supposes[2] to be produced by fire in the manner of volcanoes, and confined but to a very narrow circumference. The other kind he ascribes to the struggles of confined air, expanded by heat in the bowels of the earth, and endeavouring to get free. For how do these two causes differ? Fire is an agent of no power whatsoever without air. It is the air, which being at first compressed, and then dilated in a cannon, that drives the ball with such force. It is the air struggling for vent in a volcano, that throws up its contents to such vast heights. In short, it is the air confined in the bowels of the earth, and acquiring elasticity by heat, that produces all those appearances which are generally ascribed to the operation of fire. When, therefore, we are told that there are two causes of earthquakes, we only learn that a greater or smaller quantity of heat produces those terrible effects; for air is the only active operator in either.

Some philosophers, however, have been willing to give the air as great a share in producing these terrible efforts as they could; and, magnifying its powers, have called in but a very moderate degree of heat to put it in action. Although experience tell us that the earth is full of imflammable materials, and that fires are produced wherever we descend; although it tells us that those countries where there are volcanoes, are most subject to earthquakes; yet they step out of their way, and so find a new solution. These only allow but just heat enough to produce the most dreadful phenomena, and, backing their assertions with long calculations, give theory an air of demonstration. Mr Amontons[3] has been particularly sparing of the internal heat in this respect; and has shown, perhaps accurately enough, that a very moderate degree of heat may suffice to give the air amazing powers of expansion.

It is amusing enough, however, to trace the progress of a philosophical fancy let loose in imaginary speculations. They run thus: "A very moderate degree of heat may bring the air into a condition capable of producing earthquakes; for the air, at the depth of forty-three thousand five hundred and twenty-eight fathom below the surface of the earth becomes almost as heavy as quicksilver. This, however, is but a very slight depth in comparison of the distance to the centre, and is scarcely a

2 Buffon, vol. ii. p. 328. 3 Memoires de l'Acadamie de Sciences. An. 17(3.

seventieth part of the way. The air, therefore, at the centre, must be infinitely heavier than mercury, or any body that we know of. This granted, we shall take something more, and say, that it is very probable there is nothing but air at the centre. Now let us suppose this air heated, by some means, even to the degree of boiling water, as we have proved that the density of the air is here very great, its elasticity must be in proportion; a heat, therefore, which at the surface of the earth would have produced but a slight expansive force, must, at the centre, produce one very extraordinary, and, in short, be perfectly irresistible. Hence this force may, with great ease, produce earthquakes; and if increased, it may convulse the globe; it may (by only adding figures enough to the calculation) destroy the solar system, and even the fixed stars themselves." These reveries generally produce nothing; for, as I have ever observed, increased calculations, while they seem to tire the memory, give the reasoning faculty perfect repose.

However, as earthquakes are the most formidable ministers of nature, it is not to be wondered that a multitude of writers have been curiously employed in their consideration. Woodward has ascribed the cause to a stoppage of the waters below the earth's surface by some accident. These being thus accumulated, and yet acted upon by fires, which he supposes still deeper, both contribute to heave up the earth upon their bosom. This he thinks, accounts for the lakes of water produced in an earthquake, as well as for the fires that sometimes burst from the earth's surface upon those dreadful occasions. There are others who have supposed that the earth may be itself the cause of its own convulsions. "When," say they, "the root or basis of some large tract is worn away by a fluid underneath, the earth sinking therein, its weight occasions a tremor of the adjacent parts, sometimes producing a noise, and sometimes an inundation of water." Not to tire the reader with a history of opinions instead of facts, some have ascribed them to electricity, and some to the same causes that produce thunder.

It would be tedious, therefore, to give all the various opinions that have employed the speculative on this subject. The activity of the internal heat seems alone sufficient to account for every appearance that attends these tremendous irregularities of nature. To conceive this distinctly let us suppose at some vast distance under the earth, large quantities of inflammable matter, pyrites, bitumens, and marcasites, disposed, and only waiting for the aspersion of water, or the humidity of the air, to put their fires in motion: at last, this dreadful mixture arrives; waters find their way into those depths through the perpendicular fissures; or air insinuates itself through the same minute apertures: instantly new appearances ensue; those substances, which for ages before lay dormant, now conceive new apparent qualities; they grow hot, produce new air, and only want room for expansion. However, the narrow apertures by which the air or water had at first admission are now closed up; yet as new air is continually generated, and as the heat every moment gives this air new elasticity, it at length bursts, and dilates all round; and, in its struggles to get free, throws all above it into similar convulsions. Thus an earthquake is produced more or less extensive, according to the depth or the greatness of the cause.*

* The existence of volcanoes and hot springs led philosophers long ago to suspect that there was an intense heat in the interior of the earth. The opinion of Werner, that the former arose from the combustion of masses of coal at moderate depths, was set aside by the discovery that the seat of the volcanic agents was under the primitive rocks, of course far below the coal-formation, and that the composition of lavas was the same in all parts of the world. The notion advanced by others, that hot springs might owe their origin to the accidental mixture of substances producing chemical action in the bowels of the earth, was equally inadequate to account for the permanency of these springs—their existence without any known change for ages. At length a third species of evidence presented itself in the temperature of deep mines, which it was observed was generally higher than the mean temperature of the year in the district. It was objected that the heat might arise from the breaths of the workmen, and the lights used by them. This explanation to be sure did not account for the difference of temperature said to be observed between shallow and deep mines; but the existence of the difference alluded to was doubted; and to this as the point upon which the controversy hinged, several philosophers, especially M. Cordier, a professor of geology in Paris, directed their attention. The result is thus announced by the Parisian professor:—"1. Our experiments fully confirm the existence of a subterranean heat, which is peculiar to the terrestrial globe,—does not depend on the solar rays,—and increases rapidly with the depth. 2. The increase of the subterranean heat does not follow the same law over the whole earth; it may be twice or thrice as great in one country as another. 3. These differences do not bear any constant proportion either to the latitude or longitude. 4. The increase is more rapid than has been supposed; it may go as high as *one* degree of Fahrenheit for 24 feet, but the mean, so far as the present observations have yet extended, cannot be fixed at less than

But before we proceed with the causes, let us take a short view of the appearances which have attended the most remarkable earthquakes. By these we shall see how far the theorist corresponds with the historian. The greatest we find in anti-

one degree for 45 feet." In the deep borings made by M. Arago, it was found that the greater the depth from which the water ascended the warmer it was. Mr Bald of Alloa published some facts in the *Edinburgh Philosophical Journal* some years ago, and Mr Daubuisson gives others relating to the mines of Saxony, which establish the same conclusion. A writer in the *Annals of Philosophy* thinks that the increase in England is about one degree of Fahrenheit for every ten or twelve fathoms of descent. Hence we have reason to conclude, that it is not any peculiar local circumstances which generate the heat in warm springs; but that they merely derive their waters from reservoirs situated at a great depth. Pursuing this idea, the Bath waters which have a temperature of 116, may be supposed to come from a depth of three-fourths of a mile, and at the depth of two miles downwards we should find the temperature of boiling water; and that of melted lava at a depth which varies much in different countries, but may be estimated on an average at 60 miles. Cordier, therefore, considers the whole globe as a mass of fused matter, intensely hot, covered with a solid crust or shell, whose thickness is about one 63d part of its semidiameter, and upon which crust man and all his works are suspended over the molten abyss. Hence M. Cordier considers the quantity of matter thrown out by volcanoes, as affording a *measure of the contraction which the shell of the globe is undergoing*. He has examined and estimated the cubic contents of the matter ejected in one eruption by several volcanoes, and found that it did not amount to a cubic kilometre, that is, a cube, the side of which is rather more than half a mile. It follows, that a contraction of volume, which would shorten the radius of the globe the 50,000th part of an inch, would be sufficient to force out the matter of one eruption. There are about 200 unextinguished volcanoes known, but many of them are silent for very long periods; but assuming that there are on an average five eruptions in a year among them all, this would indicate that the radius of the globe shortened only one millimetre (1-25th part of an inch) in a century.

"This theory," says a journalist of great intelligence, "accounts for the frequency of volcanoes in the early stages of the globe's existence, when the crust was thin, the contraction rapid, and the fracture of its parts easy. As it increases in thickness, changes in its figure or volume become more difficult, and must be chiefly confined to the inner coats, among which it is probable that void spaces may be left; into these the fluid matter may be injected, which in earlier times would have reached the surface and formed eruptions. Assuming that the thickness of the crust is 60 miles, it would require a pressure equal to that of 28,000 atmospheres to make the fused lava reach the surface. Hence we see why such a vast number of volcanoes are found every where on the earth's surface, which were once active, but are now extinguished. In early times, when the earth was perfectly fluid at the surface, the attraction of the sun and moon would produce tides in the molten mass exactly as it does now in the ocean. These tides, which must have been four or five yards in height, would exert a disturbing force on the cuity is that mentioned by Pliny,[1] in which twelve cities in Asia Minor were swallowed up in one night: he tells us also of another near the lake Thrasymene, which was not perceived by the armies of the Carthaginians and Romans, that were then engaged near that lake, although it shook the greatest part of Italy. In another place[2] he gives the following account of an earthquake of an extraordinary kind. "When Lucius Marcus and Sextus Julius were consuls there appeared a very strange prodigy of the earth, (as I have read in the books of the Ætruscan discipline,) which happened in the province of Mutina. Two mountains shocked against each other, approaching and retiring with the most dreadful noise. They at the same time, and in the midst of the day, appeared cast forth fire and smoke, while a vast number of Roman knights and travellers from the Æmilian Way, stood and continued amazed spectators. Several

crusts, while it was consolidating, by breaking and displacing its parts, and may have been one cause of the confused and fractured appearance of the primitive rocks. The same phenomena must exist even yet in the interior of the earth, but its influence must be extremely feeble. The rents and fractures produced still by contractions, especially in the interior, and perhaps still more the gaseous matter disengaged during refrigeration (as the phenomena of volcanoes prove,) but kept pent up within the exterior shell exposed to an excessive temperature, explain the origin of earthquakes. These are most frequent in the regions of the globe where we would expect the crust to be thinnest, and the operation of the disturbing causes most violent. In all probability, it is the gaseous matter disengaged from the rocks during refrigeration that impregnates those mineral springs, in which a portion of such matter exists. M. Cordier observes that these springs should have been more numerous in early ages, and various phenomena he thinks announce that this was the case. The gradual refrigeration of the earth explains other facts which have perplexed philosophers. It accounts, for instance, for so large a portion of fossil plants and animals found in cold countries, having the characters of those species which now belong to the tropics. Again, it has been observed, that the land surrounding the upper parts of the Baltic has risen from two to three feet within a century, while the French *savans* have inferred from certain marks at the ruins of Tanis in Egypt, that the African continent is subsiding at the rate of a foot in a century. Considering all large portions of land as solid masses floating over a liquid abyss, and receiving unequal additions from below, we can easily understand why one part may rise and another descend. Lastly, as the metals are undoubtedly mixed with the fluid mass below, and the whole in consequence of its fluidity may have certain slow regular motions within itself, we have a key to the mysterious phenomena of magnetism—the variation of dip and polarity."

1 Plin. lib. ii. cap. 86. 2 Ibid. lib. iii. cap. 85.

towns were destroyed by this shock; and all the animals that were near them were killed." In the times of Trajan, the city of Antioch, and a great part of the adjacent country, was buried by an earthquake. About three hundred years after, in the times of Justinian, it was once more destroyed, together with forty thousand inhabitants; and, after an interval of sixty years, the same ill-fated city was a third time overturned, with the loss of not less than sixty thousand souls. In the year 1182, most of the cities of Syria, and the kingdom of Jerusalem, were destroyed by the same accident. In the year 1594, the Italian historians describe an earthquake at Puteoli, which caused the sea to retire two hundred yards from its former bed.

But one of those most particularly described in history, is that of the year 1693; the damages of which were chiefly felt in Sicily, but its motion perceived in Germany, France, and England. It extended to a circumference of two thousand six hundred leagues; chiefly affecting the sea-coast and great rivers; more perceivable also upon the mountains than in the valleys. Its motions were so rapid, that those who lay at their length were tossed from side to side, as upon a rolling billow.[1] The walls were dashed from their foundations; and no less than fifty-four cities, with an incredible number of villages, were either destroyed or greatly damaged. The city of Catanea, in particular, was utterly overthrown. A traveller, who was on his way thither, at the distance of some miles, perceived a black cloud, like night, hanging over the place. The sea, all of a sudden, began to roar; Mount Ætna to send forth great spires of flame; and soon after a shock ensued, with a noise as if all the artillery in the world had been at once discharged. Our traveller, being obliged to alight, instantly felt himself raised a foot from the ground; and turning his eyes to the city, he, with amazement, saw nothing but a thick cloud of dust in the air. The birds flew about astonished: the sun was darkened; the beasts ran howling from the hills; and although the shock did not continue above three minutes, yet near nineteen thousand of the inhabitants of Sicily perished in the ruins.—Catanea, to which city the describer was travelling, seemed the principal scene of ruin; its place only was to be found; and not a footstep of its former magnificence was to be seen remaining.

The earthquake which happened in Jamaica, in 1692, was very terrible, and its description sufficiently minute. " In two minutes' time it destroyed the town of Port Royal, and sunk the houses in a gulf forty fathoms deep. It was attended with a hollow rumbling noise, like that of thunder; and, in less than a minute, three parts of the houses, and their inhabitants, were all sunk quite under water. While they were thus swallowed up on the one side of the street, on the other the houses were thrown into heaps ; the sand of the streets rising like the waves of the sea, lifting up those that stood upon it, and immediately overwhelming them in pits. All the wells discharged their waters with the most vehement agitation. The sea felt an equal share of turbulence, and, bursting over its mounds, deluged all that came in the way. The fissures of the earth were, in some places, so great, that one of the streets appeared twice as broad as formerly. In many places, however, it opened and closed again, and continued this agitation for some time. Of these openings, two or three hundred might be seen at a time; in some whereof the people were swallowed up ; in others, the earth closing, caught them by the middle, and thus crushed them instantly to death. Other openings, still more dreadful than the rest, swallowed up whole streets ; and others, more formidable, spouted up whole cataracts of water, drowning such as the earthquake had spared. The whole was attended with the most noisome stench ; while the thundering of the distant falling mountains, the whole sky overcast with a dusky gloom, and the crash of falling habitations, gave unspeakable horror to the scene. After this dreadful calamity was over, the whole island seemed converted into a scene of desolation ; scarcely a planter's house was left standing; almost all were swallowed up ; houses, people, trees, shared one universal ruin: and in their places appeared great pools of water, which when dried up by the sun, left only a plain of barren sand, without any vestige of former inhabitants. Most of the rivers, during the earthquake, were stopped up by the falling in of the mountains ; and it was not till after some time they made themselves new channels. The mountains seemed particularly attacked by the force of the shock ; and it was supposed that the principal seat of the concussion was among them. Those who were saved got on board ships in the harbour, where

... remained above two months; the shocks continuing, during that interval, with more or less violence every day."

As this description seems to exhibit all the appearances that usually make up the catalogue of terrors belonging to an earthquake, I will suppress the detail of that which happened at Lisbon in our own times, and which is too recent to require a description.* In fact there are few particulars in the accounts of

* Goldsmith here alludes to the great earthquake of 1755. It appears to have originated beneath the Atlantic Ocean, the waves of which received almost as violent a concussion as the land. Its effects were even extended to the waters in many places where the shocks were not perceptible. It pervaded the greater portions of the continents of Europe, Africa, and America; but its extreme violence was exercised on the south-western parts of the former. Lisbon, the Portuguese capital, had already suffered greatly from an earthquake in 1531; and, since the calamity about to be described, has had three such visitations, in 1761, 1765, and 1772, which were not however attended by equally disastrous consequences. In the present instance, it had been remarked, that, since the commencement of the year 1750, less rain had fallen than had been known in the memory of the oldest of their inhabitants, unless during the spring preceding the calamitous event. The summer had been unusually cool, and the weather fine and clear for the last forty days. At length, on the 1st of November, about forty minutes past nine in the morning, a most violent shock of an earthquake was felt; its duration did not exceed six seconds; but so powerful was the concussion, that it overthrew every church and convent in the city, together with the royal palace and the magnificent opera-house adjoined to it; in short, not any building of consequence escaped. About one fourth of the dwelling-houses were thrown down: and, at a moderate computation, 30,000 individuals perished. Between the 1st and 8th of November, twenty-two shocks were reckoned. This earthquake was also felt at Oporto, Cadiz, and other parts of Europe, and equally severe in Africa. A great part of the city of Algiers was destroyed. In many places of Germany the effects of this earthquake were very perceptible; but in Holland the agitations were still more remarkable. The agitation of the waters was also perceived in various parts of Great Britain and Ireland. At sea, the shocks of this earthquake were felt most violently. Among other catastrophes, the captain of the *Nancy* frigate, off St Lucar, felt his ship so violently shaken, that he thought she had struck the ground, but on heaving the lead, found she was in a great depth of water. The earthquakes in Sicily and the two Calabrias began on the 5th of February 1783, and continued until the latter end of the May following; doing infinite damage, and exhibiting at Messina, in the parts of Sicily nearest to the continent, and in the two Calabrias, a variety of phenomena. The earth was in a constant tremor, and its motions were various, being either vertical or whirling round,—horizontal or oscillatory, that is, by pulsations or beatings from the bottom upwards. There were many openings, or cracks in the earth; and several hills had been lowered, while others were quite level. In the plains, the chasms were so deep that many roads were rendered impassable. Huge mountains were

those who were present at that scene of desolation, that we have not more minutely and accurately transmitted to us by former writers, whose narratives I have for that reason preferred. I will therefore close this description of human calamities with the account of the dreadful earthquake at Calabria, in 1638. It is related by the celebrated Father Kircher, as it happened while he was on his journey to visit Mount Ætna, and the rest of the wonders that lie towards the south of Italy. I need scarcely inform the reader, that Kircher is considered, by scholars, as one of the greatest prodigies of learning.

" Having hired a boat, in company with four more, two friars of the order of St Francis, and two seculars, we launched, on the twenty-fourth of March, 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,

severed, and portions of them driven into the valleys, which were thus filled up. The total amount of the mortality occasioned by these earthquakes in Sicily and the two Calabrias, was, agreeably to the official returns, 32,367; but Sir William Hamilton thought it still greater, and carries his estimation to 40,000, including foreigners. The shocks felt since the commencement of these formidable earthquake amounted to several hundreds; and among the most violent may be reckoned the one which happened on the 28th of March. It affected most of the higher parts of Upper Calabria, and the inferior part of Lower Calabria, being equally tremendous with the first. Indeed these shocks were the only ones sensibly felt in the capital, Naples. With relation to the former, two singular phenomena are recorded. At a distance of about three miles from the ruined city of Oppido, in Upper Calabria, was a hill, having a sandy and clayey soil, nearly 400 feet in height, and nearly 900 feet in circumference at its base. This hill is said to have been carried to the distance of about four miles from the spot where it stood, into a plain called Campo de Bassano. At the same time, the hill on which the city of Oppido stood, and which extended about three miles, divided into two parts, being situated between two rivers, its ruins filled up the valley, and stopped their course, forming two large lakes, which augmented daily. By the earthquake experienced in Chili in 1822, a great line of coast is stated to have been lifted permanently up to the height of several feet above its former level: and it deserves remark, that though earthquakes are sometimes felt in the interior of countries, their most terrible effects occur chiefly along the coast. On the 2d March, 1825, the city of Algiers was visited with a tremendous earthquake, which destroyed at least 10,000 human beings. It is worthy of remark, that the same phenomena which generally precedes the eruption of Ætna and Vesuvius, occured at Bluda, on this occasion; namely, all the wells and fountains in the neighbourhood became perfectly dry. The barometer had fallen gradually for some days before the earthquake; and the thermometer rose suddenly from 58 to $62\frac{1}{2}$ degrees on the day it happened.

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 for three days at Pelorus, upon account of the weather; and though we often put out to sea, yet we were as often driven back. At length, however, wearied with the delay, we resolved to prosecute our voyage; and, although the sea seemed more than usually agitated, yet we ventured forward. The gulf 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 whole island, and blotted out the very shores from my view. This, together with the dreadful noise, and the sulphureous 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; those 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 still 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 Tropæ, 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 of chariots driven fiercely 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 a 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, 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 were 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 greatest part of the town, and the inn at which we had set up, dashed to the ground, and burying all its inhabitants beneath its 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 Tropæ 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; Strombolo, 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 consequences; it every moment seemed to grow louder, and to approach more near. The place on which we stood now began to shake most dreadfully, so that being unable to stand, my companions and I caught hold of whatever shrub grew next 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, that 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 was passed away: then turning to look for the city, it was totally sunk. Wonderful to tell! nothing but a dismal and putrid lake was to be seen where it stood. We looked about to find some that could tell us of its sad catastrophe, but could see none! 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 some 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 induced to give us an answer. We intreated 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 loathe 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 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 reader, I hope, will excuse me for this long translation from a favourite writer, and that the sooner, as it contains some particulars relative to earthquakes not to be found elsewhere. From the whole of these accounts we may gather, that the most concomitant circumstances are these:

A rumbling sound before the earthquake. This proceeds from the air or fire, or both, forcing their way through the chasms of the earth, and endeavouring to get free; which is also heard in volcanoes.

A violent agitation or heaving of the sea, sometimes before and sometimes after that at land. This agitation is only a similar effect produced on the waters with that at land, and may be called, for the sake of perspicuity, a *seaquake;* and this also is produced by volcanoes.

A spouting up of waters to great heights. It is not easy to describe the manner in which this is performed: but volcanoes also perform the same; Vesuvius being known frequently to eject a vast body of water.

A rocking of the earth to and fro, and sometimes a perpendicular bouncing, if it may be so called, of the same. This difference chiefly arises from the situation of the place with respect to the subterranean fire. Directly under, it lifts; at a farther distance, it rocks.

Some earthquakes seem to travel onward, and are felt in different countries at different hours the same day. This arises from the great shock being given to the earth at one place, and that being communicated onward by an undulatory motion, successively affects different regions in its progress; as the blow given by a stone falling in a lake, is not perceived at the shores till some time after the first concussion.

The shock is sometimes instantaneous, like the explosion of gunpowder; and sometimes tremulous, and continuing for several minutes. The nearer the place where the shock is first given, the more instantaneous and simple it appears. At a greater distance, the earth redoubles the first blow with a sort of vibratory continuation.

As waters have generally so great a share in producing earthquakes, it is not to be wondered that they should generally follow those breaches made by the force of fire, and appear in the great chasms which the earthquake has opened.

These are some of the most remarkable phenomena of earthquakes, presenting a frightful assemblage of the most terrible effects of air, earth, fire, and water.

The valley of Solfatara, near Naples, seems to exhibit, in a minuter degree, whatever is seen of this horrible kind on the great theatre of nature. This plain, which is about twelve hundred feet long, and a thousand broad, is embosomed in mountains, and has in the middle of it a lake of noisome blackish water, covered with a bitumen, that floats upon its surface. In every part of this plain, caverns appear smoking with sulphur, and often emitting flames. The earth, wherever we walk over it, trembles beneath the feet. Noises of flames, and the hissing of waters, are heard at the bottom. The water sometimes spouts up eight or ten feet high. The most noisome fumes, fœtid water, and sulphureous vapours, offend the smell. A stone thrown into any of the caverns, is ejected again with considerable violence. These appearances generally prevail, when the sea is any way disturbed; and the whole seems to exhibit the appearance of an earthquake in miniature. However, in this smaller scene of wonders, as well as in the greater, there are many appearances for which, perhaps, we shall never account; and many questions may be asked, which no conjectures can thoroughly resolve. It was the fault of the philosophers of the last age, to be more inquisitive after the causes of things than after the things themselves. They seemed to think that a confession of ignorance cancelled their claims to wisdom; they, therefore, had a solution for every demand. But the present age has grown, if not more inquisitive, at least more modest; and none are now ashamed of that ignorance, which labour can neither remedy nor remove.

CHAP. XI.

OF THE APPEARANCE OF NEW ISLANDS AND TRACTS; AND OF THE DISAPPEARING OF OTHERS.

Hitherto we have taken a survey only of the evils which are produced by subterranean fires, but we have mentioned nothing of the benefits they may possibly produce. They may be of use in warming and cherishing the ground, in promoting vegetation, and giving a more exquisite flavour to the productions of the earth. The imagination of a person who has never been out of our own mild region, can scarcely reach to that luxuriant beauty with which all nature appears clothed in those very countries that we have but just now described as desolated by earthquakes, and undermined by subterranean fires. It must be granted, therefore, that though in those regions they have a greater share in the dangers, they have also a larger proportion in the benefits of nature.

But there is another advantage arising from subterranean fires, which, though hitherto disregarded by man, yet may one day become serviceable to him; I mean, that while they are found to swallow up cities and plains in one place, they are also known to produce promontories and islands in another. We have many instances of islands being thus formed in the midst of the sea, which though for a long time barren, have afterwards become fruitful seats of happiness and industry.

New islands are formed in two ways: either suddenly, by the action of subterraneous fires; or more slowly, by the deposition of mud, carried down by rivers, and stopped by some accident.[1] With respect particularly to the first, ancient historians, and modern travellers, give us such accounts as we can have no room to doubt of. Seneca assures us, that in his time the island of Therasia appeared unexpectedly to some mariners, as they were employed in another pursuit. Pliny assures us, that thirteen islands in the Mediterranean appeared at once emerging from the water; the cause of which he ascribes rather to the retiring of the sea in those parts, than to any subterraneous elevation. However, he mentions the island of Hiera, near that of Therasia, as formed by subterraneous explosions; and adds to his list several others formed in the same manner. In one of which he relates that fish in great abundance were found, and that all those who ate of them died shortly after.

"On the twenty-fourth of May,[2] in the year 1707, a slight earthquake was perceived at Santorin; and the day following, at sun-rising, an object was seen by the inhabitants of that island, at two or three miles distance at sea, which appeared like a floating rock. Some persons, desirous either of gain, or incited by curiosity, went there, and found, even while they stood upon this rock, that it seemed to rise beneath their feet. They perceived also, that its surface was covered with pumice-stones and oysters, which it had raised from the bottom. Every day after, until the fourteenth of June, this rock seemed considerably to increase; and then was found to be half a mile round, and about thirty feet above the sea. The earth of which it was composed seemed whitish, with a small proportion of clay. Soon after this the sea again appeared troubled, and streams arose which

1 Buffon, vol ii. p. 343. 2 Hist. de l'Acad. an. 1708. p. 23.

were very offensive to the inhabitants of Santorin. But on the sixteenth of the succeeding month, seventeen or eighteen rocks more were seen to rise out of the sea, and at length to join together. All this was accompanied with the most terrible noise, and fires which proceeded from the island that was newly formed. The whole mass, however, of all this new formed earth, uniting, increased every day, both in height and breadth, and, by the force of its explosions, cast forth rocks to seven miles distance. This continued to bear the same dreadful appearances till the month of November in the same year; and it is at present a volcano, which sometimes renews its explosions. It is about three miles in circumference; and more than from thirty-five to forty feet high."

It seems extraordinary, that, about this place in particular, islands have appeared at different times, particularly that of Hiera, mentioned above, which has received considerable additions in succeeding ages. Justin tells us,[1] that at the time the Macedonians were at war with the Romans, a new island appeared between those of Theramenes and Therasia, by means of an earthquake. We are told that this became half as large again about a thousand years after, another island rising up by its side, and joining to it, so as scarcely at present to be distinguished from the former.

A new island was formed, in the year 1720, near that of Tercera, near the continent of Africa, by the same causes. In the beginning of December, at night, there was a terrible earthquake at that place, and the top of a new island appeared, which cast forth smoke in vast quantities. The pilot of a ship, who approached it, sounded on one side of this island, and could not find ground at sixty fathom : at the other side, the sea was totally tinged of a different colour, exhibiting a mixture of white, blue, and green ; and was very shallow. This island, on its first appearance, was larger than it is at present ; for it has since that time sunk in such a manner, as to be scarcely above water.[2]

1 Justin, lib. xxx. cap. 4.

2 In the spring of 1783, a volcanic island was formed about 30 miles from the south-west point of Iceland. The discoverer, Captain Von Lowenhorn, in the Danish service, who arrived just at the time of the first eruption, when smoke and flames ascended out of the sea, relates that no island or any land could be seen, from which these flames could originate. No wonder,

A traveller, whom these appearances could not avoid affecting, speaks of them in this manner.[3] "What can be more surprising than to see fire not only break out of the bowels of the earth, but also to make itself a passage through the waters of the sea! What can be more extraordinary, or foreign to our common notions of things, than to see the bottom of the sea rise up into a mountain above the water, and to become so firm an island as to be able to resist the violence of the greatest storms. I know that subterraneous fires, when pent in a narrow passage are able to raise up a mass of earth as large as an island: but that this should be done in so regular and exact a manner, that the water of the sea should not be able to penetrate and extinguish those fires; that after having made so many passages, they should retain force enough to raise the earth; and, in fine, after having been extinguished, that the mass of earth should not fall down, or sink again with its own weight, but still remain in a manner suspended over the great arch below! This is what to me seems more surprising than any thing that has been related of Mount Ætna, Vesuvius, or any other volcano."

Such are his sentiments: however, there are few of these appearances any way more extraordinary than those attending volcanoes and earthquakes in general. We are not more to be surprised that inflammable substances should be found beneath the bottom of the sea, than at similar depths at land. These have all the force of fire giving expansion to air, and tending to raise the earth at the bottom of the sea, till it at length heaves above water. These marine volcanoes are not so frequent; for, if we may judge of the usual procedure of nature, it must very often happen, that before the bottom of the sea is elevated above the surface, a chasm is opened in it, and then the water pressing in, extinguishes the volcano before it has time to pro-

then, that he fell into the greatest consternation, when, as he expresses himself, he saw the waves on fire. The following year, the Danish governmen directed, that all ships bound to Iceland should examine the new-formed island; but so entirely had it vanished, that none of them either saw or could discover the smallest trace of it. However, towards the end of the next year, a Danish ship of war, of 64 guns, was wrecked on this rock; which is now no longer visible, but remains a most dangerous rock nearly level with the surface of the water.

3 Phil. Trans. vol v. p. 197.

duce its effects. This extinction, however, is not effected without very great resistance from the fire beneath. The water, upon dashing into the cavern, is very probably at first ejected back with great violence; and thus some of those amazing water-spouts are seen, which have so often astonished the mariner, and excited curiosity. But of these in their place.

Besides the production of those islands by the action of fire, there are others, as was said, produced by rivers or seas carrying mud, earth, and such like substances, along with their currents; and at last depositing them in some particular place.* At the mouths of most great rivers, there are to be seen banks, thus formed by the sand and mud carried down by the stream, which have rested at that place, where the force of the current is diminished by its junction with the sea. These banks, by slow degrees, increase at the bottom of the deep: the water in those places is at first found by mariners to grow more shallow; the bank soon heaves up above the surface; it is considered, for a while, as a tract of useless and barren sand; but the seeds of some of the more hardy vegetables are driven thither by the

* Islands of coral are also formed in tropical regions. Coral is the produce of different species of vermes or worms, and it consists chiefly of carbonate of lime. Now it is difficult to conceive where these animals procure such prodigious quantities of this substance. Sea-water indeed contains traces of sulphate of lime, but no other calcareous salt, as far as is known. Hence it would appear, that these creatures must either decompose sulphate of lime, though the quantity of that salt contained in sea-water seems inadequate to supply their wants, or they must form carbonate of lime from the constituents of sea-water in a way totally above our conception. Be that as it may, there is one consequence of this copious formation of coral in the tropical regions of considerable importance to navigation. The winds and waves accumulate these corals in large banks, which, entangling the sand, gradually rise above the surface of the waves, and form islands. These, in process of time, probably by the agency of birds, become covered with vegetation, and frequently loaded with timber. Mr Ellis, in his history of zoophytes, supposes that the greater part of these numerous islands in the South Sea, have been formed by coral, rising above the surface of the water. The bottom of these islands is nothing else than a coral bank; the surface is a black soil, formed of a mixture of sand and decayed vegetable matter; the whole island is flat, long, and narrow; and extends usually in its greatest length from north to south, because almost all winds between the tropics blow either from the east or the west. The sides of these islands frequently constitute a perpendicular wall; and the sea, at a little distance from them, is of an unfathomable depth.

wind, take root, and thus binding the sandy surface, the whole spot is clothed in time with a beautiful verdure. In this manner there are delightful and inhabited islands at the mouths of many rivers, particularly the Nile, the Po, the Mississippi, the Ganges, and the Senegal. There has been, in the memory of man, a beautiful and large island formed in this manner at the mouth of the river Nanquin, in China, made from depositions of mud at its opening: it is not less than sixty miles long, and about twenty broad. La Loubere informs us,[1] in his voyage to Siam, that these sand-banks increase every day, at the mouths of all the great rivers in Asia; and hence, he asserts, that the navigation up these rivers becomes every day more difficult, and will, at one time or other, be totally obstructed. The same may be remarked with regard to the Wolga, which has at present seventy openings into the Caspian sea; and of the Danube, which has seven into the Euxine. We have had an instance of the formation of a new island not very long since at the mouth of the Humber, in England. "It is yet within the memory of man," says the relator,[2] "since it began to raise its head above the ocean. It began its appearance at low water, for the space of a few hours, and was buried again till the next tide's retreat. Thus successively it lived and died, until the year 1666, when it began to maintain its ground against the insult of the waves, and then first invited the aid of human industry. A bank was thrown about its rising grounds, and being thus defended from the incursions of the sea, it became firm and solid, and, in a short time, afforded good pasturage for cattle. It is about nine miles in circumference, and is worth to the proprietor about eight hundred pounds a year." It would be endless to mention all the islands that have been thus formed, and the advantages that have been derived from them. However, it is frequently found, that new islands may often be considered as only turning the rivers from their former bed; so that in proportion as land is gained at one part, it is lost by the overflowing of some other.

Little, therefore, is gained by such accession; nor is there much more by the new islands which are sometimes formed from

1 Lettres Curieuses et Edifiantes, sec. xi. p. 234.

2 Phil. Trans. vol. iv. p. 251.

the spoils of the continent. Mariners assure us, that there are sometimes whole plains unrooted from the main lands, by floods and tempests. These being carried out to sea, with all their trees and animals upon them, are frequently seen floating in the ocean, and exhibiting a surprising appearance of rural tranquillity in the midst of danger. The greatest part, however, having the earth at their roots at length washed away, are dispersed and their animals drowned; but now and then some are found to brave the fury of the ocean, till being stuck either among rocks or sands, they again take firm footing, and become permanent islands.

As different causes have thus concurred to produce new islands, so we have accounts of others, that the same causes have contributed to destroy. We have already seen the power of earthquakes exerted in sinking whole cities, and leaving lakes in their room. There have been islands, and regions also, that have shared the same fate; and have sunk with their inhabitants never more to be heard of. Thus Pausanias[1] tells us of an island called Chryses, that was sunk near Lemnos. Pliny mentions several; among others, the island of Cea, for thirty miles, having been washed away, with several thousands of its inhabitants. But of all the noted devastations of this kind, the total submersion of the island of Atalantis, as mentioned by Plato, has been most the subject of speculation. Mankind, in general, now consider the whole of his description as an ingenious fable; but when fables are grown famous by time and authority, they become an agreeable, if not a necessary, part of literary information.

" About nine thousand years are passed," says Plato,[2] "since the island of Atalantis was in being. The priests of Egypt were well acquainted with it; and the first heroes of Athens gained much glory in their wars with the inhabitants. This island was as large as Asia Minor and Syria united; and was situated beyond the Pillars of Hercules, in the Atlantic ocean. The beauty of the buildings, and the fertility of the soil, were far beyond any thing a modern imagination can conceive: gold

1 Pausanias, l. 8. in Arcad. p. 505.
2 Plato in Critia.

and ivory were every where common; and the fruits of the earth offered themselves without cultivation. The arts and the courage of the inhabitants were not inferior to the happiness of their situation; and they were frequently known to make conquests, and overrun the continents of Europe and Asia." The imagination of the poetical philosopher riots in the description of the natural and acquired advantages, which they long enjoyed in this charming region. "If," says he, "we compare that country to our own, ours will appear a mere wasted skeleton, when opposed to it. Their mountains, to the very tops, were clothed with fertility, and poured down rivers to enrich the plains below."

However, all these beauties and benefits were destroyed in one day by an earthquake sinking the earth, and the sea overwhelming it. At present not the smallest vestiges of such an island are to be found; Plato remains as the only authority for its existence; and philosophers dispute about its situation. It is not for me to enter into the controversy, when there appears but little probability to support the fact; and, indeed, it would be useless to run back nine thousand years in search of difficulties, as we are surrounded with objects that more closely affect us, and that demand admiration at our very doors. When I consider, as Lactantius suggests, the various vicissitudes of nature; lands swallowed by yawning earthquakes, or overwhelmed in the deep; rivers and lakes disappearing, or dried away; mountains levelled into plains; and plains swelling up into mountains; I cannot help regarding this earth as a place of very little stability; as a transient abode of still more transitory beings.

CHAP. XII.

OF MOUNTAINS.

Having at last, in some measure, emerged from the deeps of the earth, we come to a scene of greater splendour; the contemplation of its external appearance. In this survey, its mountains are the first objects that strike the imagination, and excite our curiosity. There is not, perhaps, any thing in all nature that impresses an unaccustomed spectator with such ideas of awful solemnity, as these immense piles of Nature's erecting, that seem to mock the minuteness of human magnificence.

In countries where there are nothing but plains, the smallest elevations are apt to excite wonder. In Holland, which is all a flat, they show a little ridge of hills, near the sea-side, which Boerhaave generally marked out to his pupils, as being mountains of no small consideration. What would be the sensations of such an auditory, could they at once be presented with a view of the heights and precipices of the Alps or the Andes! Even among us in England, we have no adequate ideas of a mountain-prospect; our hills are generally sloping from the plain, and clothed to the very top with verdure: we can scarcely, therefore, lift our imaginations to those immense piles, whose tops peep up behind intervening clouds, sharp and precipitate, and reach to heights that human avarice or curiosity have never been able to ascend.

We, in this part of the world, are not, for that reason, so immediately interested in the question which has so long been agitated among philosophers, concerning what gave rise to these inequalities on the surface of the globe. In our own happy region, we generally see no inequalities but such as contribute to use and beauty; and we therefore are amazed at a question, inquiring how such necessary inequalities came to be formed, and seeming to express a wonder how the globe comes to be so beautiful as we find it. But though with us there may be no great cause for such a demand, yet in those places where mountains deform the face of nature, where they pour down cataracts, or give fury to tempests, there seems to be good reason for inquiry either into their causes or their uses. It has been, therefore, asked by many, in what manner mountains have come to be formed; or for what uses they are designed?

To satisfy curiosity in these respects, much reasoning has been employed, and very little knowledge propagated. With regard to the first part of the demand, the manner in which mountains were formed, we have already seen the conjectures of different philosophers on that head. One supposing that they were formed from the earth's broken shell at the time of the deluge; another, that they existed from the creation, and only acquired their deformities in process of time; a third, that they owed their original to earthquakes; and still a fourth, with much more plausibility than the rest, ascribing them entirely to the fluctuations of the deep, which he supposes in the beginning to have covered the whole earth. Such as are pleased with disquisitions of this kind, may consult Burnet, Whiston, Woodward, or Buffon. Nor would I be thought to decry any mental amusements, that at worst keep us innocently employed; but, for my own part, I cannot help wondering how the opposite demand has never come to be made; and why philosophers have never asked how we come to have plains? Plains are sometimes more prejudicial to man than mountains. Upon plains, an inundation has greater power; the beams of the sun are often collected there with suffocating fierceness; they are sometimes found desert for several hundred miles together, as in the country east of the Caspian sea, although otherwise fruitful, merely because there are no risings or depressions to form reservoirs, or collect the smallest rivulet of water. The most rational answer, therefore, why either mountains or plains were formed, seems to be that they were thus fashioned by the hand of Wisdom, in order that pain and pleasure should be so contiguous, as that morality might be exercised either in bearing the one, or communicating the other.

Indeed, the more I consider this dispute respecting the formation of mountains, the more I am struck with the futility of the question. There is neither a straight line, nor an exact superficies, in all nature. If we consider a circle, even with mathematical precision, we shall find it formed of a number of small right lines, joining at angles, together. These angles, therefore, may be considered in a circle as mountains are upon our globe; and to demand the reason for the one being mountainous, or the other angular, is only to ask, why a circle is a circle, or a globe is a globe. In short, if there be no surface without inequality in nature, why should we be surprised that the earth has such? It has often been said, that the inequalities of its surface are scarce distinguishable, if compared to its magnitude; and I think we have every reason to be content with the answer.

Some, however, have avoided the difficulty by urging the final cause. They allege, that mountains have been formed merely because they are useful to man. This carries the inquirer but a part of the way; for no one can affirm, that in all places they are useful. The contrary is known by horrid experience, in those valleys that are subject to their influence. However, as the utility of our earthly habitation is a very pleasing and flattering speculation to every philosopher, it is not to be wondered that much has been said to prove the usefulness of these. For this purpose many conjectures have been made, that have received a degree of assent even beyond their evidence; for men were unwilling to become more miserably wise.

It has been alleged, as one principal advantage that we derive from them, that they serve like hoops or ribs, to strengthen our earth, and to bind it together. In consequence of this theory, Kircher has given us a map of the earth, in this manner hooped with its mountains; which might have a much more solid foundation, did it entirely correspond with truth.*

* According to Werner, the rocks of which this globe is composed, as far as they have been penetrated below the surface, amount to 36, and they all occupy a determinate position with respect to each other. They extend round the whole earth, and inclose the central nucleus like the coats of an onion. Not that they are every where spherical, or uninterrupted: partly owing to inequalities in the centre nucleus, over which they are deposited, and partly to other causes, they rise higher in one place, and sink lower in another, sometimes slowly, and sometimes abruptly; and they are entirely wanting in many particular spots, having either never been deposited, or having been removed and carried away by some unknown cause. The position of the different rocks being thus constant, has been pitched upon as the basis of the classification of them. They have been divided into five classes; and the term *formation* has been applied to them, from the supposition that each class has been formed about the same time. Those rocks which lie lowest down, or nearest the central nucleus, belong to the first or primitive formation; and those which lie highest up, or immediately at the surface, belong to the fourth or latest formation; for the fifth formation includes only the volcanic matters, and of course is confined to particular spots. The names of the formations are as follow: 1. Primitive. 2. Transition. 3. Floetz. 4. Alluvial. 5. Volcanic. We are not to suppose, however, that the rocks belonging to the primitive formation are always at a great depth below the surface. On the contrary, they frequently constitute mountains; and the highest mountains on the surface of the earth are composed of them. In these cases we must suppose the subsequent formations either never to have been deposited, or to have been removed and carried off by some unknown means. In like manner, the transition and floetz formations often constitute mountains, and appear at the surface; and this must be accounted for in the same way. The primitive formation consists of rocks which follow others in succession in the or-

Others have found a different use for them, especially when they run surrounding our globe; which is, that they stop the vapours that are continually travelling from the equator to the poles; for these being urged by the heat of the sun, from the warm regions of the line, must all be accumulated at the poles, if they were not stopped in their way by those high ridges of mountains which cross their direction. But an answer to this may be, that

der of their names, beginning with the lowest. These are as follow: 1. Granite. 2. Gneiss. 3. Mica-slate. 4. Clay-slate. 5. Porphyry and Sienite. Alternating with gneiss, mica-slate, and clay-slate, there occur beds of several other rocks, which being of no great extent compared with being frequently repeated, have been termed *subordinate* formations. These are primitive lime-stone, primitive trap, quartz, fluity-slate, and gypsum. Along with porphyry and sienite, occur serpentine and granite. Primitive rocks contain no petrifactions. They constitute the highest mountains on the face of the earth. They are evidently chemical compounds, and contain no minerals, which show themselves to have been mechanical depositions. They must have been formed before the earth was inhabited. The transition formation consists, likewise, of five classes of rocks, only one of which, namely, *grey wacke*, is peculiar to it, and characterises it. These rocks are as follow: Transition lime-stone. 2. Grey wacke, and grey wacke-slate. 3. Transition trap. 4. Transition fluity-slate. 5. Transition gypsum. Professor Jameson has likewise discovered porphyry and granite among transition rocks. These rocks contain petrifactions of animals and vegetables; but they are of the lowest order, both of animals and vegetables, and generally consist of species which can be no longer found in a recent state. Hence these rocks must have been formed after the earth contained both animals and vegetables. The floetz formation occurs in a level country, and is usually covered by soil. As far as geological knowledge at present goes, it is known to consist of, 1. Sand-stone. Of this there are various formations; three, at least, have been ascertained. The lowest of all is red, and distinguished by the name of *old red sand-stone*. 2. Lime-stone. Of this also there are at least three formations, if we include chalk, the position of which is not very well understood. 3. Floetz gypsum. Of this there are two formatioos, one of which is distinguished by alternating with rock-salt. 4. Floetz-trap. This consists of green stone, and was first observed by Professor Jamesoo, in his examination of Dumfriesshire. 5. Independent coal. This formation, besides coal which characterises it, contains a variety of other rocks, in beds chiefly sand-stone, green-stone, clay, iron-stone, lime-stone, and shale. 6. Newest floetz-trap. This formation generally caps the hills in those countries where it occurs. It consists of basalt, wacke, grey-stone, porphyry-slate, green-stone, trap-tuff, clay-stone, sand-stone, &c. The floetz formations abound in petrifactions, and in mechanical depositions. Most of the metallic ores occur in the primitive and transition formations. The alluvial formation consists of the loose soil, gravel, sand, moss, &c. which cover the surface of the earth, and the volcanic formations consist of the ashes and lavas vomited out of volcanoes.

all the great mountains in America lie lengthwise, and therefore do not cross their direction.

But to leave these remote advantages, others assert, that not only the animal but vegetable part of the creation would perish for want of convenient humidity, were it not for their friendly assistance. Their summits are, by these, supposed to arrest, as it were, the vapours which float in the regions of the air. Their large inflections and channels are considered as so many basons prepared for the reception of those thick vapours, and impetuous rains, which descend into them. The huge caverns beneath are so many magazines or conservatories of water for the peculiar service of man: and those orifices by which the water is discharged upon the plain, are so situated as to enrich and render them fruitful, instead of returning through subterraneous channels to the sea, after the performance of a tedious and fruitless circulation.[1]

However this be, certain it is, that almost all our great rivers find their source among mountains; and, in general, the more extensive the mountain, the greater the river: thus the river Amazon, the greatest in the world, has its source among the Andes, which are the highest mountains on the globe; the river Niger travels a long course of several hundred miles from the Mountains of the Moon, the highest in all Africa; and the Danube and the Rhine proceed from the Alps, which are probably the highest mountains of Europe.

It needs scarcely be said, that, with respect to height, there are many sizes of mountains, from the gently rising upland, to the tall craggy precipice. The appearance is in general different in those of different magnitudes. The first are clothed with verdure to the very tops, and only seem to ascend to improve our prospects, or supply us with a purer air: but the lofty mountains of the other class have a very different aspect. At a distance their tops are seen, in wavy ridges, of the very colour of the clouds, and only to be distinguished from them by their figure; which, as I have said, resembles the billows of the sea.[2] As we approach, the mountain assumes a deeper colour; it gathers upon the sky, and seems to hide half the horizon behind it. Its summits also are become more distinct, and appear with

1 Nature Displayed, vol. iii. p. 88.

2 Lettres Philosophiques sur la Formation, &c. p. 166.

a broken and perpendicular line. What at first seemed a single hill, is now found to be a chain of continued mountains, whose tops running along in ridges, are embosomed in each other: so that the curvatures of one are fitted to the prominences of the opposite side, and form a winding valley between, often of several miles in extent; and all the way continuing nearly of the same breadth.

Nothing can be finer, or more exact, than Mr Pope's description of a traveller straining up the Alps. Every mountain he comes to, he thinks will be the last; he finds, however, an unexpected hill rise before him; and that being scaled, he finds the highest summit almost at as great distance as before. Upon quitting the plain, he might have left a green and fertile soil, and a climate warm and pleasing. As he ascends, the ground assumes a more russet colour; the grass becomes more mossy, and the weather more moderate. Still as he ascends, the weather becomes more cold, and the earth more barren. In this dreary passage he is often entertained with a little valley of surprising verdure, caused by the reflected heat of the sun collected into a narrow spot on the surrounding heights. But it much more frequently happens that he sees only frightful precipices beneath, and lakes of amazing depths; from whence rivers are formed, and fountains derive their original. On those places next the highest summits, vegetation is scarcely carried on; here and there a few plants of the most hardy kind appear. The air is intolerably cold; either continually refrigerated with frosts, or disturbed with tempests. All the ground here wears an eternal covering of ice, and snows that seem constantly accumulating. Upon emerging from this war of the elements, he ascends into a purer and a serener region, where vegetation is entirely ceased; where the precipices, composed entirely of rocks, rise perpendicularly above him; while he views beneath him all the combat of the elements; clouds at his feet, and thunders darting upwards from their bosoms below.[3] A thousand meteors, which are never seen on the plain, present themselves. Circular rainbows;[4] mock suns; the shadow of the mountain projected upon the body of the air;[5] and the traveller's own image reflected as in a looking-glass, upon the opposite cloud.[6]

3 Ulloa, vol i.
4 Ibid.
5 Phil. Trans. vol. v. p. 152.
6 Ulloa, vol

Such are, in general, the wonders that present themselves to a traveller in his journey either over the Alps or the Andes. But we must not suppose that this picture exhibits either a constant or an invariable likeness of those stupendous heights. Indeed, nothing can be more capricious or irregular than the forms of many of them. The tops of some run in ridges for a considerable length, without interruption; in others, the line seems indented by great valleys to an amazing depth. Sometimes a solitary and a single mountain rises from the bosom of the plain; and sometimes extensive plains, and even provinces, as those of Savoy and Quito, are found embosomed near the tops of mountains. In general, however, those countries that are most mountainous, are the most barren and uninhabitable.

If we compare the heights of mountains with each other, we shall find that the greatest and highest are found under the line.[1] It is thought by some, that the rapidity of the earth's motion in these parts, together with the greatness of the tides there, may have thrown up those stupendous masses of earth. But, be the cause as it may, it is a remarkable fact, that the inequalities of the earth's surface are greatest there. Near the poles, the earth, indeed, is craggy and uneven enough; but the heights of the mountains there are very inconsiderable. On the contrary, at the equator, where nature seems to sport in the amazing size of all her productions, the plains are extensive, and the mountains remarkably lofty. Some of them are known to rise three miles perpendicular above the bed of the ocean.*

To enumerate the most remarkable of these, according to their size, we shall begin with the Andes, of which we have an excellent description by Ulloa, who went thither by command of the king of Spain, in company with the French Academicians, to measure a degree of the meridian. His journey up these mountains is too curious not to give an extract from it.

After many incommodious days' sailing up the river Guayaquil, he arrived at Caracol, a town situated at the foot of the Andes. Nothing could exceed the inconveniences which he experienced in this voyage, from the flies and moschetoes (an animal resembling our gnat). "We were the whole day," says he, "in con-

1 Buffon, passim.

* See Plate iv. for a view of the absolute and relative heights of the most prominent mountains in the world.

tinual motion to keep them off; but at night our torments were excessive. Our gloves, indeed, were some defence to our hands; but our faces were entirely exposed; nor were our clothes a sufficient defence for the rest of our bodies; for their stings penetrating through the cloth, caused a very painful and fiery itching. One night, in coming to an anchor near a large and handsome house that was uninhabited, we had no sooner seated ourselve in it, than we were attacked on all sides by swarms of moschetoes, so that it was impossible to have one moment's quiet. Those who had covered themselves with clothes made for this purpose, found not the smallest defence: wherefore, hoping to find some relief in the open fields, we ventured out, though in danger of suffering in a more terrible manner from the serpents. But both places were equally obnoxious. On quitting this inhospitable retreat, we the next night took up our quarters in a house that was inhabited; the host of which being informed of the terrible manner we had past the night before, gravely told us, that the house we so greatly complained of, had been foresaken on account of its being the purgatory of a soul. But we had more reason to believe that it was quitted on account of its being the purgatory of the body. After having journeyed for upwards of three days, through boggy roads, in which the mules at every step sunk up to their bellies, we began at length to perceive an alteration in the climate; and having been long accustomed to heat, we now began to feel it grow sensibly colder.

"It is remarkable, that at Tariguagua we often see instances of the effects of two opposite temperatures, in two persons happening to meet: one of them leaving the plains below, and the other descending from the mountains. The former thinks the cold so severe, that he wraps himself up in all the garments h can procure; while the latter finds the heat so great, that he is scarce able to bear any clothes whatsoever. The one thinks the water so cold, that he avoids being sprinkled by it; the other is so delighted with its warmth, that he uses it as a bath. Nor is he case very different in the same person, who experiences the same diversity of sensation upon his journey up, and upon his return. This difference only proceeds from the change naturally felt at leaving a climate to which one has been accustomed, and coming into another of an opposite temperature.

" The ruggedness of the road from Teriguagua, leading up the mountain, is not easily described. In some parts the declivity is so great, that the mules can scarcely keep their footing; and in others, the acclivity is equally difficult. The trouble of having people going before to mend the road, the pains arising from the many falls and bruises, and the being constantly wet to the skin, might be supported, were not these inconveniences augmented by the sight of such frightful precipices, and deep abysses, as must fill the mind with ceaseless terror. There are some places where the road is so steep, and yet so narrow, that the mules are obliged to slide down, without making any use of their feet whatsoever. On one side of the rider, in this situation, rises an eminence of several hundred yards; and on the other, an abyss of equal depth; so that if he in the least checks his mule so as to destroy the equilibrium, they both must unavoidably perish.

" After having travelled about nine days in this manner, slowly winding along the side of the mountain, we began to find the whole country covered with a hoar frost; and a hut, in which we lay, had ice on it. Having escaped many perils, we at length, after a journey of fifteen days, arrived upon the plain, on the extremity of which stands the city of Quito, the capital of one of the most charming regions upon earth. Here, in the centre of the torrid zone, the heat is not only very tolerable, but in some places the cold also is painful. Here they enjoy all the temperature and advantages of perpetual spring; their fields being always covered with verdure, and enamelled with flowers of the most lively colours. However, although this beautiful region be higher than any other country in the world, and although it took up so many days of painful journey in the ascent, it is still overlooked by tremendous mountains; their sides covered with snow, and yet flaming with volcanoes at the top. These seemed piled one upon the other, and rise to a most astonishing height, with great coldness. However, at a determined point above the surface of the sea, the congelation is found at the same height in all the mountains. Those parts which are not subject to a continual frost, have here and there growing upon them a rush, resembling the genista, but much more soft and flexible. Towards the extremity of the part where the rush grows, and the cold begins to increase, is found a vegetable, with a round bulbous head, which, when dried, becomes of amazing elasticity. Higher up, the earth is entirely bare of vegetation, and seems covered with eternal snow. The most remarkable mountains are, that of Cotopaxi (already described as a volcano), Chimborazo, and Pichincha. Cotopaxi is more than three geographical miles above the surface of the sea: the rest are not much inferior. On the top of the latter was my station for measuring a degree of the meridian; where I suffered particular hardships from the intenseness of the cold, and the violence of the storms. The sky round was, in general, involved in thick fogs, which, when they cleared away, and the clouds, by their gravity, moved nearer to the surface of the earth, they appeared surrounding the foot of the mountain, at a vast distance below, like a sea, encompassing an island in the midst of it. When this happened, the horrid noises of tempests were heard from beneath, then discharging themselves on Quito, and the neighbouring country. I saw the lightnings issue from the clouds, and heard the thunders roll far beneath me. All this time, while the tempest was raging below, the mountain top, where I was placed, enjoyed a delightful serenity; the wind was abated; the sky clear; and the enlivening rays of the sun moderated the severity of the cold. However, this was of no very long duration, for the wind returned with all its violence, and with such velocity as to dazzle the sight; whilst my fears were increased by the dreadful concussions of the precipice, and the fall of enormous rocks; the only sounds that were heard in this frightful situation."

Such is the animated picture of these mountains, as given us by this ingenious Spaniard: and I believe the reader will wish that I had made the quotation still longer. A passage over the Alps, or a journey across the Pyrenees, appear petty trips or excursions in the comparison; and yet these are the most lofty mountains we know of in Europe.

If we compare the Alps with the mountains already described, we shall find them but little more than one half of the height of the former. The Andes, upon being measured by the barometer, are found above three thousand one hundred and thirty-six toises or fathoms above the surface of the sea.[1] Whereas the

1 Ulloa, vol. i. p. 442.

highest point of the Alps is not above sixteen hundred. The one, in other words, is above three miles high; the other about a mile and a half. The highest mountains in Asia are Mount Taurus, Mount Immaus, Mount Caucasus, and the mountains of Japan.* Of these, none equals the Andes in height; although Mount Caucasus, which is the highest of them, makes very near approaches. Father Verbiest tells of a mountain in China, which he measured, and found a mile and a half high.[1] In Africa, the mountains of the Moon, famous for giving source to the Niger and the Nile, are rather more noted than known. Of the Peak of Teneriffe, one of the Canary Islands that lie off this coast, we have more certain information. In the year 1727, it was visited by a company of English merchants, who travelled up to the top, where they observed its height, and the volcano on its very summit.[2] They found it a heap of mountains, the highest of which rises over the rest like a sugar-loaf, and gives a name to the whole mass. It is computed to be a mile and a half perpendicular from the surface of the sea. Kircher gives us an estimate of the heights of most of the other great mountains in the world; but as he has taken his calculations in general from the ancients, or from modern travellers, who had not the art of measuring them, they are quite incredible. The art of taking the heights of places by the barometer, is a new and an ingenious invention. As the air grows lighter as we ascend, the fluid in the tube rises in due proportion: thus the instrument being properly marked, gives the height with a tolerable degree of exactness; at least enough to satisfy curiosity.

Few of our great mountains have been estimated in this manner; travellers having, perhaps, been deterred, by a supposed impossibility of breathing at the top. However, it has been invariably found, that the air in the highest that our modern travellers have ascended, is not at all too fine for respiration. At the top of the Peak of Teneriffe, there was found no other inconvenience from the air, except its coldness; at the top of the

* The Himalaya Mountains between Hindostan and Thibet are ascertained to be the highest in the world. The Andes were till a late period considered to be the highest, but the most elevated peak, yet measured, of the Himalaya exceeds that of the Andes about 7000 feet.

1 Verbiest, a la Chine. 2 Phil. Trans. vol. v

Andes, there was no difficulty of breathing perceived. The accounts, therefore, of those who have asserted that they were unable to breathe, although at much less heights, are greatly to be suspected. In fact it is very natural for mankind to paint those obstacles as insurmountable, which they themselves have not had the fortitude or perseverance to surmount.

The difficulty and danger of ascending to the tops of mountains, proceeds from other causes, not the thinness of the air. For instance, some of the summits of the Alps have never yet been visited by man. But the reason is, that they rise with such a rugged and precipitate ascent, that they are utterly inaccessible. In some places they appear like a great wall of six or seven hundred feet high; in others, there stick out enormous rocks, that hang upon the brow of the steep, and every moment threaten destruction to the traveller below.

In this manner almost all the tops of the highest mountains are bare and pointed. And this naturally proceeds from their being so continually assaulted by thunders and tempests. All the earthy substances with which they might have been once covered, have for ages been washed away from their summits; and nothing is left remaining but immense rocks, which no tempest has hitherto been able to destroy.

Nevertheless, time is every day, and every hour, making depredations; and huge fragments are seen tumbling down the precipice, either loosened from the summit by frost or rains, or struck down by lightning. Nothing can exhibit a more terrible picture than one of these enormous rocks, commonly larger than a house, falling from its height, with a noise louder than thunder, and rolling down the side of the mountain. Doctor Plot tells us of one in particular, which being loosened from its bed, tumbled down the precipice, and was partly shattered into a thousand pieces. Notwithstanding, one of the largest fragments of the same, still preserving its motion, travelled over the plain below crossed a rivulet in the midst, and at last stopped on the other side of the bank! These fragments, as was said, are often struck off by lightning, and sometimes undermined by rains; but the most usual manner in which they are disunited from the mountain, is by frost: the rains insinuating between the interstices of the mountain, continue there until there comes a frost, and then, when converted into ice, the water swells with an irresistible force, and produces the same effect as gunpowder, splitting the most solid rocks, and thus shattering the summits of the mountain.

But not rocks alone, but whole mountains are, by various causes, disunited from each other. We see in many parts of the Alps, amazing clefts, the sides of which so exactly correspond with the opposite, that no doubt can be made of their having been once joined together. At Cajeta,[1] in Italy, a mountain was split in this manner by an earthquake; and there is a passage opened through it, that appears as if elaborately done by the industry of man. In the Andes these breaches are frequently seen. That at Thermopylæ, in Greece, has long been famous. The mountain of the Troglodytes, in Arabia, has thus a passage through it: and that in Savoy, which nature began, and which Victor Amadeus completed, is an instance of the same kind.

We have accounts of some of these disruptions, immediately after their happening. "In the month of June,[2] in the year 1714, a part of the mountain of Diableret, in the district of Valais, in France, suddenly fell down between two and three o'clock in the afternoon, the weather being very calm and serene. It was of a conical figure, and destroyed fifty-five cottages in the fall. Fifteen persons, together with about a hundred beasts, were also crushed beneath its ruins, which covered in extent a good league square. The dust it occasioned instantly covered all the neighbourhood in darkness. The heaps of rubbish were more than three hundred feet high. They stopped the current of a river that ran along the plain, which is now formed into several new and deep lakes. There appeared through the whole of this rubbish none of those substances that seemed to indicate that this disruption had been by means of subterraneous fires. Most probably, the base of this rocky mountain was rotted and decayed; and thus fell, without any extraneous violence." In the same manner, in the year 1618, the town of Pleurs, in France, was buried beneath a rocky mountain, at the foot of which is was situated.*

1 Buffon, vol. ii. p. 364. 2 Hist. de l'Academie des Sciences, p. 4. An. 1715

* On the 2d of September, 1806, an immense projection of the mountain of Rusfiberg in Switzerland gave way, and was precipitated into the valley of Lowertz. In four minutes it completely overwhelmed three villages, and part of two others. The torrent of earth and stones was more rapid than

These accidents, and many more that might be enumerated of the same kind, have been produced by various causes: by earthquakes, as in the mountain at Cajeta; or being decayed at the bottom, as at Diableret. But the most general way is, by the foundation of one part of the mountain being hollowed by waters, and thus wanting a support, breaking from the other Thus it generally has been found in the great chasms in the Alps; and thus it almost always is known in those disruptions of hills, which are known by the name of land-slips. These are nothing more than the slidings down of a higher piece of ground, disrooted from its situation by subterraneous inundations, and settling itself upon the plain below.

that of lava, and its effects as irresistible and terrible. The mountain, in its tremendous descent carried trees, rocks, houses, and every thing before it. The mass spread in every direction, so as to bury, completely, a space of charming country, more than three miles square. The force of the earth was so great, that it not only overspread the hollow of the valley, but even ascended to a considerable height on the side of the opposite mountain. A portion of the falling mass rolled into the lake of Lowertz, and it has been calculated that a fifth part of it is filled up.

This event was not caused by the fall of the summit of the mountain, but by an entire body of layers, which, from the base, up to the summit of Rusfiberg (being one hundred feet thick, one thousand feet wide, and nearly three miles in length), was separated from the lower layers, and slid parallel to their planes into the valley. Though this calamity was sudden, it had been preceded several hours by certain indications which are of importance to record, as they may at a future time induce people to escape from danger, and because they are the consequences of causes that determined the rapidity with which the fallen part slid from its base.

An inhabitant of Spitzbuhl, residing about two thirds up the mountain, heard amidst the rocks, about two o'clock, a kind of cracking, which he attributed to supernatural causes, and immediately ran down to Arth, to procure a clergyman to come and quiet it. Almost at the same time, a man at the foot of the mountain, while striking his spade into the ground to dig up some roots, saw the earth spirt up with a gentle explosion, and a kind of whizzing against his head. He left his work, and related this to his neighbours, for which phenomenon they could not account. The shepherds who still live in places intermediate to these two stations, assert that, from the morning and throughout the day, the mountain emitted a noise, accompanied with such agitation, that at the villages of St Anne and Arth, situated within twenty minutes' walk of the places laid waste, all the moveable goods in the houses staggered as if in a state of animation.

The following is a summary of the loss sustained: 434 individuals, 170 cows and horses, 103 goats and sheep dead; eighty-seven meadows destroyed sixty meadows damaged, ninety-three houses entirely destroyed, eight houses damaged and uninhabitable, 166 cow-houses, barns, &c. destroyed, and nineteen damaged. The total damage is estimated at £120,000.

There is not an appearance in all nature that so much astonished our ancestors as these land-slips. In fact, to behold a large upland, with its houses, its corn, and cattle, at once loosened from its place, and floating, as it were, upon the subjacent water; to behold it quitting its ancient situation, and travelling forward like a ship in quest of new adventures; this is certainly one of the most extraordinary appearances that can be imagined; and to a people ignorant of the powers of nature, might well be considered as a prodigy. Accordingly, we find all our old historians mentioning it as an omen of approaching calamities. In this more enlightened age, however, its cause is very well known; and, instead of exciting ominous apprehensions in the populace, it only gives rise to some very ridiculous law-suits among them, about whose the property shall be; whether the land which has thus slipt shall belong to the original possessor, or to him upon whose grounds it has encroached and settled. What has been the determination of the judges, is not so well known, but the circumstances of the slips have been minutely and exactly described.

In the lands of Slatberg,[1] in the kingdom of Iceland, there stood a declivity, gradually ascending for near half a mile. In the year 1713, and on the 10th of March, the inhabitants perceived a crack on its side, somewhat like a furrow made with a plough, which they imputed to the effects of lightning, as there had been thunder the night before. However, on the evening of the same day, they were surprised to hear a hideous confused noise issuing all round from the side of the hill; and their curiosity being raised, they resorted to the place. There, to their amazement, they found the earth for near five acres, all in gentle motion, and sliding down the hill upon the subjacent plain. This motion continued the remaining part of the day, and the whole night; nor did the noise cease during the whole time, proceeding probably, from the attrition of the ground beneath. The day following, however, this strange journey down the hill ceased entirely; and above an acre of the meadow below was found covered with what before composed a part of the declivity.

However, these slips, when a whole mountain's side seems

1 Phil. Trans. vol. iv. p. 250.

to descend, happen but very rarely. There are some of another kind, however, much more common; and as they are always sudden, much more dangerous. These are snow-slips, well known, and greatly dreaded by travellers. It often happens that when snow has long been accumulated on the tops and on the sides of mountains, it is borne down the precipice, either by means of tempests, or its own melting. At first, when loosened, the volume in motion is but small; but gathers as it continues to roll; and by the time it has reached the habitable parts of the mountain, is generally grown of enormous bulk. Wherever it rolls, it levels all things in its way, or buries them in unavoidable destruction. Instead of rolling, it sometimes is found to slide along from the top; yet even thus it is generally as fatal as before. Nevertheless, we have had an instance, a few years ago, of a small family in Germany, that lived for above a fortnight beneath one of these snow-slips. Although they were buried during that whole time in utter darkness, and under a bed of some hundred feet deep, yet they were luckily taken out alive; the weight of the snow being supported by a beam that kept up the roof; and nourishment being supplied them by the milk of an ass, if I remember right, that was buried under the same ruin.

But it is not the parts alone that are thus found to subside, whole mountains have been known totally to disappear. Pliny tells us,[2] that in his own time the lofty mountain of Cybotus, together with the city of Eurites, were swallowed by an earthquake. The same fate, he says, attended Phlegium, one of the highest mountains in Ethiopia; which after one night's concussion was never seen more. In more modern times, a very noted mountain in the Molucca islands, known by the name of the *Peak*, and remarkable for being seen at a very great distance from sea, was swallowed by an earthquake; and nothing but a lake was left in the place where it stood. Thus, while storms and tempests are levelled against mountains above, earthquakes and waters are undermining them below. All our histories talk of their destruction; and very few new ones (if we except mount Cenere, and one or two such heaps of cinders,) are produced. If mountains, therefore, were of such great utility as

2 Plin. lib. ii. cap. 93.

some philosophers make them to mankind, it would be a very melancholy consideration that such benefits were diminishing every day. But the truth is, the valleys are fertilized by that earth which is washed from their sides; and the plains become richer, in proportion as the mountains decay.

CHAP. XIII.

OF WATER.

In contemplating nature, we shall often find the same substances possessed of contrary qualities, and producing opposite effects. Air which liquefies one substance, dries up another. That fire which is seen to burn up the desert, is often found in other places, to assist the luxuriance of vegetation; and water which, next to fire, is the most fluid substance upon earth, nevertheless gives all other bodies their firmness and durability; so that every element seems to be a powerful servant, capable either of good or ill, and only awaiting external direction to become the friend or the enemy of mankind. These opposite qualities, in this substance in particular, have not failed to excite the admiration and inquiry of the curious.

That water is the most fluid penetrating body, next to fire, and the most difficult to confine, is incontestably proved by a variety of experiments. A vessel through which water cannot pass, may be said to retain any thing. It may be objected indeed, that syrups, oils, and honey, leak through some vessels that water cannot pass through; but this is far from being the result of the greater tenuity and fineness of their parts; it is owing to the rosin wherewith the wood of such vessels abounds, which oils and syrups have a power of dissolving; so that these fluids, instead of finding their way, may more properly be said to eat their way, through the vessels that contain them. However, water will at last find its way even through these; for it is known to escape through vessels of every substance, glass only excepted. Other bodies may be found to make their way out more readily indeed; as air, when it finds a vent, will escape at once; and quicksilver, because of its weight, quickly penetrates through whatever chinky vessel confines it: but water, though it operates more slowly, yet always finds a more certain issue. As, for instance, it is well known that air will not pass through leather; which water will very readily penetrate. Air also may be retained in a bladder; but water will quickly ooze through. And those who drive this to the greatest degree of precision, pretend to say, that it will pass through pores ten times smaller than air can do. Be this as it may, we are very certain that its parts are so small, that they have been actually driven through the pores of gold. This has been proved by the famous Florentine experiment, in which a quantity of water was shut up in a hollow ball of gold, and then pressed with a huge force by screws, during which the fluid was seen to ooze out through the pores of the metal, and to stand, like a dew, upon its surface.

As water is thus penetrating, and its parts thus minute, it may easily be supposed that they enter into the composition of all bodies, vegetable, animal, and fossil. This every chymist's experience convinces him of; and the mixture is the more obvious, as it can always be separated, by a gentle heat, from those substances with which it had been united. Fire, as was said, will penetrate where water cannot pass; but then it is not so easily to be separated. But there is scarce any substance from which its water cannot be divorced. The parings or filings of lead, tin, and antimony, by distillation, yield water plentifully: the hardest stones, sea-salt, nitre, vitriol, and sulphur, are found to consist chiefly of water; into which they resolve by force of fire. "All birds, beasts, and fishes," says Newton, "insects, trees, and vegetables, with their parts, grow from water; and, by putrefaction, return to water again." In short, almost every substance that we see, owes its texture and firmness to the parts of water that mix with its earth; and, deprived of this fluid, it becomes a mass of shapeless dust and ashes.

From hence we see, as was above hinted, that this most fluid body, when mixed with others, gives them consistence and form. Water, by being mixed with earth or ashes, and formed into a vessel, when baked before the fire, becomes a coppel, remarkable for this, that it will bear the utmost force of the hottest furnace that art can contrive. So the Chinese earth, of which porcelain is made, is nothing more than an artificial composition of earth and water, united by heat; and which a greater degree of heat could easily separate. Thus we see a body, extremely fluid of itself, in some measure assuming a new nature, by being united with others: we see a body, whose fluid and dissolving qualities are so obvious, giving consistence and hardness to all the substances of the earth.

From considerations of this kind, Thales, and many of the ancient philosophers, held that all things were made of water. In order to confirm this opinion, Helmont made an experiment, by divesting a quantity of earth of all its oils and salts, and then putting this earth, so prepared, into an earthen pot, which nothing but rain-water could enter, and planting a willow therein; this vegetable, so planted, grew up to a considerable height and bulk, merely from the accidental aspersion of rain-water; while the earth, in which it was planted, received no sensible diminution. From this experiment, he concluded, that water was the only nourishment of the vegetable tribe; and that vegetables, being the nourishment of animals, all organized substances, therefore, owed their support and being only to water. But this has been said by Woodward to be a mistake: for he shows, that water being impregnated with earthy particles, is only the conveyer of such substances into the pores of vegetables, rather than an increaser of them by its own bulk: and likewise, that water is ever found to afford so much less nourishment, in proportion as it is purified by distillation. A plant in distilled water will not grow so fast as in water not distilled: and if the same be distilled three or four times over, the plant will scarcely grow at all, or receive any nourishment from it. So that water, as such, does not seem the proper nourishment of vegetables, but only the vehicle thereof, which contains the nutritious particles, and carries them through all parts of the plant. Water, in its pure state, may suffice to extend or swell the parts of a plant, but affords vegetable matter in a moderate proportion.

However this be, it is agreed on all sides, that water, such as we find it, is far from being a pure simple substance.* The

* Water has been ascertained to be a compound substance, and its constituents are clearly proved to be 85 parts of oxygen gas, and 15 of hydrogen by weight.—M. Lavoisier has proved, that when 85 parts of oxygen gas are burned with 15 of hydrogen gas, 100 parts of water are formed; and if 100 parts of water are made to pass through a red hot iron tube, 15 parts of hydrogen gas will be procured, while the inside of the tube will be found converted into an oxyd, and to have gained 85 parts in weight.

most genuine we know is mixed with exhalations and dissolutions of various kinds; and no expedient that has been hitherto discovered, is capable of purifying it entirely. If we filter and distil it a thousand times, according to Boerhaave, it will still deposit a sediment; and by repeating the process we may evaporate it entirely away, but can never totally remove its impurities. Some, however, assert, that water, properly distilled, will have no sediment;[1] and that the little white speck which is found at the bottom of the still, is a substance that enters from without. Kircher used to show, in his Museum, a phial of water that had been kept for fifty years, hermetically sealed;[2] during which it had deposed no sediment, but continued as transparent as when first it was put in. How far, therefore, it may be brought to a state of purity by distillation, is unknown; but we very well know, that all such water as we every where see, is a bed in which plants, minerals, and animals, are all found confusedly floating together.

Rain-water, which is a fluid of Nature's own distilling, and which has been raised so high by evaporation, is nevertheless a very mixed and impure substance. Exhalations of all kinds, whether salts, sulphurs, or metals, make a part of its substance, and tend to increase its weight. If we gather the water that falls, after a thunder-clap, in a sultry summer's day, and let it settle, we shall find a real salt sticking at the bottom. In winter, however, its impure mixtures are fewer, but still may be separated by distillation. But as to that which is generally caught pouring from the tops of houses, it is particularly foul, being impregnated with the smoke of the chimneys, the vapour of the slates or tiles, and with other impurities that birds and animals may have deposited there. Besides, though it should be supposed free from all these, it is mixed with a quantity of air, which, after being kept for some time, will be seen to separate.

Spring-water is next in point of purity. This, according to Dr Halley, is collected from the air itself; which being sated

1 Hill's History of Fossils.

2 Hermetically sealing a glass vessel, means no more than heating the mouth of the phial red hot; and thus when the glass is become pliant, squeezing the mouth together with a pair of pincers, and then twisting it six or seven times round, which effectually closes it up.

with water, and coming to be condensed by the evening's cold, is driven against the tops of the mountains, where being condensed and collected, it trickles down by the sides, into the cavities of the earth; and running for a while underground, bubbles up in fountains upon the plain. This having made but a short circulation, has generally had no long time to dissolve or imbibe any foreign substances by the way.*

* The cause of springs is, that the water which falls on the surface of the earth, in rain, snow, &c. penetrates its substance till it meets with a stratum of clay, stone, or some other matter which stops its descent; it then glides laterally on the stratum which sustains it, and in the direction to which it leans, till meeting with an aperture, it appears on the surface of the earth in the form of a spring. As water always has a tendency to descend, springs are always lower than the source from which they are supplied:—Springs are most common on the sides and at the bottom of mountains; they are seldom found quite at the summit of a mountain, and are rare where a country is every where level to a considerable distance, because there the strata are parallel, and do not conduct the water to any particular point. In order to obtain water therefore in flat countries, it is in general necessary to dig into the earth, where it is found to flow copiously from the sides of the opening, at no great distance from the surface. When wells are dug in elevated situations, water is seldom met with till we have dug to a considerable depth, and got below the general level of the country.

There are some springs which exhibit a very curious phenomenon, a kind of tide or intermission by which the water at certain periods appears to rise a considerable height, and gradually to subside. These are called *Intermitting Springs.* Others have a periodical swell, and discharge a greater quantity of water at one time than at another, the changes taking place at equal intervals. These are called *Reciprocating Springs.* It was long imagined that these fountains were replenished by some connection with the sea; that the water was freshened by its progress through sand and earth, and their rising and falling depended on the tide. It was, however, found, that the periods of the water rising and falling in these springs, did not correspond in point of time with the tides of the adjacent seas, and that the periods were different in different springs, contrary to the regular rising and falling of the tides of the ocean. The phenomenon has since been satisfactorily explained

The first of these kind of springs is very easily accounted for, by supposing the channel which carries the water off from a cavern to have the form of a siphon. In this case the water will only flow when it rises in the cavern to a height equal to that of the upper curve of the siphon-formed canal, and it will fail again when it descends below it. The following explanation of the second kind of intermitting springs was suggested about a century back by Dr Atwell, of Oxford, by attending to the phenomena of Laywell spring, at Brixam, near Torbay, in Devonshire. Let AA (plate iii. fig. 4.) be a large cavern near the top of a hill, which derives its supply of water from the rains or melted snow filtering through the crevices of the mountains; and let CC represent the small channel which conveys the waters of the cavern to the opening G in the hill, where they are discharged in the form of a small spring.

River-water is generally more foul than the former.—Wherever the stream flows, it receives a tincture from its channel. Plants, minerals, and animals, all contribute to add to its impurities: so that such as live at the mouths of great rivers, are generally subject to all those disorders which contaminated and unwholesome waters are known to produce. Of all the river-water in the world, that of the Indus and the Thames is said to be the most light and wholesome.

The most impure fresh water that we know, is that of stagnating pools and lakes, which, in summer, may be more properly considered as a jelly of floating insects, than a collection of water.* In this, millions of little reptiles, undisturbed by any current, which might crush their frames to pieces, breed and engender. The whole teems with shapeless life, and only grows more fruitful by increasing putrefaction.

Of the purity of all these waters, the lightness, and not the transparency, ought to be the test. Water may be extremely clear and beautiful to the eye, and yet very much impregnated with mineral particles. In fact, sea-water is the most transparent of any, and yet it is well known to contain a large mixture of salt and bitumen. On the contrary, those waters which are lightest, have the fewest dissolutions floating in them; and may, therefore, be the most useful for all the purposes of life. But, after all, though much has been said upon this subject, and although waters have been weighed with great assiduity, to determine their degree of salubrity, yet neither this, nor their curdling

From the cavern A A let there be a small channel D, which carries water into another cavern B, and conceive the water in the second cavern to be carried off by a bent channel E *e* F, wider than D, and joining the first channel CC at *f*, before it issues from the mountain, the point of junction *f* being below the level of the bottoms of both the caverns. Then as the cavern B fills with water, the fluid will ascend to the same height in the channel E *e* F, but it will not be discharged by it till the surface in B is on a level with *e*, the highest part of the channel. The water will then be carried off by the natural siphon E *e* F G, till the whole is discharged, and consequently there will be a great swell in the spring at G. This spring will now cease, because th channel D does not convey the water into B so fast as the siphon E *e* F carries it off, and it will again commence as soon as the water in B rises to a level with the summit *e*. A machine for illustrating these phenomena is described by Ferguson in his Lectures, vol. ii. p. 106.

* A quantity of charcoal thrown into putrid water renders the water sweet in a few hours.

with soap, nor any other philosophical standard whatsoever, will answer the purposes of true information. Experience alone ought to determine the useful or noxious qualities of every spring; and experience assures us, that different kinds of water are adapted to different constitutions. An incontestible proof of this, are the many medicinal springs throughout the world, whose peculiar benefits are known to the natives of their respective countries. These are of various kinds, according to the different minerals with which they are impregnated; hot, saline, sulphureous bituminous, and oily.* But the account of these

* Mineral waters are divided into four classes, the *acidulous*, the *sulphureous*, the *chalybeate*, and the *saline.*

Acidulous waters are those which contain carbonic acid in its free state, or in combination in excess with a base. These waters are easily distinguished by their slightly acid taste, and by their sparkling when poured from one vessel to another; both of which properties they lose, when exposed to the air for a length of time, or by boiling. Besides carbonic acid, they almost always contain muriate of soda, and some of the earthy carbonates; it is the free carbonic acid, however, that imparts to them their particular properties.

Sulphureous waters are those which contain sulphuretted hydrogen. These are very easily distinguished by their odour, and by their rendering a solution of a salt of lead black, or by causing a piece of silver, when immersed in them, to acquire a dark colour. Besides sulphuretted hydrogen, they in general contain alkaline and earthy sulphates and muriates. The sulphureous waters may be subdivided into two kinds; 1st, Those which have sulphuretted hydrogen in its free state; 2d, Those in which it exists in union with an alkali or an earth.

Chalybeate waters are those which have iron as an ingredient. These are known by their peculiar taste, and by their becoming black when mixed with an infusion of nutgalls. The chalybeate waters are of different kinds; sometimes the iron is combined with sulphuric acid, more frequently it is in union with carbonic acid; this may be just in sufficient quantity to hold the iron in solution, or it may be in excess, in which case, besides chalybeate, the water possesses acid properties, forming what is called an acidulous chalybeate water.

Saline waters are those which contain the saline ingredients generally found in mineral waters, but which have not carbonic acid in excess, and are free from sulphuretted hydrogen and iron, or contain them in very trifling quantity. Saline waters may be subdivided into four kinds, viz.:—Alkaline waters, or those which contain alkali in its free state, or combined with carbonic acid, and which render the vegetable blues green. Hard waters, or those which contain carbonate or sulphate of lime. Salt waters, or those in which muriate of soda abounds. Purgative waters, or those which contain principally sulphate of magnesia.

Hot springs are most frequent in volcanic regions. No satisfactory explanation of the temperature of these springs, and, above all, of their wonderful equability in this respect, for a very long series of years, has ever been will come most properly under that of the several minerals by which they are produced.

After all, therefore, we must be contented with but an impure mixture of our daily beverage. And yet, perhaps, this very mixture may often be more serviceable to our health than

offered. When they are connected with volcanoes, we naturally ascribe the temperature of the spring to the heat of the volcano; but when they occur at a considerable distance from volcanic countries, such an explanation cannot be applied. Thus, the hot spring at Bath, has continued at a temperature higher than that of the air, for a period not less than 2000 years; yet it is so far from any volcano, that we cannot, without a very violent and improbable extension of volcanic fires, ascribe it to their energy. There are various decompositions of mineral bodies, which generate considerable heat. These decompositions are generally brought about by means of water; or to speak more properly, water is itself the substance which is decomposed, and which generates heat by its decomposition. Thus, for example, there are varieties of pyrites, which are converted into sulphate of iron by the contact of water, and such a change is accompanied by an evolution of heat. Were we to suppose the Bath spring to flow through a bed of such pyrites, its heat might be occasioned by such a decomposition. Such probably is the way in which those springs, that contain sulphurated hydrogen gas, receive their impregnation. But we are pretty certain, that such a supposition will not apply to Bath water: first, because it does not contain the notable quantity of sulphate, or iron, which would be necessary upon such a supposition; and, secondly, because instead of sulphurated hydrogen gas, which would infallibly result from such a decomposition of pyrites, there is an evolution of azotic gas. This evolution of azotic gas, however, is a decisive proof that the heat of Bath water is owing to some decomposition or other which takes place within the surface of the earth; though from our imperfect acquaintance with the nature of mineral strata, through which the water flows, we cannot give any satisfactory information about what that decomposition actually is In the island of St Miguel, one of the Azores, which exhibits, according to Mr Masson, very obvious marks of having abounded in volcanoes, there are a considerable number of hot springs of various temperatures; some boiling hot, others cooler, and some so low that they are used as baths, and have acquired great celebrity for the wonderful cures they have performed. Mr Masson informs us, that these springs are surrounded with abundance of native sulphur, which, he affirms, is exhaled by them in abundance—a circumstance which renders it probable, that the heat of these springs depends upon the decomposition of pyrites.

In the island of Amsterdam there are several hot springs; in one of them was immersed Fahrenheit's Thermometer, which in the air stood at sixty-two degrees, and it ascended immediately to 196°. In another it rose 204°; and the bulb of the thermometer being applied to a crevice, ascended in less than a minute to the boiling point. Some fish being caught and put into the spring, were boiled fit for eating in 15 minutes. In the island of Iceland there are many hot springs, and several magnificent spouting springs, which are called *Geysers* that of a purer kind. We know that it is so with regard to vegetables: and why not, also, in general, to man? Be this as it will, if we are desirous of having water in its greatest purity, we are ordered, by the curious in this particular, to distil it from snow, gathered upon the tops of the highest mountains, and to take none but the outer and superficial part thereof. This we must be satisfied to call pure water; but even this is far short of the pure unmixed philosophical element; which, in reality, is nowhere to be found.

As water is thus mixed with foreign matter, and often the repository of minute animals, or vegetable seeds, we need not be surprised that, when carried to sea, it is always found to putrefy. But we must not suppose that it is the element itself which thus grows putrid and offensive, but the substances with which it is impregnated. It is true, the utmost precautions are taken to destroy all vegetable and animal substances that may have previously been lodged in it, by boiling; but, notwithstanding this, there are some that will still survive the operation, and others that find their way during the time of its stowage. Seamen, therefore, assure us, that their water is generally found to putrefy twice, at least, and sometimes three times, in a long voyage. In about a month after it has been at sea, when the bung is taken out of the cask, it sends up a noisome and dangerous vapour, which would take fire upon the application of a candle.[1] The whole body of the water then is found replete with little worm-like insects, that float, with great briskness, through all its parts. These generally live for about a couple of days; and then dying, by depositing their spoils, for a while increase the putrefaction. After a time, the heavier parts of these sinking to the bottom, the lighter float in a scum, at the top; and this is what mariners call the water's purging itself. There is still, however, another race of insects, which are bred, very probably, from the spoils of the former; and produce, after some time, similar appearances: these dying, the water is then thought to change no more. However, it very often happens, especially in hot climates, that nothing can drive these nauseous insects from the ship's store of water. They often increase to a very disagreeable and frightful size, so as to deter the mariner, though parching with thirst, from tasting that cup which they have contaminated.

1 Phil. Trans. vol. v. part ii. p. 71

This water, as thus described, therefore, is a very different fluid from that simple elementary substance upon which philosophical theories have been founded; and concerning the nature of which there have been so many disputes. Elementary water is no way compounded; but is without taste, smell, or colour; and incapable of being discerned by any of the senses, except the touch. This is the famous dissolvent of the chymists, into which, as they have boasted, they can reduce all bodies; and which makes up all other substances, only by putting on a different disguise. In some forms, it is fluid, transparent, and evasive of the touch; in others, hard, firm, and elastic. In some, it is stiffened by cold; in others, dissolved by fire. According to them, it only assumes external shapes from accidental causes; but the mountain is as much a body of water, as the cake of ice that melts on its brow; and even the philosopher himself is composed of the same materials with the cloud or meteor which he contemplates.

Speculation seldom rests when it begins. Others, disallowing the universality of this substance, will not allow that in a state of nature there is any such thing as water at all. "What assumes the appearance," say they, "is nothing more than melted ice. Ice is the real element of Nature's making; and when found in a state of fluidity, it is then in a state of violence. All substances are naturally hard; but some more readily melt with heat than others. It requires a great heat to melt iron; a smaller heat will melt copper; silver, gold, tin, and lead, melt with smaller still; ice, which is a body like the rest, melts with a very moderate warmth; and quicksilver melts with the smallest warmth of all. Water, therefore, is but ice kept in continual fusion; and still returning to its former state, when the heat is taken away." Between these opposite opinions, the controversy has been carried on with great ardour, and much has been written on both sides; and yet when we come to examine the debate, it will probably terminate in this question, whether cold or heat first began their operations upon water? This is a fact of very little importance, if known; and, what is more, it is a fact we can never know.

Indeed, if we examine into the operations of cold and heat upon water, we shall find that they produce somewhat similar effects. Water dilates in its bulk by heat, to a very considerable degree; and, what is more extraordinary, it is likewise dilated by cold in the same manner.

If water be placed over a fire, it grows gradually larger in bulk, as it becomes hot, until it begins to boil; after which no art can either increase its bulk or its heat. By increasing the fire, indeed, it may be more quickly evaporated away; but its heat and its bulk still continue the same. By the expanding of this fluid, by heat, philosophers have found a way to determine the warmth or the coldness of other bodies; for if put into a glass tube, by its swelling and rising, it shows the quantity of heat in the body to which it is applied; and by its contracting and sinking, it shows the absence of the same. Instead of using water in this instrument, which is called a thermometer, they now make use of spirit of wine, which is not apt to freeze, and which is endued even with a greater expansion, by heat, than water.* The instrument consists of nothing more than a hol-

* Mercury expands by heat and contracts by cold with greater uniformity than even spirit of wine: it is therefore the most proper and the most commonly used for thermometers. There are four different thermometers used at present in Europe; these are, Fahrenheit's, Celsius's, Reaumur's, and De Lisle's. Fahrenheit's thermometer is used in Britain. The space between the boiling and freezing points is divided into 180°; but the scale begins at the temperature produced by mixing together snow and common salt, which is 32° below the freezing point; of course the freezing point is marked 32°, and the boiling point 212°.

The thermometer of Celsius is used in Sweden; it has been used also in France since the first revolution, under the name of the *thermometre centigrade*. In it the space between the freezing and boiling points, is divided into 100°. The freezing point is marked 0, the boiling point 100°.

The thermometer known by the name of *Reaumur*, which was in fact constructed by De Luc, was used in France before the revolution, and is still used in Italy and Spain. In it the space between the boiling and freezing points is divided into 80°. The freezing point is marked 0, the boiling point 80°.

De Lisle's thermometer is used in Russia. The space between the boiling and freezing points is divided into 150°; but the gradation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

The temperatures which we can measure by a mercurial thermometer are confined within narrow limits. For mercury freezes at about 39° below zero, and boils at 660°. Hence we cannot employ it to measure greater heats than 660°, nor greater degrees of cold than 39°. Yet many temperatures connected with our most common processes are much higher than 660°. The heat of a common fire, the temperature at which silver, copper, and gold melts, and many other such points, offer familiar examples.—See Dr Thomson's "Outline of the Science of Heat and Electricity," 1830, 8vo.

low ball of glass, with a long tube growing out of it. This being partly filled with spirits of wine tinctured red, so as to be seen when it rises, the ball is plunged into boiling water, which making the spirit within expand and rise in the tube, the water marks the greatest height to which it ascends; at this point the tube is to be broken off, and then hermetically sealed, by melting the glass with a blow-pipe: a scale being placed by the side, completes the thermometer. Now as the fluid expands or condenses with heat or cold, it will rise and fall in the tube in proportion; and the degree or quantity of ascent or descent will be seen in the scale.

No fire, as was said, can make water hotter, after it begins to boil. We can, therefore, at any time be sure of an equable certain heat; which is that of boiling water, which is invariably the same. The certainty of such a heat is not less useful than the instrument that measures it. It affords a standard, fixed degree of heat over the whole world; boiling water being as hot in Greenland as upon the coast of Guinea. One fire is more intense than another; of heat there are various degrees; but boiling water is a heat every where the same, and easily procurable.

As heat thus expands water, so cold, when it is violent enough to freeze the same, produces exactly the same effect, and expands it likewise. Thus water is acted upon in the same manner by two opposite qualities; being dilated by both. As a proof that it is dilated by cold, we have only to observe the ice floating on the surface of a pond, which it would not do were it not dilated, and grown more bulky, by freezing, than the water which remains unfroze. Mr Boyle, however, put the matter past a doubt, by a variety of experiments.[1] Having poured a proper quantity of water into a strong earthen vessel, he exposed it, uncovered, to the open air, in frosty nights; and observed, that continually the ice reached higher than the water before it was frozen. He filled also a tube with water, and stopped both ends with wax: the water, when frozen, was found to push out the stopples from both ends; and a rod of ice appeared at each end of the tube, which showed how much it was swollen by the cold within.

1 Boyle, vol I. p 610.

From hence, therefore, we may be very certain of the cold dilating the water; and experience also shows, that the force of this expansion has been found as great as any which heat has been found to produce. The touch-hole of a strong gun-barrel being stopped, and a plug of iron forcibly driven into the muzzle, after the barrel had been filled with water, it was placed in a mixture of ice and salt; the plug, though soldered to the barrel, at first gave way, but being fixed in more firmly, within a quarter of an hour the gun-barrel burst with a loud noise, and blew up the cover of the box wherein it lay. Such is its force in an ordinary experiment. But it has been known to burst cannons, filled with water, and then left to freeze; for the cold congealing the water, and the ice swelling, it became irresistible. The bursting of rocks by frost, which is frequent in the northern climates, and is sometimes seen in our own, is an equal proof of the expansion of congealed water. For having by some means insinuated itself into the body of the rock, it has remained there till the cold was sufficient to effect it by congelation. But when once frozen, no obstacle is able to confine it from dilating; and, if it cannot otherwise find room, the rock must burst asunder

This alteration in the bulk of water might have served as a proof that it was capable of being compressed into a narrower space than it occupied before; but, till of late, water was held to be incompressible. The general opinion was, that no art whatsoever could squeeze it into a narrower compass; that no power on earth, for instance, could force a pint of water into a vessel that held an hair's-breadth less than a pint. And this, said they, appears from the famous Florentine experiment; where the water, rather than suffer a compressure, was seen to ooze through the pores of the solid metal; and, at length, making a cleft in the side, spun out with great vehemence. But later trials have proved that water is very compressible, and partakes of that elasticity which every other body possesses in some degree. Indeed, had not mankind been dazzled by the brilliancy of one inconclusive experiment, there were numerous reasons to convince them of its having the same properties with other substances. Ice, which is water in another state, is very elastic. A stone, flung slantingly along the surface of a pond, bounds from the water several times; which shows it to be elastic also. But the trials of Mr Canton have put this past all doubt; which being somewhat similar to those of the great Boyle, who pressed it with weights properly applied, carry sufficient conviction.*

* With the barometer at $29\frac{1}{2}$, and thermometer at 50, Canton declares the following to be the results he obtained:

Compression of spirit of wine	66 parts in a million.	
Oil of olives	48	ditto.
Rain-water	46	ditto.
Sea-water	40	ditto.
Mercury	3	ditto.

These results he obtained in the following manner: He took a glass tube about two feet long, with a ball at one end, of an inch and a quarter in diameter; he filled the ball, and part of the tube, with water which had previously been deprived of air as much as possible; he then placed it under the receiver of an air pump, and removed from it the pressure of the atmosphere; under this treatment he observed that the water rose a little way in the tube. On the contrary, when he placed the apparatus upon a condensing engine, and by condensing the air in the receiver, increased the pressure upon the water, he observed that the water descended a little way in the tube. In this manner he found that water expanded one part in 21,740 when the pressure of the atmosphere was removed, and submitted to a compression of one part in 10,870 under the weight of a double atmosphere. He also observed that water possessed the remarkable property of being more compressible in winter than in summer; contrary to the effect on spirit of wine and oil of olives. Lest it might be supposed that the compressibility thus discovered might be owing to air lodged within the fluids employed, a quantity of water was caused to imbibe more air than it contained in a preceding trial; but its compressibility was not increased. These experiments, although upon the whole so apparently decisive of the questions they were instituted to determine, are yet not to be received without some caution; and in particular, the remark that the addition of a portion of so compressible a fluid as air, did not render water more compressible than before, is rather staggering, and is calculated to throw the veil of doubt over all the rest. It remains therefore, for future investigation to fix the judgment of philosophers on this subject; in the mean time, even granting all the compressibility that has been contended for, the quantity of it is too small to be noticed in practice.

Persons at sea frequently try an experiment which proves, in a great degree, the incompressibility of water. Having corked a bottle containing only air, and therefore called empty, they tie a rope to it, and sink it to a considerable depth by a sufficient weight; on pulling up the bottle, they generally find it either broken, or the cork forced in: but on sinking to the same or even any greater depth, a bottle filled with water, they find it, when drawn up, to be uninjured, because the water resists compression, and therefore supports the bottle; which support, under the pressure at a great depth, the air cannot supply.

What has been hitherto related, is chiefly applicable to the element of water alone ; but its fluidity is a property that it possesses in common with several other substances, in other respects greatly differing from it. That quality which gives rise to the definition of the fluid, namely, that its parts are in a continual intestine motion, seems extremely applicable to water. What the shapes of those parts are, it would be vain to attempt to discover. Every trial only shows the futility of the attempt ; all we find is, that they are extremely minute ; and that they roll over each other with the greatest ease. Some, indeed, from this property alone, have not hesitated to pronounce them globular ; and we have, in all our hydrostatic books, pictures of these little globes in a state of sliding and rolling over each other. But all this is merely the work of imagination ; we know that substances of any kind, reduced very small, assume a fluid appearance, somewhat resembling that of water. Mr Boyle, after finely powdering and sifting a little dry powder of plaster of Paris, put it in a vessel over the fire, where it soon began to boil like water, exhibiting all the motions and appearances of a boiling liquor. Although but a powder, the parts of which we know are very different from each other, and just as accident has formed them, yet it heaved in great waves like water. Upon agitation, a heavy body will sink to the bottom, and a light one emerge to the top. There is no reason, then, to suppose the figure of the parts of water round, since we see their fluidity very well imitated by a composition, the parts of which are of various forms and sizes. The shape of the parts of the water, therefore, we must be content to continue ignorant of. All we know is, that earth, air, and fire, conduce to separate the parts from each other.

Earthy substances divide the parts from each other, and keep them asunder. This division may be so great, that the water will entirely lose its fluidity thereby. Mud, potter's clay, and dried bricks, are but so many different combinations of earth and water ; each substance in which the parts of water are most separated from each other, appearing to be the most dry. In some substances, indeed, where the parts of water are greatly divided, as in porcelain, for instance, it is no easy matter to recover and bring them together again ; but they continue in a manner fixed and united to the manufactured clay. This circumstance led Doctor Cheney into a very peculiar train of thinking. He suspected that the quantity of water, on the surface of the earth, was daily decreasing. For, says he, some parts of it are continually joined to vegetable, animal, and mineral substances, which no art can again recover. United with these, the water loses its fluidity; for if, continues he, we separate a few particles of any fluid, and fasten them to a solid body, or keep them asunder, they will be fluid no longer. To produce fluidity, a considerable number of such particles are required; but here they are close and destitute of their natural properties. Thus, according to him, the world is growing every day harder and harder, and the earth firmer and firmer; and there may come a time when every object around us may be stiffened in universal frigidity! However, we have causes enough of anxiety in this world already, not to add this preposterous concern to the number.

That air also contributes to divide the parts of water, we can have no manner of doubt; some have even disputed whether water be not capable of being turned into air. However, though this cannot be allowed, it must be granted, that it may be turned into a substance which greatly resembles air (as we have seen in the experiment of the æolipile) with all its properties; except that, by cold, this new-made air may be condensed again into water.

But of all the substances which tend to divide the parts of water, fire is the most powerful. Water, when heated into steam, acquires such force, and the parts of it tend to fly off from each other with such violence, that no earthly substance we know of is strong enough to confine them. A single drop of water, converted into steam, has been found capable of raising a weight of twenty tons; and would have raised twenty thousand, were the vessel confining it sufficiently strong, and the fire below increased in proportion.

From this easy yielding of its parts to external pressure, arises the art of determining the specific gravity of bodies by plunging them in water; with many other useful discoveries in that part of natural philosophy, called *hydrostatics.* The laws of this science, which Archimedes began, and Pascal, with some other of the moderns, have much improved, rather belongs to experimental than to natural history. However, I will take leave to mention some of the most striking paradoxes in this branch of science, which are as well confirmed by experiment, as rendered universal by theory. It would, indeed, be unpardonable, while discoursing on the properties of water, to omit giving some account of the manner in which it sustains such immense bulks, as we see floating upon its soft and yielding surface; how some bodies, that are known to sink at one time, swim with ease, if their surface be enlarged; how the heaviest body, even gold itself, may be made to swim upon water: and how the lightest, such as cork, shall remain sunk at the bottom; how the pouring in of a single quart of water, will burst a hogshead hooped with iron: and how it ascends, in pipes, from the valley, to travel over the mountain; these are circumstances that are at first surprising; but, upon a slight consideration, lose their wonder.

[1] In order to conceive the manner in which all these wonders are effected, we must begin by observing that water is possessed of an invariable property, which has not hitherto been mentioned, that of always keeping its surface level and even. Winds, indeed, may raise it into waves, or art spurt it up in fountains; but ever, when left to itself, it sinks into a smooth even surface, of which no one part is higher than another. If I should pour water, for instance, into the arm of a pipe of the shape of the letter U, the fluid would rise in the other arm just to the same height; because, otherwise, it would not find its level, which it invariably maintains. A pipe bending from one hill down into the valley, and rising by another, may be considered as a tube of this kind, in which the water, sinking in one arm, rises to maintain its level in the other. Upon this principle all water pipes depend; which can never raise the water higher than the fountain from which they proceed.

Again, let us suppose for a moment, that the arms of the pipe already mentioned, may be made long or short at pleasure; and let us still further suppose, that there is some obstacle at the bottom of it which prevents the water pouring into one arm, from rising in the other. Now it is evident, that this obstacle at the bottom will sustain a pressure from the water in one arm, equal to what would make it rise in the other; and this pressure

[1] In the above sketch, the manner of demonstrating used by Monsieur D'Alembert is made use of, as the most obvious, and the most satisfactory. Vide Essai sur, &c.

will be great, in proportion as the arm filled with water is tall. We may, therefore, generally conclude, that the bottom of every vessel is pressed by a force, in proportion to the height of the water in that vessel. For instance, if the vessel filled with water be forty feet high, the bottom of that vessel will sustain such a pressure as would raise the same water forty feet high, which is very great. From hence we see how extremely apt our pipes, that convey water to the city, are to burst; for descending from a hill of more than forty feet high, they are pressed by the water contained in them, with a force equal to what would raise it to more than forty feet high; and that this is sometimes able to burst a wooden pipe, we can have no room to doubt of.

Still recurring to our pipe, let us suppose one of its arms ten times as thick as the other; this will produce no effect whatsoever upon the obstacle below, which we supposed hindering its rise in the other arm; because, how thick soever the pipe may be, its contents would only rise to its own level; and it will, therefore, press the obstacle with a force equal thereto. We may, therefore, universally conclude, that the bottom of any vessel is pressed by its water, not as it is broad or narrow, but in proportion as it is high. Thus the water contained in a vessel not thicker than my finger, presses its bottom as forcibly as the water contained in a hogshead of an equal height; and, if we made holes in the bottoms of both, the water would burst out as forceful from the one as the other. Hence we may, with great ease, burst a hogshead with a single quart of water; and it has been often done. We have only,[2] for this, to place a hogshead on one end, filled with water: we then bore a hole in its top, into which we plant a narrow tin pipe, of about thirty feet high: by pouring a quart of water into this, at the top, as it continues to rise higher in the pipe, it will press more forcibly on the bottom and sides of the hogshead below, and at last burst it.

Still returning to our simple instrument of demonstration. If we suppose the obstacle at the bottom of the pipe to be moveable, so as that the force of the water can push it up into the other arm; such a body as quicksilver, for instance. Now, it is evident, that the weight of water weighing down upon this

2 Nollet's Lectures.

quicksilver in one arm, will at last press it up in the other arm; and will continue to press it upwards, until the fluid in both arms be upon a par. So that here we actually see quicksilver, the heaviest substance in the world, except gold and platina, floating upon water, which is but a very light substance.

When we see water thus capable of sustaining quicksilver, we need not be surprised that it is capable of floating much lighter substances, ships, animals, or timber. When any thing floats upon water, we always see that a part of it sinks in the same. A cork, a ship, a buoy, each buries itself in a bed on the surface of the water; this bed may be considered as so much water displaced; the water will, therefore, lose so much of its own weight, as is equal to the weight of that bed of water which it displaces. If the body be heavier than a similar bulk of water, it will sink; if lighter, it will swim. Universally, therefore, a body plunged in water, loses as much of its weight as is equal to the weight of a body of water of its own bulk. Some light bodies, therefore, such as cork, lose much of their weight, and therefore swim; other more ponderous bodies sink, because they are heavier than their bulk of water.

Upon this simple theorem entirely depends the art of weighing metals hydrostatically. I have a guinea, for instance, and desire to know whether it be pure gold; I have weighed it in the usual way with another guinea, and find it exactly of the same weight, but still I have some suspicion, from its greater bulk, that it is not pure. In order to determine this, I have nothing more to do than to weigh it in water with that same guinea that I know to be good, and of the same weight; and this will instantly show the difference; for the true ponderous metal will sink, and the false bulky one will be sustained in proportion to the greatness of its surface. Those whose business it is to examine the purity of metals, have a balance made for this purpose, by which they can precisely determine which is most ponderous, or, as it is expressed, which has the greatest specific gravity. Seventy-one pound and a half of quicksilver, is found to be equal in bulk to a hundred pound weight of gold. In the same proportion sixty of lead, fifty-four of silver, forty-seven of copper, forty-five of brass, forty-two of iron, and thirty-nine of tin, are each equal to a hundred pound of the same most ponderous of all metals.

This method of precisely determining the purity of gold, by weighing in water, was first discovered by Archimedes, to whom mankind have been indebted for many useful discoveries. Hiero, king of Sicily, having sent a certain quantity of gold to be made into a crown, the workman, it seems, kept a part for his own use, and supplied the deficiency with a baser metal. His fraud was suspected by the king, but could not be detected till he applied to Archimedes, who weighed the crown in water; and by this method, informed the king of the quantity of gold which was taken away.

It has been said, that all fluids endeavour to preserve their level; and, likewise, that a body pressing on the surface, tended to destroy that level. From hence, therefore, it will easily be inferred, that the deeper any body sinks, the greater will be the resistance of the depressed fluid beneath. It will be asked, therefore, as the resistance increases in proportion as the body descends, how comes the body after it has got a certain way, to sink at all? The answer is obvious: From the fluid above pressing it down with almost as great a force as the fluid beneath presses it up. Take away, by any art, the pressure of the fluid from above, and let only the resistance of the fluid from below be suffered to act, and after the body is gone down very deep, the resistance will be insuperable. To give an instance: A small hole opens in the bottom of a ship at sea, forty feet, we will suppose, below the surface of the water; through this the water bursts up with great violence; I attempt to stop it with my hand, but it pushes the hand violently away. Here the hand is, in fact, a body attempting to sink upon water, at a depth of forty feet, with the pressure from above taken away. The water, therefore, will overcome my strength; and will continue to burst in till it has got to its level; if I should then dive into the hold, and clap my hand upon the opening, as before, I should perceive no force acting against my hand at all; for the water above presses the hand as much down against the hole, as the water without presses it upward. For this reason, also, when we dive to the bottom of the water, we sustain a very great pressure from above, it is true, but it is counteracted by the pressure from below; and the whole acting uniformly on the surface of the body, wraps us close round without injury.

As I have deviated thus far, I will just mention one or two properties more, which water, and all such like fluids, is found to possess. And, first, their ascending in vessels which are emptied of air, as in our common pumps for instance. The air, however, being the agent in this case, we must previously examine its properties, before we undertake the explanation. The other property to be mentioned is, that of their ascending in small capillary tubes. This is one of the most extraordinary and inscrutable appearances in nature. Glass tubes may be drawn, by means of a lamp, as fine as a hair; still preserving their hollow within. If one of these be planted in a vessel of water, or spirit of wine, the liquor will immediately be seen to ascend; and it will rise higher, in proportion as the tube is smaller; a foot, two feet, and more. How does this come to pass? Is the air the cause? No: the liquor rises, although the air be taken away. Is attraction the cause? No: for quicksilver does not ascend, which it otherwise would. Many have been the theories of experimental philosophers to explain this property. Such as are fond of travelling in the regions of conjecture, may consult Hawksbee, Morgan, Jurin, or Watson, who have examined the subject with great minuteness. Hitherto, however, nothing but doubts, instead of knowledge, have been the result of their inquiries. It will not, therefore, become us to enter into the minuteness of the inquiry, when we have so many greater wonders to call our attention away.[1]

1 This phenomenon, which has so long embarrassed philosophers, is easily soluble upon the principle, that the attraction between the particles of glass and water is greater than the attraction between the particles of water themselves: for, if a glass tube be held parallel to the horizon, and a drop of water be applied to the under side of the tube, it will adhere to it: nor will it fall from the glass, till its bulk and gravity are so far increased as to overbalance the attraction of the glass. Hence it is easy to conceive, how sensibly such a power must act on the surface of a fluid not viscid, as water, contained within the cavity of a small glass tube; as also that the quantity of the fluid raised, will be as the surface of the bore which it fills, that is, as the diameter of the tube.

CHAP. XIV.

OF THE ORIGIN OF RIVERS.

"The sun ariseth, and the sun goeth down, and pants for the place from whence he arose. All things are filled with labour, and man cannot utter it. All rivers run into the sea, yet the sea is not full. Unto the place whence the rivers come, thither they return again. The eye is not satisfied with seeing, nor the ear with hearing."[2] Thus speaks the wisest of the Jews. And at so early a period was the curiosity of man employed in observing these great circulations of nature. Every eye attempted to explain those appearances; and every philosopher who has long thought upon the subject, seems to give a peculiar solution. The inquiry whence rivers are produced; whence they derive those unceasing stores of water, which continually enrich the world with fertility and verdure; has been variously considered, and divided the opinions of mankind more than any other topic in natural history.

In this contest the various champions may be classed under two leaders; Mr De la Hire, who contends that rivers must be supplied from the sea, strained through the pores of the earth; and Dr Halley, who has endeavoured to demonstrate that the clouds alone are sufficient for the supply. Both sides have brought in mathematics to their aid; and have shown that long and laborious calculations can at any time be made to obscure both sides of a question.

De la Hire[3] begins his proofs, that rain-water, evaporated from the sea, is insufficient for the production of rivers: by showing that rain never penetrates the surface of the earth above sixteen inches. From thence he infers, that it is impossible for it in many cases, to sink so as to be found at such considerable depths below. Rain-water, he grants, is often seen to mix with rivers, and to swell their currents; but a much greater part of it evaporates. "In fact," continues he, "if we suppose the earth every where covered with water, evaporation alone would be sufficient to carry off two feet nine inches of it in a year; and

2 Ecclesiastes, chap. i. ver. 5. 7, 8 3 Hist. de l' Acad. 1713, p. 56

yet we very well know, that scarcely nineteen inches of rain-water falls in that time: so that evaporation would carry off a much greater quantity than is ever known to descend. The small quantity of rain-water that falls is, therefore, but barely sufficient for the purposes of vegetation. Two leaves of a fig-tree have been found, by experiment, to imbibe from the earth, in five hours and a half, two ounces of water. This implies the great quantity of fluid that must be exhausted in the maintenance of one single plant. Add to this, that the waters of the river Rungis will, by calculation, rise to fifty inches; and the whole country from whence they are supplied never receives fifty inches in the year by rain. Besides this, there are many salt springs, which are known to proceed immediately from the sea, and are subject to its flux and reflux. In short, wherever we dig beneath the surface of the earth, except in a very few instances, water is to be found; and it is by this subterraneous water that springs and rivers, nay, a great part of vegetation itself, is supported. It is this subterraneous water which is raised into steam, by the internal heat of the earth; that feeds plants. It is this subterraneous water that distils through interstices; and there, cooling, forms fountains. It is this that, by the addition of rains, is increased into rivers, and pours plenty over the whole earth.'

On the other side of the question[1], it is asserted, that the vapours which are exhaled from the sea, and driven by the winds upon land, are more than sufficient to supply not only plants with moisture, but also to furnish a sufficiency of water to the greatest rivers. For this purpose, an estimate has been made of the quantity of water emptied at the mouths of the greatest rivers; and of the quantity also raised from the sea by evaporation; and it has been found, that the latter by far exceeds th former. This calculation was made by Mr Marriotte. By him it was found, upon receiving such rain as fell in a year, in a proper vessel fitted for that purpose; that one year with another, there might fall about twenty inches of water upon the surface of the earth, throughout Europe. It was also computed that the river Seine, from its source to the city of Paris, might cover an extent of ground, that would supply it annually with above seven millions of cubic feet of this water, formed by evaporation.

1 Phil. Trans. vol. ii. p. 128.

But upon computing the quantity which passed through the arches of one of its bridges in a year, it was found to amount only to two hundred and eighty millions of cubic feet, which is not above the sixth part of the former number. Hence it appears, that this river may receive a supply, brought to it by the evaporated waters of the sea, by its current; and, therefore, evaporation is more than sufficient for maintaining the greatest rivers, and supplying the purposes also of vegetation.*

* The property which water has of evaporating spontaneously at all temperatures, is one of the most important in the whole economy of nature. For upon it the growth of plants, and the existence of living creatures upon the earth, depends. The vapours thus continually rising, not merely from the surface of the sea, lakes, and rivers, but also from the dry land, are again condensed, and fall in the state of rain or dew. The rain penetrates into the earth, and makes its way out again in springs. These collecting together constitute rivers, which making their way to the sea, afford the means of living and enjoyment to numerous tribes and languages which occupy their banks. Let us suppose for a moment that this spontaneous evaporation were to cease, and let us contemplate the consequences. No more rain or dew could fall, the springs would cease to flow, the rivers would be dried up; the whole water in the globe would be accumulated in the ocean; the earth would become dry and parched; vegetables being deprived of moisture, could no longer continue to grow; the cattle and beasts of every kind would lack their usual food; man himself would perish; the earth would become a dull, inanimate, sterile mass, without any vegetables to embellish its surface, or any living creature to wander through its frightful deserts.

If the atmosphere contained no vapour whatever, the annual evaporation from the surface of water could easily be determined, provided we were acquainted with the mean temperature of the place. But as the atmosphere is never free from vapour, we must either determine the mean quantity present by trial, or determine the actual evaporation by experiment. Now as far as evaporation is concerned, the surface of the globe presents three principal varieties; namely, water, ground covered with grass or other vegetables, and bare soil.

Dr Dobson made a set of experiments during the years 1772, 1773, 1774, and 1775, to determine the evaporation from the surface of water at Liverpool during these years. He took a cylindrical vessel of twelve inches diameter, and having nearly filled it with water, exposed it beside a rain gauge of the same aperture, and by adding water, or removing it occasionally, he kept the surface at nearly the same height. By carefully registering the quantities added or taken away, and comparing them with the rain that fell, the amount of evaporation was ascertained. The mean annual evaporation from the surface of water at Liverpool amounted to 36.37 inches. The mean annual fall of rain at Liverpool, as ascertained by Dr Dobson, is (without reckoning the dew) 37.48 inches. We see at once from this that more rain falls at Liverpool than can be accounted for by the evaporation. Consequently there must be a supply of vapour from the sea, and probably from the warmer regions of the globe.

In this manner, the sea supplies sufficient humidity to the air, for furnishing the earth with all necessary moisture. One part of its vapours falls upon its own bosom, before it arrives upon land. Another part is arrested by the sides of mountains, and is compelled, by the rising stream of air, to mount upward towards the summits. Here it is presently precipitated, dripping down by the crannies of the stone. In some places, entering into the caverns of the mountain, it gathers in those receptacles, which being once filled, all the rest overflows; and breaking out by the sides of the hills, forms single springs. Many of these run down by the valleys or guts between the ridges of the mountain, and, coming to unite, form little rivulets or brooks; many of these meeting in one common valley, and gaining the plain ground, being grown less rapid, become a river;

A set of experiments upon the evaporation from ground covered with vegetables, and from bare soil, was made by Mr Thomas Hoyle and Mr Dalton, at Manchester, during the years 1796, 1797, 1798. They got a cylindrical vessel of tinned iron, ten inches in diameter, and three feet deep. There were inserted into it two pipes turned downwards for the water to run off from it into bottles. One of these pipes was near the bottom of the vessel, the other was an inch from the top. This vessel was filled up for a few inches with gravel and sand, and all the rest of it with good fresh soil. It was then put into a hole in the ground, and the space arouud filled up with earth, except on one side for the convenience of putting bottles to the two pipes. Water was poured on to sadden the earth, and as much as would was suffered to run through without notice, by which the earth might be considered saturated as with water. For some weeks the soil was constantly above the level of the upper pipe, but latterly it was always a little below it; which made it impossible for any water to run through the upper pipe. For the first year the soil at top was bare, but during the last two years it was covered with grass the same as a green field. Things being thus circumstanced, a regular register was kept of the quantity of rain water that ran off from the surface of the earth by the upper pipe (while that took place,) and also of the quantity which sunk down through the three feet of earth, and ran out through the lower pipe. A rain guage of the same diameter was kept close by to find the quantity of rain for any corresponding time. By this apparatus the quantity evaporated from the earth in the vessel during three years was ascertained. The annual evaporation was 25.158 inches. Now if to the rain we add five inches for dew (not reckoned in Mr Dalton's observations), it follows that the mean annual evaporation from earth at Manchester, amounts to thirty inches. It follows likewise, from these observations of Dalton and Hoyle, that there is but little difference between the evaporation of *green soil* and bare soil. For the evaporation during the first year, when the soil in the vessel was bare, differed but little from that of the two following years when it was covered with grass.

and many of these uniting, make such vast bodies of water as the Rhine, the Rhone, and the Danube.

There is still a third part which falls upon the lower grounds, and furnishes plants with their wonted supply. But the circulation does not rest even here; for it is again exhaled into vapour by the action of the sun; and afterwards returned to that great mass of waters whence it first arose. "This," adds Dr Halley, "seems the most reasonable hypothesis; and much more likely to be true, than that of those who derive all springs from the filtering of the sea-waters, through certain imaginary tubes or passages within the earth; since it is well known that the greatest rivers have their most copious fountains the most remote from the sea."[1]

This seems the most general opinion; and yet, after all, it is still pressed with great difficulties; and there is still room to look out for a better theory. The perpetuity of many springs, which always yield the same quantity, when the least rain or vapour is afforded, as well as when the greatest, is a strong objection. Derham[2] mentions a spring at Upminster, which he could never perceive by his eye to be diminished, in the greatest droughts, even when all the ponds in the country, as well as an adjoining brook, have been dry for several months together. In the rainy seasons, also, it was never overflowed; except sometimes, perhaps, for an hour or so, upon the immission of the external rains. He, therefore, justly enough concludes, that had this spring its origin from rain or vapour, there would be found an increase or decrease of its water, corresponding to the causes of its production.

Thus the reader, after having been tossed from one hypothesis to another, must at last be content to settle in conscious ignorance. All that has been written upon this subject, affords him rather something to say, than something to think; something rather for others than for himself. Varenius, indeed, although he is at a loss for the origin of rivers, is by no means so as to their formation. He is pretty positive that all rivers are artificial. He boldly asserts that their channels have been originally formed by the industry of man. His reasons are, that when a new spring breaks forth, the water does not

1 Phil. Trans. vol. ii. p. 128. 2 Derham Physico-Theol.

make itself a new channel, but spreads over the adjacent land "Thus," says he, "men are obliged to direct its course; or, otherwise, Nature would never have found one." He enumerates many rivers that are certainly known, from history, to have been dug by men. He alleges, that no salt-water rivers are found, because men did not want salt-water; and as for salt, that was procurable at less expense than digging a river for it. However, it costs a speculative man but a small expense of thinking to form such an hypothesis. It may perhaps engross the reader's patience to detain him longer upon it.

Nevertheless, though Philosophy be thus ignorant as to the production of rivers, yet the laws of their motion, and the nature of their currents, have been very well explained. The Italians have particularly distinguished themselves in this respect; and it is chiefly to them that we are indebted for the improvement.[1]

All rivers have their source either in mountains, or elevated lakes;* and it is in their descent from these that they acquire

1 S. Guglielmini della Natura de Fiumi, passim.

* Extensive accumulations of water, surrounded on all sides by the land, and having no direct communication with the ocean, or with any sea, are called *lakes*. Lakes are of four distinct kinds. The *first class* comprehends those which have no issue, and which do not receive any running water. These *pools* are generally very small, and do not merit much attention. Some of these, as the Arendt, in Vieille Marche, are formed by the sinking down of the circumjacent lands: others, like the lake Albano, near Rome, appear to be old craters of volcanoes filled with water. The *second class* consists of those lakes which have an outlet, but which do not receive any running water. Such a lake is formed by a spring, or rather by a multitude of springs, which, placed on a lower level in a kind of reservoir, are obliged to fill that before they find an outlet for their own waters. These lakes are nevertheless fed by little streams of water, almost invisible, which descend from the surrounding lands, or from subterraneous canals. Some great rivers have lakes of this kind for their source. These lakes are naturally situated on great elevations; there is one of this kind on *Mount Rotando*, in Corsica, which is 9294 feet above the level of the sea. The *third class* of lakes is very numerous, consisting of all such as receive and discharge streams of water. Each of the lakes of this class may be looked upon as forming a basin for receiving the neighbouring waters; they have in general only one opening, which almost always takes its name from the principal river which flows into it. But it cannot, in strict propriety, be said that these rivers *traverse* the lakes, as their waters mingle with those of the basin over which they are diffused. These lakes have often sources of their own, either near the borders, or in their bottom. There are four or five lakes of this class in North America, which, in point of extent, resemble seas, and which, notwithstand-

that velocity which maintains their future current. At first their course is generally rapid and headlong; but it is retarded in its journey, by the continual friction against its banks, by the many obstacles it meets to divert its stream, and by the plains generally becoming more level as it approaches towards the sea.

ing, by the flow of a continual stream of fresh river-water, preserve their clearness and sweetness. The *fourth class* of lakes present phenomena much more difficult to explain. We mean those lakes which receive streams of water, and often great rivers, without having any visible outlet. The most celebrated of these is the Caspian Sea; Asia contains a great many others besides. The Niger, if it does not touch the sea, most probably falls into a lake of this kind, and not into a marsh. South America contains the lake Titicaca, which has no efflux, although it receives another very considerable one into it. In short, these lakes appear to belong to the interior of great continents; they are placed on elevated plains, which have no sensible declivity towards the sea, and which do not permit these collections of water to open for themselves a passage through which they may flow out. But why do these lakes, which are always receiving supplies of water, but have no outlet, why do they not overflow their banks? We may answer, that with respect to those which are situated in a hot climate, evaporation, as Halley observes, is sufficient to carry off their excess of water. It remains to be determined, whether the reasonings of this philosopher can with justness be applied to a climate so cold for example as that of the Caspian Sea. Let us, in the first place, observe, that the quantity of water which the rivers pour into this basin, has been exaggerated: there are no other great rivers except the Wolga, the Iaik, and the Kur, which flow into it; the remainder consists only of small rivulets. We must add, that the whole of the eastern coast scarcely furnishes one rivulet to this extraordinary sea. And let us also remark, (for in physical geography every fact is worthy of attention,) that the Wolga, by no means a deep river, seems to be in part absorbed by the ground which borders its course; and it is this humidity which renders these lands so distinguished for their fertility, when compared with the neighbouring soil. Finally, were we determined to suppose that there is a disproportion between the extent of the Caspian Sea and its evaporation, on the one side, and the volume of water that it receives on the other, (which we are far from allowing,) we have still to take into account the absorption of its waters by the calcareous mountains which border it towards the south and south west. We know how porous and spongy land of this kind is. All accounts agree in describing the mountains to the south of the Caspian as being still more penetrated with moisture, and more abounding in springs than those of Mingrelia, which proves either absorption, or (what is of more consequence,) a very strong evaporation. The insalubrity of the air near these lakes, is another circumstance which still farther confirms the opinion of Halley. The physical phenomena which certain lakes present, have always excited the astonishment of the multitude.

The *periodical lakes* are the most common. Those which are formed by excessive rains, and which are again dried up by the rays of the sun, by evaporation, or infiltration, appear to be scarcely worthy of our attention. In Europe these are nothing but pools, but between the tropics, these pools

If this acquired velocity be quite spent, and the plain through which the river passes is entirely level; it will, notwithstanding, still continue to run from the perpendicular pressure of the water, which is always in exact proportion to the depth. This perpendicular pressure is nothing more than the weight of the upper waters pressing the lower out of their places; and consequently driving them forward as they cannot recede against the stream. As this pressure is greatest in the deepest parts of the river, so we generally find the middle of the stream most rapid; both because it has the greatest motion thus communicated by the pressure and the fewest obstructions from the banks on either side.*

sometimes cover spaces of several hundred leagues in length and breadth. Such are the famous lakes of *Xarayes* and *Paria*, inscribed on maps of America, and expunged from them by turns; it is probable that Africa contains a great many of this description. If there exist now in the numerous cavities of the earth subterraneous lakes of this kind, and if these communicate with other lakes which are visible, it is easy to imagine that the waters of these last may sometimes entirely disappear, by sinking down into the basin of the subterraneous lakes in proportion as they dry up. This lower basin again filling itself anew, the waters issue from it to fill the superior basin. If, in a supposable series of subterraneous cavities, the last link of the chain happen to be a mass of subterraneous water, situated at an elevated level in the bosom of a mountain, the periodical return of the waters in the visible basin may be accompanied by a motion similar to that of the spouting fountains. It is by means of such hydraulic machinery that nature keeps up the wonders of the lake of Cirknitz in Illyria, and in many others of the same description.

The variations and motions of lakes, which do not depend upon an augmentation of quantity, present very complicated questions: That any lakes communicate under ground with the sea, and owe their regular tides to such communication is much to be doubted. The equilibrium of the atmosphere, deranged by electricity, or by any other cause, may occasion water to rise up, by altering the pressure which retains it at its level. There is a bay in lake Huron where electric clouds continually remain, and no traveller has ever passed it without hearing thunder. In Portugal there is a pool near Beja in Alentejo, which, by its loud noise, indicates the approach of a storm. Other lakes appear agitated by the disengagement of subterraneous gases, or by winds which blow in some cavern with which the lake communicates. Near Boleslaw, in Bohemia, a lake of unfathomable depth sometimes in winter emits blasts of wind sufficiently strong to raise up in the air pieces of ice several quintals in weight. Two considerable lakes, *Loch Lomond* in Scotland, and the *Welter* in Sweden, often experience during the serenest weather violent agitations. In the Murche of Brandebaurg, the pool of Krestin often commences in fine weather to boil up in whirlpools so as to engulph the little boats of the fishermen. Perhaps the decomposition of calcareous stones has an influence upon some of these phenomena.

* Many great rivers in fact flow with an almost imperceptible declivity. The

Rivers thus set into motion are almost always found to make their own beds. Where they find the bed elevated, they wear its substance away, and deposit the sediment in the next hollow, so as in time to make the bottom of their channels even. On the other hand, the water is continually gnawing and eating away the banks on each side; and this with more force as the current happens to strike more directly against them. By these means it always has a tendency to render them more straight and parallel to its own course. Thus it continues to rectify its banks and enlarge its bed; and, consequently, to diminish the force of its stream, till there becomes an equilibrium between the force of the water, and the resistance of its banks, upon which both will remain without any further mutation. And it is happy for man that bounds are thus put to the erosion of the earth by water; and that we find all rivers only dig and widen themselves but to a certain degree."[1]

In those plains [2] and large valleys where great rivers flow, the

river of the Amazons has only ten feet and a half of declivity upon two hundred leagues of extent of water, which makes $\frac{1}{27}$ of an inch for every 1000 feet. The Seine, between Valvins and Serves, has only one foot declivity out of 6600. The Loire has, between Pouilly and Briare, one foot in 7500; but between Briare, and Orleans only one foot in 13,596. In East Frizeland, in the United Provinces, two small neighbouring rivers have, the one $\frac{1}{8}$ of an inch, the other $\frac{1}{3}$ of declivity for every 1000 feet. The Marwede, between Herdinxveld and Dort, falls an inch along 1,125 feet; but between Dort and the sea, only one inch along 9000 feet. Even the most rapid rivers have less declivity than is commonly imagined. The Rhine between Schaffhausen and Strasburgh has a fall of 4 feet in a mile; and of 2 feet between Strasburgh and Schenkeoschantz. Hence we see the reason why one river may receive another almost as large as itself, without any considerable enlargement of its bed; the augmentation of its body only accelerates its course. Sometimes one river falling into another with great rapidity, and at a very acute angle, will force the former to retrace its course and return for a short space towards its source. This has happened more than once to the Rhone near Geneva; the impetuous Arva, which descends from the mountains of Savoy, being swollen beyond its usual size, has made the more gentle waters of the Rhone flow back into the lake of Geneva; causing the wheels of the mills to revolve backwards. Some rivers have no stream whatever, and the cause is easily discovered; the land having scarcely any declivity, does not impart a sufficiently strong impulse to their waters, which are constantly retarded, and finally absorbed by the sand. Sometimes these waters are evaporated by the heat of the sun, as is the case with the rivers of Arabia and Africa; but they more commonly flow into pools, marshes, or salt lakes.

1 Guglielmini della Natura de Fiumi, passim.

2 Buffon de Fleuves, passim, vol. ii.

bed of the river is usually lower than any part of the valley. But it often happens, that the surface of the water is higher than many of the grounds that are adjacent to the banks of the stream. If, after inundations, we take a view of some rivers, we shall find their banks appear above water at a time that all the adjacent valley is overflowed. This proceeds from the frequent deposition of mud, and such like substances, upon the banks, by the rivers frequently overflowing; and thus, by degrees, they become elevated above the plain; and the water is often seen higher also.

Rivers, as every body has seen, are always broadest at the mouth, and grow narrower towards their source. But what is less known, and probably more deserving curiosity, is, that they run in a more direct channel as they immediately leave their sources; and that their sinuosities and turnings become more numerous as they proceed. It is a certain sign among the savages of North America, that they are near the sea, when they find the rivers winding, and every now and then changing their direction. And this is even now become an indication to the Europeans themselves, in their journeys through those trackless forests. As those sinuosities, therefore, increase as the river approaches the sea, it is not to be wondered at that they sometimes divide, and thus disembogue by different channels. The Danube disembogues into the Euxine by seven mouths; the Nile by the same number; and the Wolga by seventy.

The currents[1] of rivers are to be estimated very differently from the manner in which those writers, who have given us mathematical theories on this subject, represent them. They found their calculations upon the surface being a perfect plain from one bank to the other; but this is not the actual state of nature; for rivers in general, rise in the middle; and this convexity is greatest in proportion as the rapidity of the stream is greater. Any person, to be convinced of this, need only lay his eye, as nearly as he can, on a level with the stream, and looking across to the opposite bank, he will perceive the river in the midst to be elevated considerably above what it is at the edges. This rising, in some rivers, is often found to be three feet high; and is ever increased in proportion to the rapidity of the stream. In

1 Buffon de Fleuves, passim. vol. ii

this case, the water in the midst of the current loses a part of its weight, from the velocity of its motion; while that at the sides, for the contrary reason, sinks lower. It sometimes however happens, that this appearance is reversed; for when tides are found to flow up with violence against the natural current of the water, the greatest rapidity is then found at the sides of the river, as the water there least resists the influx from the sea. On those occasions, therefore, the river presents a concave rather than a convex surface; and as in the former case, the middle waters rose in a ridge, in this case they sink in a furrow.

The stream of all rivers is more rapid in proportion as its channel is diminished. For instance, it will be much swifter where it is ten yards broad, than where it is twenty; for the force behind still pushing the water forward, when it comes to the narrow part, it must make up by velocity what it wants in room.

It often happens that the stream of a river is opposed by one of its jutting banks, by an island in the midst, the arches of a bridge, or some such obstacle. This produces not unfrequently a back current; and the water having passed the arch with great velocity, pushes the water on each side of its direct current. This produces a side current, tending to the bank; and not unfrequently a whirlpool; in which a large body of waters are circulated in a kind of cavity, sinking down in the middle. The central point of the whirlpool is always lowest, because it has the least motion: the other parts are supported, in some measure, by the violence of theirs, and consequently rise higher as their motion is greater; so that towards the extremity of the whirlpool, must be higher than towards the centre.

If the stream of a river be stopped at the surface, and yet be free below; for instance, if it be laid over by a bridge of boats, there will then be a double current; the water at the surface will flow back, while that at the bottom will proceed with increased velocity. It often happens that the current at the bottom is swifter than at the top, when, upon violent land-floods, the weight of waters towards the source presses the waters at the bottom, before it has had time to communicate its motion to the surface. However, in all other cases, the surface of the stream is swifter than the bottom, as it is not retarded by rubbing over the bed of the river.

It might be supposed that bridges, dams, and other obstacles in the current of a river, would retard its velocity. But the difference they make is very inconsiderable. The water, by these stoppages, gets an elevation above the object; which, when it has surmounted, it gives a velocity that recompenses the former delay. Islands and turnings also retard the course of the stream but very inconsiderably; any cause which diminishes the quantity of the water, most sensibly diminishes the force and the velocity of the stream.

An increase [1] of water in the bed of the river always increases its rapidity; except in cases of inundation. The instant the river has overflowed its banks, the velocity of its current is always turned that way, and the inundation is perceived to continue for some days; which it would not otherwise do, if, as soon as the cause was discontinued, it acquired its former rapidity.

A violent storm, that sets directly up against the course of the stream, will always retard, and sometimes entirely stop its course. I have seen an instance of this, when the bed of a large river was left entirely dry for some hours, and fish were caught among the stones at the bottom.

Inundations are generally greater towards the source of rivers than farther down; because the current is generally swifter below than above; and that for the reasons already assigned.

A little river [2] may be received into a large one, without augmenting either its width or depth. This, which at first view seems a paradox, is yet very easily accounted for. The little river, in this case, only goes towards increasing the swiftness of the larger, and putting its dormant waters into motion. In this manner the Venetian branch of the Po, was pushed on by the Ferrarese branch and that of Panaro, without any enlargement of its breadth or depth from these accessions.

A river tending to enter another, either perpendicularly, or in an opposite direction, will be diverted by degrees from that direction; and be obliged to make itself a more favourable entrance downward, and more conspiring with the stream of the former.

The union of two rivers into one, makes it flow the swifter; since the same quantity of water, instead of rubbing against four shores, now only rubs against two. And, besides, the cur-

1 Buffon, vol. ii. p. 6? 2 Guglielmini.

rent being deeper, becomes, of consequence, more fitted for motion.

With respect to the places from whence rivers proceed, it may be taken for a general rule, that the largest [3] and highest mountains supply the greatest and most extensive rivers. It may also be remarked, in whatever direction the ridge of the mountain runs, the river takes an opposite course. If the mountain, for instance, stretches from north to south, the river runs from east to west; and so contrariwise. These are some of the most generally received opinions with regard to the course of rivers; however, they are liable to many exceptions; and nothing but an actual knowledge of each particular river can furnish us with an exact theory of its current.

The largest rivers of Europe are, first, the Wolga, which is about six hundred and fifty leagues in length, extending from Reschow to Astrachan. It is remarkable of this river, that it abounds with water during the summer months of May and June; but all the rest of the year is so shallow as scarce to cover its bottom, or allow a passage for loaded vessels that trade up its stream. It was up this river that the English attempted to trade into Persia, in which they were so unhappily disappointed, in the year 1741. The next in order is the Danube. The course of this is about four hundred and fifty leagues, from the mountains of Switzerland to the Black Sea. It is so deep between Buda and Belgrade, that the Turks and Christians have fleets of men-of-war upon it; which frequently engaged during the last war between the Ottomans and the Austrians: however it is unnavigable further down, by reason of its cataracts, which prevent its commerce into the Black Sea. The Don, or Tanais, which is four hundred leagues from the source of that branch of it called the *Softna*, to its mouth in the Euxine Sea. In one part of its course, it approaches near the Wolga; and Peter the Great had actually begun a canal, by which he intended joining those two rivers; but this he did not live to finish. The Nieper, or Boristhenes. which rises in the middle of Muscovy, and runs a course of three hundred and fifty leagues, to empty itself into the Black Sea. The Old Cossacks inhabit the banks and islands of this river; and frequently cross the Black Sea, to plunder the

3 Dr Halley.

maritime places on the coasts of Turkey. The Dwina, which takes its rise in a province of the same name in Russia, that runs a course of three hundred leagues, and disembogues into the White Sea, a little below Archangel.

The largest rivers in Asia are, the Hohanho, in China, which is eight hundred and fifty leagues in length, computing from its source at Raja Ribron, to its mouth in the gulf of Changi. The Jenisca of Tartary, about eight hundred leagues in length, from the lake Selinga, to the Icy Sea. This river is, by some, supposed to supply most of that great quantity of drift wood which is seen floating in the seas near the Arctic circle. The Oby, of five hundred leagues, running from the lake of Kila into the Northern Sea. The Amour, in Eastern Tartary, whose course is about five hundred and seventy-five leagues, from its source to its entrance into the sea of Kamtschatka. The Kiam, in China, five hundred and fifty leagues in length. The Ganges, one of the most noted rivers in the world, and about as long as the former.* It rises in the mountains which separate India

* The Ganges pursues a course of 1350 miles. It is a smooth-running and navigable river, and is supposed to employ upon it 30,000 boatmen. About 220 miles from the sea (but 300 reckoning the windings of the rivers,) commences the head of the Delta of the Ganges, which is considerably more than twice the area of the Nile. The inundation of the river is in the latter end of July, and overflows an extent of 100 miles in breadth contiguous to the river. The inundations of the Ganges and the Nile differ in this particular (that is to say, the lands of Bengal and Egypt.) that the Nile owes its floods entirely to the rain water that falls in the mountains, near its source; but the inundations in Bengal are as much occasioned by the rain that falls there, as by the waters of the Ganges; as a proof of it, the lands in general are overflowed to a considerable height long before the bed of the river is filled. The average swell of the Ganges, in the rainy seasons, is about 31 feet, and its fall about four inches per mile; and the river flows at the rate of about three miles in the hour, but in the rainy season the rate is increased to six miles in the hour. The average quantity of water discharged by the Ganges into the sea is 80,000 cubic feet per second: but during the rainy season the quantity discharged amounts to 405,000 cubic feet. The Ganges varies its channel very much during its course through Bengal, wearing away the banks on one side, while land is formed on the other side. The *Burrampooter*, which has its source from the opposite side of the same mountains (the mountains of Thibet) that give rise to the Ganges, first takes its course eastward, or directly opposite to that of the Ganges, through the country of Thibet, where it is named the *Sanpoo*, or Zanciu, which bears the same interpretation as the Gonga of Hindostan: namely, the River. The Burrampooter enters Bengal on the north-east, after which it makes a circuit round the western point of the Marrow mountains; and then altering its course to south it meets

from Tartary; and running through the dominion of the Great Mogul, discharges itself by several mouths into the bay of Bengal. It is not only esteemed by the Indians for the depth and pureness of its stream, but for a supposed sanctity which they believe to be in its waters. It is visited annually by several hundred thousand pilgrims, who pay their devotions to the river as to a god: for savage simplicity is always known to mistake the blessings of the Deity, for the Deity himself. They carry their dying friends from distant countries, to expire on its banks; and to be buried in its stream. The water is lowest in April or May; but the rains beginning to fall soon after, the flat country is overflowed for several miles, till about the end of September; the waters then begin to retire, leaving a prolific sediment behind, that enriches the soil, and, in a few days' time, gives a luxuriance to vegetation, beyond what can be conceived by a European. Next to this may be reckoned the still more celebrated river Euphrates. This rises from two sources, northward of the city Erzerum, in Turcomania, and unites about three days' journey below the same; from whence, after performing a course of five hundred leagues, it falls into the gulf of Persia, fifty miles below the city of Bassora in Arabia. The river Indus is extended, from its source to its discharge into the Arabian Sea, four hundred leagues.

The largest rivers of Africa are, the Senegal, which runs a course of not less than eleven hundred leagues, comprehending the Niger, which some have supposed to fall into it. However, later accounts seem to affirm that the Niger is lost in the sands, about three hundred miles up from the western coasts of Africa.* Be this as it may, the Senegal is well known to be

the Ganges, about 40 miles from the sea. It is larger than the Ganges, and during the last 60 miles, before it forms a junction with that river, its width is regularly from four to five miles, and, but for its freshness, might pass for an arm of the sea. Major Rennel was the original discoverer that the Sanpoo, of Thibet, is the same with the Burrampooter. Before that time the Sanpoo had been supposed to discharge into the sea by the Gulf of Ava.

* Many attempts have been made to determine the course of the Niger both by geographers and travellers in ancient as well as modern times; but we are yet involved in the darkness of conflicting theories and contradictory reports. The very direction of this river was for a long period a debateable question. The Arabs of the middle ages attributed to the Niger a westward course to 'the Sea of Darkness,' or the Atlantic. They also conceived that the Niger and the Nile sprung from the same origin. Leo Africanus, however acknowledges that

navigable for more than three hundred leagues up the country; and how much higher it may reach is not yet discovered, as the dreadful fatality of the inland parts of Africa, not only deters curiosity, but even avarice, which is a much stronger passion. At the end of last war, of fifty Englishmen that were sent to the factory at Galam, a place taken from the French, and nine hundred miles up the river, only one returned to tell the fate of his companions, who were destroyed by the climate. The celebrated river Nile is said to be nine hundred and seventy leagues, from its source among the Mountains of the Moon, in Upper Æthiopia, to its opening into the Mediterranean Sea.* The

some geographers had made the Niger run from W. to E., and terminate in a great lake. This was in fact the opinion of Herodotus 2000 years before; and in this opinion Ptolemy had coincided. The Portuguese, on seeing the Senegal, the Gambia, and other great rivers proceeding from the unknown interior of Africa, discharge themselves into the Atlantic, conceived that these rivers might be the mouths of the Niger itself, and therefore gave it a westward course. It was reserved for Mungo Park, to decide the question as to the direction of the Niger in favour of the old Grecian geographer: on the 21st of July, 1796, that intrepid traveller beheld, from the heights of Sego, "the majestic Niger flowing slowly from W. to E." Equally as unsettled were the early notions as to the *source* of this river: for whilst some believed it to originate in the mountains of Mauritania, others affirmed that it issued from a lake to the S. of Bornou; and others, as we have hinted, identified its fountain-head with that of the Nile. It is now decided from observation that the great central river of Africa, has its source near Mount Lamba, in the country of the Soulimas, on the northern declivities of the Kong mountains, between 9° and 10° W. of Greenwich, and, according to Major Laing, at an elevation of 1638 feet above the level of the Atlantic. It runs first N. E. through an unexplored country; and then, inclining a little more towards the E., passes the large cities of Bammakou, Yamima, Sego, and Sansanding. From the latter place it runs N. E., through lake Dibbie, to Timbuctoo, and thence sweeps in a circular direction to the S. of Houssa, where we are yet ignorant what becomes of it. The river is called, during the known part of its course, *Joliba* by the native Africans. This name is a corruption of *Dhioliba*: *ba* signifying 'a river,' in the Bambarra and Mandingo languages, and *dioli*, or *dhioli*, pronounced *joli* or *djoli*, signifying 'red.' The Joliba, therefore, means 'the Red river.'

* The length of the Nile is about 2,000 miles; but, as it receives few collateral branches, and none from the month of the Tacazze to the Delta—a distance of nearly 1350 nautical miles—its breadth is seldom, if ever, more than one-third of a mile, and its average depth is only about 12 feet. This, however, must be understood as relating to its situation when confined within its banks: during an inundation, it lays every level spot upon its banks under water. The ancients were not well acquainted with any other river which annually inundated the country around it. This circumstance, therefore, must have attracted no inconsiderable share of their attention. To

sources of this river were considered as inscrutable by the ancients; and the causes of its periodical inundation were equally unknown. They have both been ascertained by the missionaries who have travelled into the interior parts of Æthiopia.

moderns, the overflowing of the Nile is no longer a matter of surprise; nor is the Nile in this respect singular. Every river which has its source within the tropics annually overflows its banks; and the cause is the same in all. The incessant torrents of rain which attend the vertical sun, and which constitute the winter of tropical regions, swell every river beyond its ordinary bounds, and lay the level country under water. This is found to be the case with the Plata and the Amazon, and with every considerable stream whose source is not far removed from the equator. The Nile rises within the tropics, and consequently inundates yearly the neighbouring countries. The proper rise of the waters is to the inhabitants an affair the most important. A few feet less than the ordinary height, would prevent the spreading of the waters to a sufficient distance; a few feet more than the usual quantity would prevent the water from draining off in the proper season for sowing and spread devastation throughout the country, as in the years 1818 and 1829; and, in either case, a famine, and perhaps an extensive loss of lives, would be the consequence. When the Nile has attained the proper height, and when it seems not to rise too far, Egypt is the scene of festivity and congratulation; the inhabitants are assured of abundance, and anticipate with joy the approaching harvest.

Of the sources of this river, much ignorance and difference of opinion long prevailed: but it now appears that the sources of one of its principal branches —if not of the Nile itself—was known to Europeans long before they credited the fact. Bruce, it is true—who undertook a search which was believed to have eluded every former adventurer—assures us that he was the first of Europeans who saw the fountains from which the Nile originates; and, so anxious was he to secure this honour to himself, that he minutely examines the accounts of such travellers as pretend to have visited them before him, and his decision, as was to be expected, is in his own favour. But his examination of Kircher's account of the sources of the Nile, plainly evinces, that the latter either visited these sources himself, or received his information from such as had visited them. What were considered the sources of the Blue River, by some regarded as the head or main branch of the Nile, were found and described by two Jesuits, Paez and Tellez, two centuries before the pretended discovery of Bruce. A few differences and inaccuracies detected by Bruce in the account, serve rather to confirm than invalidate the truth of this early visit. Still, Bruce deserves all praise for his enterprising and laborious researches; and the reception of his narrative, even by his own countrymen, can scarcely be accounted generous, when it is considered that it was at first doubted whether he had really ever seen the head of the river which he described as the chief branch of the Nile; and when this could no longer be insinuated, it was immediately discovered that he had only visited the head of an inferior branch, and that the true Nile originated far to the west, among the Mountains of the Moon. Whether the branch visited by Bruce, called the *Bahr-el-Azreek* or 'Blue River,' or the Western branch, called the *Bahr-el-Abiad* or 'White River'

The Nile takes its rise in the kingdom of Gojam,[1] from a small aperture on the top of a mountain, which, though not above a foot and a half over, yet was unfathomable. This fountain, when arrived at the foot of the mountain, expands into a river; and being joined by others, forms a lake thirty leagues long, and as many broad; from this, its channel, in some measure, winds back to the country where it first began; from thence, precipitating by frightful cataracts, it travels through a variety of desert regions, equally formidable, such as Amhara, Olaca, Damot, and Xaoa. Upon its arrival in the kingdom of Upper Egypt, it runs through a rocky channel, which some late travellers have mistaken for its cataracts. In the beginning of its course, it receives many lesser rivers into it; and Pliny was mistaken in saying that it received none. In the beginning also of its course it has many windings; but, for above three hundred leagues from the sea, it runs in a direct line. Its annual overflowings arise from a very obvious cause, which is almost universal with the great rivers that take their source near the line. The rainy season, which is periodical in those climates, floods the rivers; and as this always happens in our summer, so the Nile is at that time overflown. From these inundations, the inhabitants of Egypt derive happiness and plenty; and, when the river does not arise to its accustomed heights, they prepare for an indifferent harvest. It begins to overflow about the seventeenth of June; it generally continues to augment for forty days, and decreases in about as many more. The time of increase and decrease, however, is much more inconsiderable now than it was among the ancients. Herodotus informs us, that it was an hundred days rising, and as many falling; which shows that the in-

had the better claim to be regarded as the head or main branch of the Egyptian river was long disputed. The name of the Nile indicates its relation to the Blue River rather than to the other stream. M. Calliaud, a French traveller, who accompanied a predatory excursion of the pasha of Egypt's two sons into Nubia, states that two considerable rivers, the *Tournat* and the *Jabousse* flow from Abyssinia into the Blue River,—the latter at the distance of two days and a half southward of Fazœle,—a circumstance which renders it impossible that the Azreek should have its rise in Abyssinia. But, wherever the most distant sources of the Nile are actually situated, it appears to be chiefly fed by the rivers of Abyssinia, and to these its inundations are chiefly owing. We may regard therefore the Abyssinian Nile, or the Blue River, as the head-stream of the river of Egypt.

1 Kircher, Mund. Subt. vol. ii. p. 72.

undation was much greater at that time than at present. Mr Buffon[2] has ascribed the present diminution, as well to the lessening of the Mountains of the Moon, by their substance having so long been washed down with the stream, as to the rising of the earth in Egypt, that has for so many ages received this extraneous supply. But we do not find, by the buildings that have remained since the times of the ancients, that the earth is much raised since then. Besides the Nile in Africa, we may reckon the Zara, and Coanza, from the greatness of whose openings into the sea, and the rapidity of whose streams, we form an estimate of the great distance from whence they come. Their courses, however, are spent in watering deserts and savage countries, whose poverty or fierceness have kept strangers away.

But of all parts of the world, America, as it exhibits the most lofty mountains, so also it supplies the largest rivers. The foremost of these is the great river Amazon, which, from its source in the lake of Lauricocha, to its discharge into the Western Ocean, performs a course of more than twelve hundred leagues.[3] The breadth and depth of this river are answerable to its vast length; and, where its width is most contracted, its depth is augmented in proportion. So great is the body of its waters, that other rivers, though before the objects of admiration, are lost in its bosom. It proceeds, after their junction, with its usual appearance, without any visible change in its breadth or rapidity; and, if we may so express it, remains great without ostentation. In some places it displays its whole magnificence, dividing into several large branches, and encompassing a multitude of islands; and, at length, discharging itself into the ocean, by a channel of a hundred and fifty miles broad. Another river, that may almost rival the former, is the St Lawrence, in Canada, which rising in the lake Assiniboils, passes from one lake to another, from Christinaux to Alempigo; from thence to lake Superior; thence to the lake Hurons; to lake Erie; to lake Ontario; and, at last, after a course of nine hundred leagues pours their collected waters into the Atlantic Ocean. The river Mississippi is of more than seven hundred leagues in length, beginning at its source near the lake Assiniboils, and ending at

2 Buffon, vol. ii. p 82. 3 Ulloa, vol. i. p. 383.

its opening into the Gulf of Mexico. The river Plate runs a length of more than eight hundred leagues from its source in the river Parana, to its mouth. The river Oroonoko is seven hundred and fifty leagues in length, from its source near Pasta, to its discharge into the Atlantic Ocean.

Such is the amazing length of the greatest rivers; and even in some of these, the most remote sources very probably yet continue unknown. In fact, if we consider the number of rivers which they receive, and the little acquaintance we have with the regions through which they run, it is not to be wondered at that geographers are divided concerning the sources of most of them. As among a number of roots by which nourishment is conveyed to a stately tree, it is difficult to determine precisely that by which the tree is chiefly supplied; so among the many branches of a great river, it is equally difficult to tell which is the original. Hence it may easily happen, that a similar branch is taken for the capital stream; and its runnings are pursued, and delineated, in prejudice of some other branch that better deserved the name and the description. In this manner,[1] in Europe, the Danube is known to receive thirty lesser rivers; the Wolga thirty-two or thirty-three. In Asia, the Hohanho receives thirty-five; the Jenisca above sixty; the Oby as many; the Amour about forty; the Nanquin receives thirty rivers; the Ganges twenty; and the Euphrates about eleven. In Africa, the Senegal receives more than twenty rivers; the Nile receives not one for five hundred leagues upwards, and then only twelve or thirteen. In America, the river Amazon receives above sixty, and those very considerable; the river St Lawrence about forty, counting those which fall into its lakes; the Mississippi receives forty; and the river Plate above fifty.

I mentioned the inundations of the Ganges and the Nile; but almost every other great river, whose source lies within the tropics, have their stated inundations also. The river Pegu has been called, by travellers, the Indian Nile, because of the similar overflowings of its stream: this it does to an extent of thirty leagues on each side; and so fertilizes the soil, that the inhabitants send great quantities of rice into other countries, and have still abundance for their own consumption. The river

1 Buffon, vol. ii. p. 74.

Senegal has likewise its inundations, which cover the whole flat country of Negroland, beginning and ending much about the same time with those of the Nile; as, in fact, both rivers rise from the same mountains. But the difference between the effects of the inundations in each river is remarkable: in the one, it distributes health and plenty; in the other, diseases, famine, and death. The inhabitants along the torrid coasts of the Senegal, can receive no benefit from any additional manure the river may carry down to their soil, which is by nature more than sufficiently luxuriant; or, even if they could, they have not industry to turn it to any advantage. The banks therefore, of the rivers, lie uncultivated, overgrown with rank and noxious herbage, and infested with thousands of animals of various malignity. Every new flood only tends to increase the rankness of the soil, and to provide fresh shelter for the creatures that infest it. If the flood continues but a few days longer than usual, the improvident inhabitants, who are driven up in the higher grounds, want provisions, and a famine ensues. When the river begins to return into its channel, the humidity and heat of the air are equally fatal; and the carcases of infinite numbers of animals, swept away by the inundation, putrefying in the sun, produce a stench that is almost insupportable. But even the luxuriance of the vegetation becomes a nuisance. I have been assured, by persons of veracity who have been up the river Senegal, that there are some plants growing along the coast, the smell of which is so powerful, that it is hardly to be endured. It is certain, that all the sailors and soldiers who have been at any of our factories there, ascribe the unwholesomeness of the voyage up the stream, to the vegetable vapour. However this be, the inundations of the rivers in this wretched part of the globe, contribute scarce any advantage, if we except the beauty of the prospects which they afford. These, indeed, are finished beyond the utmost reach of art: a spacious glassy river, with its banks here and there fringed to the very surface by the mangrove-tree, that grows down into the water, presents itself to view; lofty forests of various colours, with openings between, carpeted with green plants, and the most gaudy flowers; beasts and animals, of various kinds, that stand upon the banks of the rivers, and, with a sort of wild curiosity, survey the mariners as they pass, contribute to heighten the scene. This is the sketch of an African prospect; which delights the eye, even while it destroys the constitution.

Besides these annually periodical inundations, there are many rivers that overflow at much shorter intervals. Thus most of those in Peru and Chili have scarce any motion by night; but upon the appearance of the morning sun, they resume their former rapidity: this proceeds from the mountain snows, which, melting with the heat, increase the stream, and continue to drive on the current, while the sun continues to dissolve them. Some rivers also flow with an even steady current, from their source to the sea; others flow with greater rapidity, their stream being poured down in a cataract, or swallowed by the sands, before they reach the sea.

The rivers of those countries that have been least inhabited, are usually more rocky, uneven, and broken into waterfalls or cataracts, than those where the industry of man has been more prevalent. Wherever man comes, nature puts on a milder appearance: the terrible and the sublime, are exchanged for the gentle and the useful: the cataract is sloped away into a placid stream; and the banks become more smooth and even.[1] It must have required ages to render the Rhone or the Loire navigable: their beds must have been cleaned and directed; their inequalities removed; and by a long course of industry, Nature must have been taught to conspire with the desires of her controller. Every one's experience must have supplied instances of rivers thus being made to flow more evenly, and more beneficially to mankind; but there are some whose currents are so rapid, and falls so precipitate, that no art can obviate; and that must for ever remain as amazing instances of incorrigible nature.

Of this kind are the cataracts of the Rhine; one of which I have seen exhibit a very strange appearance; it was that at Schathausen, which was frozen quite across, and the water stood in columns where the cataract had formerly fallen. The Nile, as was said, has its cataracts. The river Vologda, in Russia, has two. The river Zara, in Africa, has one near its source. The river Velino, in Italy, has a cataract of above an hundred and fifty feet perpendicular. Near the city of Gottenburgh,[2] in

1 Buffon, vol. ii. p. 90. 2 Phil Trans. vol. ii. p. 325.

Sweden, the river rushes down from a prodigious high precipice, into a deep pit, with a terrible noise, and such dreadful force, that those trees designed for the masts of ships, which are floated down the river, are usually turned upside down in their fall, and often are shattered to pieces, by being dashed against the surface of the water in the pit; this occurs if the masts fall sideways upon the water; but if they fall endways, they dive so far under water, that they disappear for a quarter of an hour, or more: the pit, into which they are thus plunged, has been often sounded with a line of some hundred fathoms long, but no ground has been found hitherto. There is also a cataract at Powers-court, in Ireland, in which, if I am rightly informed, the water falls three hundred feet perpendicular; which is a greater descent than that of any other cataract in any part of the world. There is a cataract at Albany, in the province of New York, which pours its stream fifty feet perpendicular. But of all the cataracts in the world, that of Niagara, in Canada, if we consider the great body of water that falls, must be allowed to be the greatest, and the most astonishing.

This amazing fall of water is made by the river St Lawrence, in its passage from the lake Erie into the lake Ontario. We have already said that the St Lawrence was one of the largest rivers in the world; and yet the whole of its waters are here poured down by a fall of a hundred and fifty feet perpendicular. It is not easy to bring the imagination to correspond with the greatness of the scene; a river, extremely deep and rapid, and that serves to drain the waters of almost all North America into the Atlantic ocean, is here poured precipitately down a ledge of rocks, that rise, like a wall, across the whole bed of its stream. The width of the river, a little above, is near three quarters of a mile broad; and the rocks, where it grows narrower, are four hundred yards over. Their direction is not straight across, but hollowing inwards like a horse-shoe; so that the cataract, which bends to the shape of the obstacle, rounding inwards, presents a kind of theatre the most tremendous in nature. Just in the middle of this circular wall of waters, a little island, that has braved the fury of the current, presents one of its points, and divides the stream at top into two; but it unites again long before it has got to the bottom. The noise of the fall is heard at several leagues distance; and the fury of the waters at the bottom of their fall is inconceivable. The dashing produces a mist that rises to the very clouds; and that produces a most beautiful rainbow, when the sun shines. It may easily be conceived, that such a cataract quite destroys the navigation of the stream; and yet some Indian canoes, as it is said, have been known to venture down it with safety.

Of those rivers that lose themselves in the sands, or are swallowed up by chasms in the earth, we have various information. What we are told by the ancients, of the river Alpheus, in Arcadia, that sinks into the ground, and rises again near Syracuse in Sicily, where it takes the name of Arethusa, is rather more known than credited. But we have better information with respect to the river Tigris being lost in this manner under mount Taurus; of the Guadalquiver, in Spain, being buried in the sands; of the river Greatah, in Yorkshire, running under ground, and rising again; and even of the great Rhine itself, a part of which is no doubt lost in the sands, a little above Leyden. But it ought to be observed of this river, that by much the greatest part arrives at the ocean; for, although the ancient channel which fell into the sea, a little to the west of that city, be now entirely choked up, yet there are still a number of small canals, that carry a great body of water to the sea; and, besides, it has also two very large openings, the Leeh and the Waal, below Rotterdam, by which it empties itself abundantly.

Be this as it will, nothing is more common in sultry and sandy deserts, than rivers being thus either lost in the sands, or entirely dried up by the sun. And hence we see, that under the line, the small rivers are but few; for such little streams as are common in Europe, and which with us receive the name of rivers, would quickly evaporate, in those parching and extensive deserts. It is even confidently asserted, that the great river Niger is thus lost before it reaches the ocean; and that its supposed mouths, the Gambia and the Senegal, are distinct rivers, that come a vast way from the interior parts of the country. It appears, therefore, that the rivers under the Line are large; but it is otherwise at the Poles,[1] where they must necessarily be small. In that desolate region, as the mountains are covered with perpetual ice, which melts but little, or not at all, the

1 Crantz's History of Greenland, vol. i. p. 41.

springs and rivulets are furnished with a very small supply. Here, therefore, men and beasts would perish, and die for thirst, if Providence had not ordered, that in the hardest winter, thaws should intervene, which deposit a small quantity of snow-water in pools under the ice; and from this source the wretched inhabitants drain a scanty beverage.

Thus, whatever quarter of the globe we turn to, we shall find new reasons to be satisfied with that part of it in which we reside. Our rivers furnish all the plenty of the African stream, without its inundation; they have all the coolness of the polar rivulet, with a more constant supply; they may want the terrible magnificence of huge cataracts, or extensive lakes, but they are more navigable, and more transparent; though less deep and rapid than the rivers of the torrid zone, they are more manageble, and only wait the will of man to take their direction. The rivers of the torrid zone, like the monarchs of the country, rule with despotic tyranny; profuse in their bounties, and ungovernable in their rage. The rivers of Europe, like their kings, are the friends, and not the oppressors, of the people; bounded by known limits, abridged in the power of doing ill, directed by human sagacity, and only at freedom to distribute happiness and plenty,

CHAP. XV.

OF THE OCEAN IN GENERAL; AND OF ITS SALTNESS.

If we look upon a map of the world, we shall find that the ocean occupies considerably more of the globe, than the land is found to do. This immense body of waters is diffused round both the Old and New Continent, to the south; and may surround them also to the north, for what we know, but the ice in those regions has stopped our inquiries. Although the ocean, properly speaking, is but one extensive sheet of waters, continued over every part of the globe, without interruption, and although no part of it is divided from the rest, yet geographers have distinguished it by different names; as, the Atlantic or Western ocean, the Northern ocean, the Southern ocean, the

Pacific ocean, and the Indian ocean. Others have divided it differently, and given other names; as the Frozen ocean, the Inferior ocean, or the American ocean. But all these being arbitrary distinctions, and not of Nature's making, the naturalist may consider them with indifference.

In this vast receptacle, almost all the rivers of the earth ultimately terminate; nor do such great supplies seem to increase its stores; for it is neither apparently swollen by their tribute, nor diminished by their failure; it still continues the same. Indeed, what is the quantity of water of all the rivers and lakes in the world, compared to that contained in this great receptacle?[1] If we should offer to make a rude estimate, we shall find that all the rivers in the world, flowing into the bed of the sea, with a continuance of their present stores, would take up at least eight hundred years to fill it to its present height. For, supposing the sea to be eighty-five millions of square miles in extent, and a quarter of a mile, upon an average, in depth, this, upon calculation, will give about twenty-one millions of cubic miles of water, as the contents of the whole ocean. Now, to estimate the quantity of water which all the rivers supply, take any one of them; the Po, for instance, the quantity of whose discharge into the sea is known to be one cubic mile of water in twenty-six days. Now it will be found, upon a rude computation, from the quantity of ground the Po, with its influent streams, covers, that all the rivers of the world furnish about two thousand times that quantity of water. In the space of a year, therefore, they will have discharged into the sea about twenty-six thousand cubic miles of water; and not till eight hundred years will they have discharged as much water as is contained in the sea at present. I have not troubled the reader with the odd numbers, lest he should imagine I was giving precision to a subject that is incapable of it.

Thus great is the assemblage of waters diffused round our habitable globe; and yet, immeasurable as they seem, they are mostly rendered subservient to the necessities and the conveniences of so little a being as man. Nevertheless, if it should be asked whether they be made for him alone, the question is not easily resolved. Some philosophers have perceived so much

1 Buffon, vol. i. p. 70.

analogy to man in the formation of the ocean, that they have not hesitated to assert its being made for him alone. The distribution of land and water,[2] say they, is admirable; the one being laid against the other so skilfully, that there is a just equipoise of the whole globe. Thus the Northern ocean balances against the Southern; and the New Continent is an exact counterweight to the Old. As to any objection from the ocean's occupying too large a share of the globe, they contend, that there could not have been a smaller surface employed to supply the earth with a due share of evaporation. On the other hand, some take the gloomy side of the question; they either magnify[3] its apparent defects; or assert, that what seems defects to us, may be real beauties to some wiser order of beings.[4] They observe, that multitudes of animals are concealed in the ocean, and but a small part of them are known; the rest, therefore, they fail not to say, were certainly made for their own benefit, and not for ours. How far either of these opinions be just, I will not presume to determine; but of this we are certain, that God has endowed us with abilities to turn this great extent of waters to our own advantage. He has made these things, perhaps, for other uses; but he has given us faculties to convert them to our own. This much agitated question, therefore, seems to terminate here. We shall never know whether the things of this world have been made for our use; but we very well know that we have been made to enjoy them. Let us then boldly affirm, that the earth, and all its wonders, are ours; since we are furnished with powers to force them into our service. Man is the lord of all the sublunary creation; the howling savage, the winding serpent, with all the untameable and rebellious offspring of Nature are destroyed in the contest, or driven at a distance from his habitations. The extensive and tempestuous ocean, instead of limiting or dividing his power, only serves to assist his industry, and enlarge the sphere of his enjoyments. Its billows and its monsters, instead of presenting a scene of terror, only call up the courage of this little intrepid being; and the greatest danger that man now fears on the deep, is from his fellow creatures. Indeed, when I consider the human race as

2 Derham's Physico-Theol. 3 Burnet's Theory, passim.
4 Pope's Ethic Epistles, passim.

Nature has formed them, there is but very little of the habitable globe that seems made for them. But when I consider them as accumulating the experience of ages, in commanding the earth, there is nothing so great or so terrible. What a poor contemptible being is the naked savage, standing on the beach of the ocean, and trembling at its tumults! How little capable is he of converting its terrors into benefits; or of saying, behold an element made wholly for my enjoyment! He considers it as an angry deity, and pays it the homage of submission. But it is very different when he has exercised his mental powers; when he has learned to find his own superiority, and to make it subservient to his commands. It is then that his dignity begins to appear, and that the true Deity is justly praised for having been mindful of man; for having given him the earth for his habitation, and the sea for an inheritance.

This power which man has obtained over the ocean, was at first enjoyed in common; and none pretended to a right in that element where all seemed intruders. The sea, therefore, was open to all, till the time of the emperor Justinian. His successor Leo granted such as were in possession of the shore, the sole right of fishing before their respective territories. The Thracian Bosphorus was the first that was thus appropriated; and from that time it has been the struggle of most of the powers of Europe to obtain an exclusive right in this element. The republic of Venice claims the Adriatic. The Danes are in possession of the Baltic. But the English have a more extensive claim to the empire of all the seas encompassing the kingdoms of England, Scotland, and Ireland; and although these have been long contested, yet they are now considered as their indisputable property. Every one knows that the great power of the nation is exerted on this element; and that the instant England ceases to be superior upon the ocean, its safety begins to be precarious.

It is in some measure owing to our dependence upon the sea, and to our commerce there, that we are so well acquainted with its extent and figure. The bays, gulfs, currents, and shallows of the ocean, are much better known and examined than the provinces and kingdoms ofthe earth itself. The hopes of acquiring wealth by commerce, has carried man to much greater length than the desire of gaining information could have done. In consequence of this, there is scarce a strait or a harbour.

scarce a rock or a quick sand, scarce an inflexion of the shore, or the jutting of a promontory, that has not been minutely described. But as these present very little entertainment to the imagination, or delight to any but those whose pursuits are lucrative, they need not be dwelt upon here. While the merchant and the mariner are solicitous in describing currents and soundings, the naturalist is employed in observing wonders, though not so beneficial, yet to him of a much more important nature. The saltness of the sea seems to be foremost.

Whence the sea has derived that peculiar bitterish saltness which we find in it, appears, by Aristotle, to have exercised the curiosity of naturalists in all ages. He supposed (and mankind were for ages content with the solution) that the sun continually raised dry saline exhalations from the earth, and deposited them upon the sea; and hence, say his followers, the waters of the sea are more salt at top than at bottom. But, unfortunately for this opinion, neither of the facts is true. Sea-salt is not to be raised by the vapours of the sun; and sea-water is not salter at the top than at the bottom. Father Bohours is of opinion, that the Creator gave the waters of the ocean their saltness at the beginning: not only to prevent their corruption, but to enable them to bear greater burthens. But their saltness does not prevent their corruption; for stagnant sea-water, like fresh, soon grows putrid: and, as for their bearing greater burthens, fresh water answers all the purposes of navigation quite as well. The established opinion, therefore, is that of Boyle,[1] who supposes, "That the sea's saltness is supplied not only from rocks or masses of salt at the bottom of the sea, but also from the salt which the rains, and rivers, and other waters, dissolve in their passage through many parts of the earth, and at length carry with them to the sea." But as there is a difference in the taste of rock-salt found at land, and that dissolved in the waters of the ocean, this may be produced by the plenty of nitrous and bituminous bodies that, with the salts, are likewise washed into that great receptacle. These substances being thus once carried to the sea, must for ever remain there; for they do not rise by evaporation so as to be returned back from whence they came. Nothing but the fresh

1 Boyle, vol. iii. p. 221.

waters of the sea rise in vapours; and all the saltness remains behind. From hence it follows, that every year the sea must become more and more salt; and this speculation Dr Halley carries so far as to lay down a method of finding out the age of the world by the saltness of its waters. "For if it be observed," says he, "what quantity of salt is at present contained in a certain weight of water taken up from the Caspian Sea, for example, and, after some centuries what greater quantity of salt is contained in the same weight of water, taken from the same place; we may conclude, that in proportion as the saltness has increased in a certain time, so much must it have increased before that time; and we may thus by the rule of proportion make an estimate of the whole time wherein the water would acquire the degree of saltness it should be then possessed of."[1] All this may be fine: however, an experiment, begun in this century, which is not to be completed till some centuries hence, is rather a little mortifying to modern curiosity; and I am induced to think, the inhabitants round the Caspian Sea will not be apt to undertake the inquiry.

This saltness is found to prevail in every part of the ocean; and as much at the surface as at the bottom. It is also found in all those seas that communicate with the ocean; but rather in a less degree.

The great lakes, likewise, that have no outlets nor communication with the ocean, are found to be salt; but some of them in less proportion. On the contrary, all those lakes through which rivers run into the sea, however extensive they be, are, notwithstanding, very fresh: for the rivers do not deposite their salts in the bed of the lake, but carry them with their currents into the ocean. Thus the lakes Ontario and Erie, in North America, although for magnitude they may be considered as inland seas, are nevertheless fresh-water lakes; and kept so by the river St Lawrence, which passes through them. But those lakes that have no communication with the sea, nor any rivers going out, although they be less than the former, are, however, always salt. Thus, that which goes by the name of the Dead Sea, though very small, when compared to those already mentioned, is so exceedingly salt, that its waters seem scarcely capable

1 Phil. Trans. vol. v. p. 218.

of dissolving any more. The lakes of Mexico and of Titicaca in Peru, though of no great extent, are nevertheless salt; and both for the same reason.

Those who are willing to turn all things to the best, have not failed to consider this saltness of the sea as a peculiar blessing from providence, in order to keep so great an element sweet and wholesome. What foundation there may be in the remark, I will not pretend to determine; but we shall shortly find a much better cause for its being kept sweet, namely, its motion.

On the other hand, there have been many who have considered the subject in a different light, and have tried every endeavour to make salt-water fresh, so as to supply the wants of mariners in long voyages, or when exhausted of their ordinary stores. At first it was supposed simple distillation would do; but it was soon found, that the bitter part of the water still kept mixed. It was then tried by uniting salt of tartar with sea-water, and distilling both, but here the expense was greater than the advantage. Calcined bones were next thought of; but a hogshead of calcined bones, carried to sea, would take up as much room as a hogshead of water, and was more hard to be obtained. In this state, therefore, have the attempts to sweeten sea-water rested; the chymist, satisfied with the reality of his invention, and the mariner convinced of its being useless. I cannot, therefore, avoid mentioning a kind of succedaneum which has been lately conceived to answer the purposes of fresh water, when mariners are quite exhausted. It is well known, that persons who go into a warm bath, come out several ounces heavier than they went in; their bodies have imbibed a correspondent quantity of water. This more particularly happens, if they have been previously debarred from drinking, or go in with a violent thirst; which they quickly find quenched, and their spirits restored. It was supposed, that in case of a total failure of fresh water at sea, a warm bath might be made of sea-water, for the use of mariners; and that their pores would thus imbibe the fluid without any of its salts, which would be seen to crystalize on the surface of their bodies. In this manner it is supposed, a sufficient quantity of moisture may be procured to sustain life, till time or accident furnish a more copious supply.

But however this be, the saltness of the sea can by no means be considered as a principal cause in preserving its waters from putrefaction. The ocean has its currents, like rivers which circulate its contents round the globe; and these may be said to be the great agents that keep it sweet and wholesome. Its saltness alone would by no means answer this purpose: and some have even imagined that the various substances with which it is mixed, rather tend to promote putrescence than impede it. Sir Robert Hawkins, one of our most enlightened navigators, gives the following account of a calm in which the sea, continuing for some time without motion, began to assume a very formidable appearance. "Were it not," says he, "for the moving of the sea, by the force of winds, tides, and currents, it would corrupt all the world. The experiment of this I saw in the year 1590, lying with a fleet about the islands of the Azores, almost six months; the greatest part of which time we were becalmed. Upon which all the sea became so replenished with several sorts of jellies, and of serpents, adders, and snakes, as seemed wonderful. some green, some black, some yellow, some white, some of divers colours; and many of them had life; and some there were a yard and a half, and two yards long: which had I not seen, I could hardly have believed. And hereof are witnesses all the company of the ships which were then present; so that hardly a man could draw a bucket of water clear of some corruption. In which voyage towards the end thereof, many of every ship fell sick, and began to die apace. But the speedy passage into our country was a remedy to the crazed, and a preservative for those that were not touched."

This shows abundantly how little the sea's saltness was capable of preserving it from putrefaction: but to put the matter beyond all doubt, Mr Boyle kept a quantity of sea-water, taken up in the English Channel, for some time barrelled up; and in the space of a few weeks it began to acquire a fetid smell.[1] He was also assured, by one of his acquaintance, who was becalmed for twelve or fourteen days in the Indian Sea, that the water for want of motion, began to stink; and that had it continued much longer, the stench would probably have poisoned him. It is the motion, therefore, and not the saltness of the sea, that

1 Boyle, vol. iii. p. 222.

preserves it in its present state of salubrity; and this very probably, by dashing and breaking in pieces the rudiments, if I may so call them, of the various animals that would otherwise breed there, and putrefy.

There are some advantages, however, which are derived from the saltness of the sea. Its waters being evaporated, furnish that salt which is used for domestic purposes; and although in some places it is made from springs, and in others dug out of mines, yet the greatest quantity is made only from the sea. That which is called *bay salt,* (from its coming to us by the Bay of Biscay,) is a stronger kind, made by evaporation in the sun; that called *common salt,* is evaporated in pans over the fire, and is of a much inferior quality to the former.

Another benefit arising from the quantity of salt dissolved in the sea is, that it thus becomes heavier, and consequently more buoyant. Mr Boyle, who examined the difference between sea-water and fresh, found that the former appeared to be about a forty-fifth part heavier than the latter. Those, also, who have had opportunities of bathing in the sea, pretend to have experienced a much greater ease in swimming there than in fresh water. However, as we see they have only a forty-fifth part more of their weight sustained by it, I am apt to doubt whether so minute a difference can be practically perceivable. Be this as it may, as sea-water alters in its weight from fresh so it is found also to differ from itself in different parts of the ocean. In general, it is perceivable to be heavier, and consequently salter, the nearer we approach the Line.[2]

But there is an advantage arising from the saltness of the waters of the sea, much greater than what has been yet mentioned; which is, that their congelation is thus retarded. Some indeed have gone so far as to say, that sea-water never freezes;[3] but this is an assertion contradicted by experience. However it is certain, that it requires a much greater degree of cold to freeze it than fresh water; so that while rivers and springs are seen converted into one solid body of ice, the sea is always fit for navigation, and no way affected by the coldness of the severest winter. It is, therefore, one of the greatest blessings we derive from this element that, when at land all the stores of

2 Phil. Trans. vol. ii p. 267. 3 Macrobius.

nature are locked up from us, we find the sea ever open to our necessities, and patient of the hand of industry.

But it must not be supposed, because in our temperate climate we never see the sea frozen, that it is in the same manner open in every part of it. A very little acquaintance with the accounts of mariners, must have informed us, that at the polar regions it is embarrassed with mountains and moving sheets of ice, that often render it impassable. These tremendous floats are of different magnitudes; sometimes rising more than a thousand feet above the surface of the water;[1] sometimes diffused into plains of above two hundred leagues in length; and, in many parts, sixty or eighty broad. They are usually divided by fissures; one piece following another so close, that a person may step from one to the other. Sometimes mountains are seen rising amidst these plains, and presenting the appearance of a variegated landscape, with hills and valleys, houses, churches, and towers. These are appearances in which all naturalists are agreed; but the great contest is respecting their formation. Mr Buffon asserts,[2] that they are formed from fresh water alone, which congealing at the mouths of great rivers, accumulate those huge masses that disturb navigation. However, this great naturalist seems not to have been aware, that there are two sorts of ice floating in these seas; the flat ice and the mountain ice: the one formed of sea-water only; the other of fresh.[3]

The flat, or driving ice, is entirely composed of sea-water; which, upon dissolution, is found to be salt; and is readily distinguished from the mountain, or fresh water ice, by its whiteness, and want of transparency. This ice is much more terrible to mariners than that which rises up in lumps: a ship can avoid the one, as it is seen at a distance; but it often gets in among the other, which, sometimes closing, crushes it to pieces. This, which manifestly has a different origin from the fresh-water ice, may perhaps have been produced in the Icy Sea, beneath the pole; or along the coasts of Spitzbergen or Nova-Zembla.

The mountain ice, as was said, is different in every respect, being formed of fresh water, and appearing hard and transparent, it is generally of a pale green colour, though some pieces are of a beautiful sky-blue; many large masses also appear gray, and

1 Crantz's History of Greenland, vol. i. p. 31.
2 Buffon, vol. ii. p. 91. 3 Crantz.

some black. If examined more nearly, they are found to be incorporated with earth, stones, and brush-wood, washed from the shore. On these also are sometimes found, not only earth, but nests with birds' eggs, at several hundred miles from land. The generality of these, though almost totally fresh, have nevertheless a thick crust of salt-water frozen upon them, probably from the power that ice has sometimes to produce ice. Such mountains as are here described, are most usually seen at spring-time, and after a violent storm, driving out to sea, where they at first terrify the mariner, and are soon after dashed to pieces by the continual washing of the waves; or driven into the warmer regions of the south, there to be melted away. They sometimes, however, strike back upon their native shores, where they seem to take root at the feet of mountains; and, as Martius tells us, are sometimes higher than the mountains themselves. Those seen by him were blue, full of clefts and cavities made by the rain, and crowned with snow, which alternately thawing and freezing every year, augmented their size. These, composed of materials more solid than that driving at sea, presented a variety of agreeable figures to the eye, that with a little help from fancy assumed the appearance of trees in blossom; the inside of churches, with arches, pillars, and windows; and the blue-coloured rays, darting from within, presented the resemblance of a glory.

If we inquire into the origin and formation of these, which, as we see, are very different from the former, I think we have a very satisfactory account of them in Crantz's History of Greenland; and I will take leave to give the passage with a very few alterations. "These mountains of ice," says he, "are not salt, like the sea-water, but sweet; and, therefore, can be formed nowhere except on the mountains, in rivers, in caverns, and against the hills near the sea-shore. The mountains of Greenland are so high that the snow which falls upon them, particularly on the north-side, is in one night's time wholly converted into ice: they also contain clefts and cavities, where the sun seldom or never injects his rays; besides these, are projections, or landing places, on the declivities of the steepest hills, where the rain and snow-water lodge, and quickly congeal. When now the accumulated flakes of snow slide down, or fall with the rain from the eminences above on these prominences; or, when here and there a mountain-spring comes rolling down to such a lodging-place, where the ice has already seated itself, they all freeze, and add their tribute to it. This, by degrees, waxes to a body of ice, that can no more be overpowered by the sun; and which, though it may indeed, at certain seasons, diminish by a thaw, yet, upon the whole, through annual acquisitions, it assumes an annual growth. Such a body of ice is often prominent far over the rocks. It does not melt on the upper surface, but underneath; and often cracks into many larger or smaller clefts, from whence the thawed water trickles out. By this it becomes at last so weak, that being overloaded with its own ponderous bulk, it breaks loose, and tumbles down the rocks with a terrible crash. Where it happens to overhang a precipice on the shore, it plunges into the deep with a shock like thunder; and with such an agitation of the water, as will overset a boat at some distance, as many a poor Greenlander has fatally experienced." Thus are these amazing ice-mountains launched forth to sea, and found floating in the waters round both the poles. It is these that have hindered mariners from discovering the extensive countries that lie round the South Pole; and that probably block up the passage to China by the North.

I will conclude this chapter with one effect more, produced by the saltness of the sea; which is the luminous appearance of its waves in the night. All who have been spectators of a sea by night, a little ruffled with winds, seldom fail of observing its fiery brightness. In some places it shines as far as the eye can reach;[1] at other times, only when the waves boom against the side of the vessel, or the oar dashes into the water. Some seas shine often; others more seldom; some, ever when particular winds blow; and others, within a narrow compass; a long tract of light being seen along the surface, whilst all the rest is hid in total darkness. It is not easy to account for these extraordinary appearances: some have supposed that a number of luminous insects produced the effect, and this is in reality sometimes the case; in general, however, they have every resemblance to that light produced by electricity; and, probably, arise from the agitation and dashing of the saline particles of the fluid against each other. But the manner in which this is done, for we can pro-

1 Boyle, vol. i. p. 294.

duce nothing similar by any experiments hitherto made, remains for some happier accident to discover. Our progress in the knowledge of nature is slow; and it is a mortifying consideration, that we are hitherto more indebted for success to chance than industry.

CHAP. XVI.

OF THE TIDES MOTION, AND CURRENTS, OF THE SEA; WITH THEIR EFFECTS.

It was said in the former chapter, that the waters of the sea were kept sweet by their motion; without which they would soon putrefy, and spread universal infection. If we look for final causes, here indeed we have a great and an obvious one that presents itself before us. Had the sea been made without motion, and resembling a pool of stagnant water, the noble races of animated nature would shortly be at an end. Nothing would then be left alive but swarms of ill-formed creatures, with scarcely more than vegetable life; and subsisting by putrefaction. Were this extensive bed of waters entirely quiescent, millions of the smaller reptile kinds would there find a proper retreat to breed and multiply in; they would find there no agitation, no concussion in the parts of the fluid to crush their feeble frames, or to force them from the places where they were bred: there they would multiply, in security and ease, enjoy a short life, and putrefying, thus again give nourishment to numberless others, as little worthy of existence as themselves. But the motion of this great element effectually destroys the number of these viler creatures; its currents and its tides produce continual agitations, the shock of which they are not able to endure; the parts of the fluid rubbing against each other destroy all viscidities; and the ocean, if I may so express it, acquires health by exercise.

The most obvious motion of the sea, and the most generally acknowledged, is that of its tides. This element is observed to flow for certain hours, from the south towards the north; in which motion or flux, which lasts about six hours, the sea gradually swells; so that entering the mouths of rivers, it drives back the river-waters to their heads. After a continual flux of six hours, the sea seems to rest for a quarter of an hour; and then begins to ebb, or retire back again, from north to south, for six hours more; in which time the waters sinking, the rivers resume their natural course. After a seeming pause of a quarter of an hour, the sea again begins to flow as before: and thus it has alternately risen and fallen, twice a-day, since the creation.

This amazing appearance did not fail to excite the curiosity, as it did the wonder of the ancients. After some wild conjectures of the earliest philosophers, it became well known in the time of Pliny, that the tides were entirely under the influence, in a small degree, of the sun; but in a much greater of the moon. It was found that there was a flux and reflux of the sea, in the space of twelve hours fifty minutes, which is exactly the time of a lunar day. It was observed, that whenever the moon was in the meridian, or, in other words, as nearly as possible over any part of the sea, that the sea flowed to that part, and made a tide there; on the contrary, it was found, that when the moon left the meridian, the sea began to flow back again from whence it came; and there might be said to ebb. Thus far the waters of the sea seemed very regularly to attend the motions of the moon. But as it appeared, likewise, that when the moon was in the opposite meridian, as far off on the other side of the globe, that there was a tide on this side also; so that the moon produced two tides, one by her greatest approach to us, and another by her greatest distance from us: in other words, the moon, in once going round the earth, produced two tides, always at the same time; one on the part of the globe directly under her; and the other, on the part of the globe directly opposite.

Mankind continued for several ages content with knowing the general cause of these wonders, hopeless of discovering the particular manner of the moon's operation. Kepler was the first who conjectured that attraction was the principal cause; asserting, that the sphere of the moon's operation extended to the earth, and drew up its waters. The precise manner in which this is done, was discovered by Newton.

The moon has been found, like all the rest of the planets, to attract and to be attracted by the earth. This attraction prevails throughout our whole planetary system. The more matter there is contained in any body, the more it attracts; and its influence decreases in proportion as the distance, when squared, increases. This being premised, let us see what must ensue upon supposing the moon in the meridian of any tract of the sea. The surface of the water immediately under the moon, is nearer the moon than any other part of the globe is; and, therefore, must be more subject to its attraction, than the waters any where else. The waters will, therefore, be attracted by the moon, and rise in a heap; whose eminence will be the highest where the attraction is greatest. In order to form this eminence, it is obvious that the surface, as well as the depths, will be agitated; and that wherever the water runs from one part, succeeding waters must run to fill up the space it has left. Thus the waters of the sea, running from all parts to attend the motion of the moon, produce the flowing of the tide; and it is high tide at that part wherever the moon comes over it, or to its meridian.

But when the moon travels onward, and ceases to point over the place where the waters were just risen, the cause here of their rising ceasing to operate, they will flow back by their natural gravity into the lower parts from whence they had travelled; and this retiring of the waters will form the ebbing of the sea.

Thus the first part of the demonstration is obvious; since, in general, it requires no great sagacity to conceive that the waters nearest the moon are most attracted, or raised highest by the moon. But the other part of the demonstration, namely, how there come to be high tides at the same time, on the opposite side of the globe, and where the waters are farthest from the moon, is not so easy to conceive. To comprehend this, it must be observed, that the part of the earth and its waters that are farthest from the moon, are the parts of all others that are least attracted by the moon; it must also be observed, that all the waters, when the moon is on the opposite side of the earth, must be attracted by it in the same direction that the earth itself attracts them; that is, if I may so say, quite through the body of the earth, towards the moon itself. This, therefore, being conceived, it is plain that those waters which are farthest from the moon, will have less weight than those of any other part, on the same side of the globe ; because the moon's attraction, which conspires with the earth's attraction, is there least. Now, therefore, the waters farthest from the moon, having less weight, and being lightest, will be pressed on all sides, by those that, having more attraction, are heavier : they will be pressed, I say on all sides ; and the heavier waters flowing in, will make them swell and rise, in an eminence directly opposite to that on the other side of the globe, caused by the more immediate influence of the moon.

In this manner the moon, in one diurnal revolution, produces two tides ; one raised immediately under the sphere of its influence, and the other directly opposite to it. As the moon travels, this vast body of waters rears upward, as if to watch its motions ; and pursues the same constant rotation. Howevei, in this great work of raising the tides, the sun has no small share ; it produces its own tides constantly every day, just as the moon does, but in a much less degree, because the sun is at an immensely greater distance. Thus there are solar tides, and lunar tides. When the forces of these two great luminaries concur, which they always do when they are either in the same, or in opposite parts of the heavens, they jointly produce a much greater tide, than when they are so situated in the heavens, as each to make peculiar tides of their own. To express the very same thing technically ; in the conjunctions and oppositions of the sun and moon, the attraction of the sun conspires with the attraction of the moon ; by which means the high spring-tides are formed. But in the quadratures of the sun and moon, the water raised by the one is depressed by the other ; and hence the lowe. neap-tides have their production. In a word, the tides are greatest in the syzigies, and least in the quadratures.

This theory well understood, and the astronomical terms pre iously known, it may readily be brought to explain the various appearances of the tides, if the earth were covered with a deep sea, and the waters uninfluenced by shoals, currents, straits, or tempests. But in every part of the sea, near the shores, the geographer must come in to correct the calculations of the astronomer. For, by reason of the shallowness of some places, and the narrowness of the straits in others, there arises a great diversity in the effect, not to be accounted for without an exact knowledge of all the circumstances of the place. In the great depths of the ocean, for instance, a very slow and imperceptible motion of the whole body of water will suffice to raise its surface several feet high; but if the same increase of water is to be conveyed through a narrow channel, it must rush through it with the most impetuous rapidity. Thus, in the English Channel, and the German Ocean, the tide is found to flow strongest in those places that are narrowest; the same quantity of water being, in this case, driven through a smaller passage. It is often seen, therefore, pouring through a strait with great force; and, by its rapidity, considerably raised above the surface of that part of the ocean into which it runs.

This shallowness and narrowness in many parts of the sea, give also rise to a peculiarity in the tides of some parts of the world. For in many places, and in our own seas in particular, the greatest swell of the tide is not while the moon is in its meridian height, and directly over the place, but some time after it has declined from thence. The sea, in this case, being obstructed, pursues the moon with what despatch it can, but does not arrive with all its waters till long after the moon has ceased to operate. Lastly, from the shallowness of the sea, and from its being obstructed by shoals and straits, we may account for the Mediterranean, the Baltic, and the Black Sea, having no sensible tides. These, though to us they seem very extensive, are not however large enough to be affected by the influence of the moon; and as to their communication with the ocean, through such narrow inlets, it is impossible, in a few hours' time, that they should receive and return water enough to raise or depress them in any considerable degree.

In general, therefore, we may observe, that all tides are much higher, and more considerable, in the torrid zone, than in the rest of the ocean; the sea in those parts being generally deeper, and less affected by changeable winds, or winding shores.[1] The greatest tide we know of, is that at the mouth of the river Indus, where the water rises thirty feet in height. How great, therefore, must have been the amazement of Alexander's soldiers at so strange an appearance! They who always before had been accustomed only to the scarcely perceptible risings of the Mediterranean, or the minute intumescense of the Black Sea, when

1 Buffon, vol. ii p. 187.

made at once spectators of a river rising and falling thirty feet in a few hours, must, no doubt, have felt the most extreme awe and, as we are told,[1] a mixture of curiosity and apprehension. The tides are also remarkably high on the coasts of Malay, in the straits of Sunda, in the Red Sea, at the mouth of the river St Lawrence, along the coasts of China and Japan, at Panama, and in the gulf of Bengal. The tides at Tonquin, however, are the most remarkable in the world. In this part there is but one tide, and one ebb, in twenty-four hours; whereas, as we have said before, in other places there are two. Besides, there, twice in each month, there is no tide at all, when the moon is near the equinoctial, the water being for some time quite stagnant. These, with some other odd appearances attending the same phenomena, were considered by many as inscrutable; but Sir Isaac Newton, with peculiar sagacity, adjudged them to arise from the concurrence of two tides, one from the South Sea, and the other from the Indian Ocean. Of each of these tides there come successively two every day; two at one time greater, and two at another that are less. The time between the arrival of the two greater, is considered by him as high tide; the time between the two lesser, as ebb. In short, with this clue, that great mathematician solved every appearance, and so established his theory as to silence every opposer.

This fluctuation of the sea from the tides, produces another, and more constant rotation of its waters, from the east to the west, in this respect following the course of the moon. This may be considered as one great and general current of the waters of the sea; and although it be not every where distinguishable it is nevertheless every where existent, except when opposed by some particular current or eddy, produced by partial and local causes. This tendency of the sea towards the west, is plainly perceivable in all the great straits of the ocean; as, for instance, in those of Magellan, where the tide running in from the east, rises twenty feet high, and continues flowing six hours; whereas the ebb continues but two hours, and the current is directed to the west. This proves that the flux is not equal to the reflux; and that from both results a motion of the sea west-

1 Quintus Curtius.

ward, which is more powerful during the time of the flux than the reflux.

But this motion westward has been sensibly observed by navigators, in their passage back from India to Madagascar, and so on to Africa. In the great Pacific Ocean also it is very perceivable; but the places where it is most obvious, are, as was said, in those straits which join one ocean to another. In the straits between the Maldivia islands, in the gulf of Mexico, between Cuba and Jucatan. In the straits of the gulf of Paria, the motion is so violent, that it hath received the appellation of the Dragon's Mouth. Northward, in the sea of Canada, in Waigat's straits, in the straits of Java, and, in short, in every strait where the ocean on one part pours into the ocean on the other. In this manner, therefore, is the sea carried with an unceasing circulation round the globe; and at the same time that its waters are pushed backward and forward with the tide, they have thus a progressive current to the west, which though less observable, is not the less real.

Beside these two general motions of the sea, there are others which are particular to many parts of it, and are called currents. These are found to run in all directions, east, west, north, and south; being formed, as was said above, by various causes; the prominence of the shores, the narrowness of the straits, the variations of the wind, and the inequalities at the bottom. These, though no great object to the philosopher, as their causes are generally local and obvious, are nevertheless of the most material consequence to the mariner; and without a knowledge of which he could never succeed. It often has happened, that when a ship has unknowingly got into one of these, every thing seems to go forward with success, the mariners suppose themselves every hour approaching their wished-for port, the wind fills their sails, and the ship's prow seems to divide the water; but, at last, by miserable experience they find that, instead of going forward, they have been all the time receding. The business of currents therefore, makes a considerable article in navigation; and the direction of their stream, and their rapidity, has been carefully set down. This some do by the observation of the surface of the current; or by the driving of the froth along the shore; or by throwing out what is called the *log-line*, with a buoy made for that purpose, and by the direction and motion of this, they judge of the setting and the rapidity of the current.

These currents are generally found to be most violent under the equator, where indeed all the motions of the ocean are most perceptible. Along the coasts of Guinea, if a ship happens to overshoot the mouth of any river it is bound to, the current prevents its return, so that it is obliged to steer out to sea, and take a very large compass, in order to correct the former mistake. These set in a contrary direction to the general motion of the sea westward; and that so strongly, that a passage which, with the current, is made in two days, is with difficulty performed in six weeks against it. However, they do not extend above twenty leagues from the coast; and ships going to the East Indies, take care not to come within the sphere of their action. At Sumatra, the currents, which are extremely rapid, run from south to north; there are also strong currents between Madagascar and the Cape of Good Hope. On the western coast of America, the currents always run from the south to the north, where a south wind, continually blowing, most probably occasions this phenomenon. But the currents that are most remarkable, are those continually flowing into the Mediterranean sea, both from the ocean by the straits of Gibraltar, and at its other extremity, from the Euxine sea by the Archipelago. This is one of the most extraordinary appearances in nature; this large sea receiving not only the numerous rivers that fall into it, such as the Nile, the Rhone, and the Po, but also a very great influx from the Euxine sea on one part, and the ocean on the other. At the same time, it is seen to return none of those waters it is thus known to receive. Outlets running from it there are none; no rivers but such as bring it fresh supplies; no straits but what are constantly pouring their waters into it. It has, therefore, been the wonder of mankind in every age, how, and by what means, this vast concourse of waters are disposed of; or how this sea, which is always receiving, and never returning, is no way fuller than before. In order to account for this, some have said, that the water was conveyed by subterraneous passages into the Red Sea.* There was a story told of an Arabian califf who caught a dolphin in this sea; admiring the beauty of which, he let it go again, having

* Kircher Mund. Subt. vol. 1.

previously marked it by a ring of iron. Some time after a dolphin was caught in the Red sea, and quickly known by the ring to be the same that had been taken in the Mediterranean before. Such, however, as have not been willing to found their opinions upon a story, have attempted to account for the disposal of the waters of the Mediterranean by evaporation. For this purpose they have entered into long calculations upon the extent of its surface, and the quantity of water that would be raised from such a surface in a year. They then compute how much water runs in by its rivers and straits in that time; and find, that the quantity exhausted by evaporation, greatly exceeds the quantity supplied by rivers and seas. This solution, no doubt, would be satisfactory, did not the ocean, and the Euxine, evaporate as well as the Mediterranean: and as these are subject to the same drain, it must follow, that all the seas will in this respect be upon a par; and, therefore, there must be some other cause for this unperceived drain, and continual supply. This seems to be satisfactorily enough accounted for by Dr Smith, who supposes an under current running through the straits of Gibraltar, to carry out as much water into the ocean, as the upper current continually carries in from it. To confirm this, he observes, that nearer home, between the North and the South Foreland, the tide is known to run one way at top, and the ebb another way at bottom. This double current he also confirms by an experiment communicated to him by an able seaman, who being with one of the king's frigates in the Baltic, found he went with his boat into the mid-stream, and was carried violently by the current; upon which a basket was sunk, with a large cannon-ball, to a certain depth of water, which gave a check to the boat's motion: as the basket sunk still lower, the boat was driven, by the force of the water below, against the upper current; and the lower the basket was let down, the stronger the under current was found, and the quicker was the boat's motion against the upper stream, which seemed not to be above four fathom deep. From hence we may readily infer, that the same cause may operate at the straits of Gibraltar; and that while the Mediterranean seems replenishing at top, it may be emptying at bottom.

The number of the currents at sea are impossible to be recounted, nor indeed are they always known; new ones are daily produced by a variety of causes, and as quickly disappear. When a regular current is opposed by another in a narrow strait, or where the bottom of the sea is very uneven, a whirlpool is often formed. These were formerly considered as the most formidable obstructions to navigation; and the ancient poets and historians speak of them with terror; they are described as swallowing up ships, and dashing them against the rocks at the bottom; apprehension did not fail to add imaginary terrors to the description, and placed at the centre of the whirlpool a dreadful den, fraught with monsters whose howlings served to add new horrors to the dashings of the deep. Mankind at present, however, view these eddies of the sea with very little apprehension; and some have wondered how the ancients could have so much overcharged their descriptions. But all this is very naturally accounted for. In those times when navigation was in its infancy, and the slightest concussion of the waves generally sent the poor adventurer to the bottom, it is not to be wondered at that he was terrified at the violent agitations in one of these. When his little ship, but ill fitted for opposing the fury of the sea, was got within the vortex, there was then no possibility of ever returning. To add to the fatality, they were always near the shore; and along the shore was the only place where this ill-provided mariner durst venture to sail. These were, therefore, dreadful impediments to his navigation; for if he attempted to pass between them and the shore, he was sometimes sucked in by the eddy; and if he attempted to avoid them out at sea, he was often sunk by the storm. But in our time, and in our present improved state of navigation, Charybdis, and the Euripus, with all the other irregular currents of the Mediterranean, are no longer formidable. Mr Addison, not attending to this train of thinking, upon passing through the straits of Sicily, was surprised at the little there was of terror in the present appearance of Scylla and Charybdis; and seems to be of opinion, that their agitations are much diminished since the times of antiquity. In fact, from the reasons above, all the wonders of the Mediterranean sea are described in much higher colours than they merit, to us who are acquainted with the more magnificent terrors of the ocean. The Mediterranean is one of the smoothest and most gentle seas in the world; its tides are scarcely perceivable, except in the gulf of Venice, and shipwrecks are less known there than in any other part of the world.

It is in the ocean, therefore, that these whirlpools are particularly dangerous, where the tides are violent, and the tempests fierce. To mention only one, that called *the Maelstroom*, upon the coasts of Norway, which is considered as the most dreadful and voracious in the world. The name it has received from the natives, signifies *the navel of the sea;* since they suppose that a great share of the water of the sea is sucked up and discharged by its vortex. A minute description of the internal parts is not to be expected, since none who were there ever returned to bring back information. The body of the waters that form this whirlpool, are extended in a circle above thirteen miles in circumference.[1] In the midst of this stands a rock, against which the tide in its ebb is dashed with inconceivable fury. At this time it instantly swallows up all things that come within the sphere of its violence, trees, timber, and shipping. No skill in the mariner, nor strength of rowing, can work an escape: the sailor at the helm finds the ship at first go in a current opposite to his intentions; his vessel's motion, though slow in the beginning, becomes every moment more rapid; it goes round in circles still narrower, and narrower, till at last it is dashed against the rocks, and instantly disappears: nor is it seen again for six hours; till the tide flowing, it is vomited forth with the same violence with which it was drawn in. The noise of this dreadful vortex still farther contributes to increase its terror, which, with the dashing of the waters, and the dreadful valley, if it may be so called, caused by their circulation, makes one of the most tremendous objects in nature.*

1 Kircher, Mund. Subt. vol. i. p. 156.

* Sea animals coming within the attraction of this dreadful whirlpool are unable to avoid its fury, and various instances are recorded of their struggling, roaring, and bellowing in a frightful manner, when approaching its vortex; showing that they were sensible of their danger. The like happen frequently to bears, which attempt to swim to the island to prey upon the sheep. There is no doubt of this whirlpool being formed by the accidental situation of the island of Moskoe, and the adjacent islands, with the nature and structure of their shores; the vast body of the Northern ocean forcing itself through these rocky narrow passages, produces this dreadful vortex.

Off the coast of Argyleshire there is a vortex of considerable extent, called the Corbrechtan; the noise of it can be heard at many miles, and appears like the distant sound of a number of chariots.

CHAP. XVII.

OF THE CHANGES PRODUCED BY THE SEA UPON THE EARTH.

From what has been said, as well of the earth as of the sea, they both appear to be in continual fluctuation. The earth, the common promptuary that supplies subsistence to men, animals, and vegetables, is continually furnishing its stores to their support. But the matter which is thus derived from it, is soon restored, and laid down again to be prepared for fresh mutations. The transmigration of souls is, no doubt, false and whimsical; but nothing can be more certain than the transmigration of bodies: the spoils of the meanest reptile may go to the formation of a prince; and, on the contrary, as the poet has it, the body of Cæsar may be employed in stopping a beer-barrel. From this, and other causes, therefore, the earth is in continual change. Its internal fires, the deviation of its rivers, and the falling of its mountains, are daily altering its surface; and geography can scarcely recollect the lakes and the valleys that history once described.

But these changes are nothing to the instability of the ocean. It would seem that inquietude was as natural to it as its fluidity. It is first seen with a constant and equable motion going towards the west; the tides then interrupt this progression, and for a time drive the waters in a contrary direction: beside these agitations, the currents act their part in a smaller sphere, being generally greatest where the other motions of the sea are least; namely nearest the shore; the winds also contribute their share in this universal fluctuation; so that scarcely any part of the sea is wholly seen to stagnate.

> Nil enim quiescit, undis impellitur unda,
> Et spiritus et calor toto se corpore miscent.

As this great element is thus changed, and continually labouring internally, it may be readily supposed that it produces correspondent changes upon its shores, and those parts of the earth subject to its influence. In fact, it is every day making considerable alterations, either by overflowing its shores in one place, or deserting them in others; by covering over whole tracts of country that were cultivated and peopled, at one time; or by leaving its bed to be appropriated to the purposes of vegetation, and to supply a new theatre for human industry, at another.

In this struggle between the earth and the sea for dominion, the greatest number of our shores seem to defy the whole rage of the waves, both by their height, and the rocky materials of which they are composed. The coasts of Italy, for instance, are bordered with rocks of marble of different kinds, the quarries of which may easily be distinguished at a distance from sea, and appear like perpendicular columns of the most beautiful kinds of marble, ranged along the shore. In general, the coasts of France, from Brest to Bourdeaux, are composed of rocks; as are also those of Spain and England, which defend the land, and only are interrupted, here and there, to give an egress to rivers, and to grant the conveniences of bays and harbours to our shipping. It may in general be remarked, that wherever the sea is most violent and furious, there the boldest shores, and of the most compact materials, are found to oppose it. There are many shores several hundred feet perpendicular, against which the sea, when swollen with tides or storms, rises and beats with inconceivable fury. In the Orkneys,[2] where the shores are thus formed, it sometimes, when agitated by a storm, rises two hundred feet perpendicular, and dashes up its spray, together with sand and other substances that compose its bottom, upon land, like showers of rain.

From hence, therefore, we may conceive how the violence of the sea, and the boldness of the shore, may be said to have made each other. Where the sea meets no obstacles, it spreads its waters with a gentle intumescence, till all its power is destroyed, by wanting depth to aid the motion. But when its progress is checked in the midst, by the prominence of rocks, or the abrupt elevation of the land, it dashes with all the force of its depth against the obstacle, and forms, by its repeated violence, that abruptness of the shore which confines its impetuosity. Where the sea is extremely deep, or very much vexed by tempests, it is no small obstacle that can confine its rage; and for this reason we see the boldest shores projected against the

1 Buffon, vol. ii. p. 199. 2 Ibid. p. 191.

deepest waters; all less impediments having long since been surmounted and washed away. Perhaps of all the shores in the world, there is not one so high as that on the west of St Kilda, which, upon a late admeasurement,[1] was found to be six hundred fathoms perpendicular above the surface of the sea. Here also, the sea is deep, turbulent, and stormy; so that it requires great force in the shore to oppose its violence. In many parts of the world, and particularly upon the coasts of the East Indies, the shores, though not high above water, are generally very deep, and consequently the waves roll against the land with great weight and irregularity. This rising of the waves against the shore, is called by mariners *the surf of the sea;* and in shipwrecks is generally fatal to such as attempt to swim on shore. In this case no dexterity in the swimmer, no float he can use, neither swimming-girdle nor cork-jacket, will save him; the weight of the superincumbent waves breaks upon him at once, and crushes him with certain ruin. Some few of the natives, however, have the art of swimming and of navigating their little boats near those shores, where an European is sure of instant destruction.

In places where the force of the sea is less violent, or its tides less rapid, the shores are generally seen to descend with a more gradual declivity. Over these, the waters of the tide steal by almost imperceptible degrees, covering them for a large extent, and leaving them bare on its recess. Upon these shores, as was said, the sea seldom beats with any great violence, as a large wave has not depth sufficient to float it onwards, so that here only are to be seen gentle surges making calmly towards land, and lessening as they approach. As the sea, in the former description, is generally seen to present prospects of tumult and uproar, here it more usually exhibits a scene of repose and tranquil beauty. Its waters which, when surveyed from the precipice, afforded a muddy greenish hue, arising from their depth and position to the eye,[2] when regarded from a shelving shore, wear the colour of the sky, and seem rising to meet it. The deafening noise of the deep sea, is here converted into gentle murmurs; instead of the waters dashing against the face of the rock, it advances and recedes, still going forward, but with just

1 Description of St Kilda. 2 Newton's Optics, p. 163—167.

force enough to push its weeds and shells, by insensible approaches, to the shore.

There are other shores, beside those already described, which either have been raised by art, to oppose the sea's approaches, or, from the sea's gaining ground, are threatened with imminent destruction. The sea's being thus seen to give and take away lands at pleasure, is, without question, one of the most extraordinary considerations in all natural history. In some places it is seen to obtain the superiority by slow and certain approaches; or to burst in at once, and overwhelm all things in undistinguished destruction; in other places it departs from its shores, and where its waters have been known to rage, it leaves fields covered with the most beautiful verdure.

The formation of new lands by the sea's continually bringing its sediment to one place, and by the accumulation of its sands in another, is easily conceived. We have had many instances of this in England.* The island of Oxney, which is adjacent to Romney-marsh, was produced in this manner. This had for a long time been a low level, continually in danger of being overflown by the river Rother; but the sea, by its depositions, has gradually raised the bottom of the river, while it has hollowed the mouth; so that the one is sufficiently secured from inundations, and the other is deep enough to admit ships of considerable burthen. The like also may be seen at that bank called the *Dogger-sands*, where two tides meet, and which thus receives new increase every day, so that in time the place seems to promise fair for being habitable earth. On many parts of the coasts of France, England, Holland, Germany, and Prussia, the sea has been sensibly known to retire.[3] Hubert Thomas asserts, in his description of the Country of Liege, that the sea formerly encompassed the city of Tongres, which, however, is at present thirty-five leagues distant from it: this assertion he supports by many strong reasons; and, among others, by the iron rings fixed in the walls of the town, for fastening the ships that came into the port. In Italy there is a considerable piece of ground gained at the mouth of the river Arno; and Ravenna, that once

* It is supposed that there existed an isthmus between Great Britain and France, which is conceived to have been broken down by the sea, before the commencement of any accurate historical records respecting these islands.

3 Buffon, vol. vi. p. 121.

stood by the sea-side, is now considerably removed from it. But we need scarcely mention these, when we find that the whole republic of Holland seems to be a conquest upon the sea and in a manner rescued from its bosom. The surface of the earth, in this country, is below the level of the bed of the sea, and I remember, upon approaching the coast, to have looked down upon it from the sea, as into a valley: however, it is every day rising higher by the depositions made upon it by the sea, the Rhine, and the Meuse; and those parts which formerly admitted large men of war, are now known to be too shallow to receive ships of very moderate burthen.[1] The province of Jucatan, a peninsula in the gulf of Mexico, was formerly a part of the sea. This tract, which stretches out into the ocean a hundred leagues, and which is above thirty broad, is every where, at a moderate depth below the surface, composed of shells, which evince that its land once formed the bed of the sea. In France, the town of Aigues Mortes was a port in the times of St Louis, which is now removed more than four miles from the sea. Psalmodi, in the same kingdom, was an island in the year 815, but is now more than six miles from the shore. All along the coasts of Norfolk, I am very well assured, that in the memory of man the sea has gained fifty yards in some places, and has lost as much in others.

Thus numerous, therefore, are the instances of new lands having been produced from the sea, which, as we see, is brought about two different ways; first, by the waters raising banks of sand and mud where their sediment is deposited; and, secondly, by their relinquishing the shore entirely, and leaving it unoccupied to the industry of man.

But as the sea has been thus known to recede from some lands, so has it, by fatal experience, been found to encroach upon others; and probably these depredations on one part of the shore, may account for their dereliction from another; for the current which rested upon some certain bank having got an egress in some other place, it no longer presses upon its former bed, but pours all its stream into the new entrance; so that every inundation of the sea may be attended with some correspondent derelictiou of another shore.

1 Buffon, vol. vi. p. 424

However this be, we have numerous histories of the sea's inundations, and its burying whole provinces in its bosom. Many countries that have been thus destroyed, bear melancholy witness to the truth of history; and show the tops of their houses, and the spires of their steeples, still standing at the bottom of the water. One of the most considerable inundations we have in history, is that which happened in the reign of Henry I. which overflowed the estates of the Earl Godwin, and forms now that bank called the Godwin Sands. In the year 1546, a similar irruption of the sea destroyed a hundred thousand persons in the territory of Dort; and yet a greater number round Dullart. In Friezland, and Zealand, there were more than three hundred villages overwhelmed; and their ruins continue still visible at the bottom of the water in a clear day. The Baltic Sea has, by slow degrees, covered a large part of Pomerania; and, among others, destroyed and overwhelmed the famous port of Vineta. In the same manner, the Norwegian Sea has formed several little islands from the main land, and still daily advances upon the continent. The German Sea has advanced upon the shores of Holland, near Catt; so that the ruins of an ancient citadel of the Romans, which was formerly built upon this coast, are now actually under water. To these accidents several more might be added; our own historians, and those of other countries, abound with them; almost every flat shore of any extent, being able to show something that it has lost, or something that it has gained from the sea.

There are some shores on which the sea has made temporary depredations; where it has overflowed, and after remaining perhaps some ages, it has again retired of its own accord, or been driven back by the industry of man.[2] There are many lands in Norway, Scotland, and the Maldivia Islands, that are at one time covered with water, and at another free. The country round the isle of Ely, in the times of Bede, about a thousand years ago, was one of the most delightful spots in the whole kingdom; it was not only richly cultivated, and produced all the necessaries of life, but grapes also, that afforded excellent wine. The accounts of that time are copious in the description of its verdure and fertility; its rich pastures covered with flowers

2 Buffon, vol. ii. p. 425.

and herbage; its beautiful shades, and wholsome air. But the sea, breaking in upon the land, overwhelmed the whole country, took possession of the soil, and totally destroyed one of the most fertile valleys in the world. Its air, from being dry and healthful, from that time became most unwholesome, and clogged with vapours; and the small part of the country that, by being higher than the rest, escaped the deluge, was soon rendered uninhabitable, from its noxious vapours. Thus this country continued under water for some centuries: till at last the sea, by the same caprice which had prompted its invasions, began to abandon the earth in like manner. It has continued for some ages to relinquish its former conquests; and although the inhabitants can neither boast the longevity nor the luxuries of their former pre-occupants, yet they find ample means of subsistence; and if they happen to survive the first years of their residence there, they are often known to arrive at a good old age.

But although history be silent as to many other inundations of the like kind, where the sea has overflowed the country, and afterwards retired, yet we have numberless testimonies of another nature, that prove it beyond the possibility of a doubt: I mean those numerous trees that are found buried at considerable depths in places where either rivers or the sea have accidentally overflown.[1] At the mouth of the river Ness, near Bruges, in Flanders, at the depth of fifty feet, are found great quantities of trees lying as close to each other as they do in a wood; the trunks, the branches, and the leaves, are in such perfect preservation, that the particular kind of each tree may instantly be known. About five hundred years ago, this very ground was known to have been covered by the sea; nor is there any history or tradition of its having been dry ground, which we can have no doubt must have been the case. Thus we see a country flourishing in verdure, producing large forests, and trees of various kinds, overwhelmed by the sea. We see this element depositing its sediment to a height of fifty feet; and its waters must, therefore, have risen much higher. We see the same, after it has thus overwhelmed and sunk the land so deep beneath its slime, capriciously retiring from the same coasts, and leaving that habitable once more, which it had formerly destroyed. All this is

[1] Buffon, vol. ii. p. 103.

wonderful; and, perhaps, instead of attempting to inquire after the cause, which has hitherto been inscrutable, it will best become us to rest satisfied with admiration.

At the city of Modena in Italy, and about four miles round it, wherever it is dug, when the workmen arrive at the depth of sixty-three feet, they come to a bed of chalk, which they bore with an auger five feet deep: they then withdraw from the pit, before the auger is removed, and upon its extraction, the water bursts up through the aperture with great violence, and quickly fills this new-made well, which continues full, and is affected neither by rains nor droughts. But that which is most remarkable in this operation, is the layers of earth as we descend. At the depth of fourteen feet are found the ruins of an ancient city, paved streets, houses, floors, and different pieces of Mosaic. Under this is found a solid earth, that would induce one to think had never been removed; however, under it is found a soft oozy earth, made up of vegetables; and at twenty-six feet depth, large trees entire, such as walnut-trees, with the walnuts still sticking on the stem, and their leaves and branches in exact preservation. At twenty-eight feet deep, a soft chalk is found, mixed with a vast quantity of shells; and this bed is eleven feet thick. Under this, vegetables are found again, with leaves, and branches of trees as before; and thus alternately chalk and vegetable earth to the depth of sixty-three feet. These are the layers wherever the workmen attempt to bore; while in many of them they also find pieces of charcoal, bones, and bits of iron. From this description, therefore, it appears, that this country has been alternately overflowed and deserted by the sea, one age after another: nor were these overflowings and retirings of trifling depth, or of short continuance. When the sea burst in, it must have been a long time in overwhelming the branches of the fallen forest with its sediment; and still longer in forming a regular bed of shells eleven feet over them. It must have, therefore, taken an age, at least, to make any one of these layers; and we may conclude, that it must have been many ages employed in the production of them all. The land also, upon being deserted, must have had time to grow compact, to gather fresh fertility, and to be drained of its waters before it could be disposed to vegetation, or before its trees could have shot forth again to maturity.

We have instances nearer home of the same kind given us in the Philosophical Transactions; one of them by Mr Derham. An inundation of the sea, at Dagenham, in Essex, laying bare a part of the adjacent pasture for above two hundred feet wide, and, in some places, twenty deep, it discovered a number of trees that had lain there for many ages before: these trees, by lying long under ground, were become black and hard, and their fibres so tough, that one might as easily break a wire, as any of them: they lay so thick in the place where they were found, that in many parts he could step from one to another: he conceived also, that not only all the adjacent marshes, for several hundred acres, were covered underneath with such timber, but also the marshes along the mouth of the Thames, for several miles. The meeting with these trees at such depths, he ascribes to the sediment of the river, and the tides, which constantly washing over them, have always left some part of their substance behind, so as, by repeated alluvions, to work a bed of vegetable earth over them, to the height at which he found it.

The levels of Hatfield-Chace, in Yorkshire, a tract of above eighteen thousand acres, which was yearly overflown, was reduced to arable and pasture-land, by one Sir Cornelius Vermusden, a Dutchman. At the bottom of this wide extent, are found millions of the roots and bodies of trees, of such as this island either formerly did, or does at present, produce. The roots of all stand in their proper postures; and by them, as thick as ever they could grow, the respective trunks of each, some above thirty yards long. The oaks, some of which have been sold for fifteen pounds a-piece, are as black as ebony, very lasting, and close-grained. The ash-trees are as soft as earth, and are commonly cut in pieces by the workmen's spades, and as soon as flung up into the open air, turn to dust. But all the rest, even the willows themselves, which are softer than the ash, preserve their substance and texture to this very day. Some of the firs appear to have vegetated, even after they were fallen, and to have, from their branches, struck up large trees, as great as the parent trunk. It is observable, that many of these trees have been burnt, some quite through, some on one side, some have been found chopped and squared, others riven with great wooden wedges; all sufficiently manifesting, that the country which was deluged had formerly been inhabited. Near a great root of one tree, were found eight coins of the Roman emperors; and, in some places, the marks of the ridge and furrow were plainly perceivable, which testified that the ground had formerly been patient of cultivation.

The learned naturalist who has given this description,[1] has pretty plainly evinced, that this forest in particular, must have been thus levelled by the Romans; and that the falling of the trees must have contributed to the accumulation of the waters. "The Romans," says he, "when the Britons fled, always pursued them into the fortresses of low woods, and miry forests. in these the wild natives found shelter; and, when opportunity offered, issued out and fell upon their invaders without mercy. In this manner the Romans were at length so harassed, that orders were issued out for cutting down all the woods and forests in Britain. In order to effect this, and destroy the enemy the easier, they set fire to the woods, composed of pines and other inflammable timber, which spreading, the conflagration destroyed not only the forest, but infinite numbers of the wretched inhabitants who had taken shelter therein. When the pine-trees had thus done what mischief they could, the Romans then brought their army nearer, and, with whole legions of the captive Britons, cut down most of the trees that were yet left standing; leaving only here and there some great trees untouched, as monuments of their fury. These, unneedful of their labour, being destitute of the support of the underwood, and of their neighbouring trees, were easily overthrown by the winds, and, without interruption, remained on the places where they happened to fall. The forest, thus fallen, must necessarily have stopped up the currents, both from land and sea; and turned into great lakes, what were before but temporary streams. The working of the waters here, the consumption and decay of rotten boughs and branches, and the vast increase of water-moss which flourishes upon marshy grounds, soon formed a covering over the trunks of the fallen trees, and raised the earth several feet above its former level. The earth thus every day swelling, by a continual increase from the sediment of the waters, and by the lightness of the vegetable substances of which it was composed, soon overtopt the waters by which this intumescence

1 Phil Trans. vol. iv. part ii. p. 214.

was at first effected; so that it entirely got rid of its inundations, or only demanded a slight assistance from man for that purpose." This may be the origin of all bogs, which are formed by the putrefaction of vegetable substances, mixed with the mud and slime deposited by waters, and at length acquiring a sufficient consistency.

From this we see what powerful effects the sea is capable of producing upon its shores, either by overflowing some, or deserting others; by altering the direction of these, and rendering those craggy and precipitate, which before were shelving. But the influence it has upon these, is nothing to that which it has upon that great body of earth which forms its bottom. It is at the bottom of the sea that the greatest wonders are performed, and the most rapid changes are produced; it is there that the motion of the tides and the currents have their whole force, and agitate the substances of which their bed is composed. But all these are almost wholly hid from human curiosity: the miracles of the deep are performed in secret; and we have but little information from its abysses, except what we receive by inspection at very shallow depths, or by the plummet, or from divers, who are known to descend from twenty to thirty fathoms.[1]

The eye can reach but a very short way into the depths of the sea; and that only when its surface is glassy and serene. In many seas it perceives nothing but a bright sandy plain at bottom, extending for several hundred miles, without an intervening object. But in others, particularly in the Red Sea, it is very different: the whole bottom of this extensive bed of waters is, literally speaking, a forest of submarine plants and corals, formed by insects for their habitation, sometimes branching out to a great extent. Here are seen the madrepores, the sponges, mosses, sea-mushrooms, and other marine productions, covering every part of the bottom; so that some have even supposed the sea to have taken its name from the colour of its plants below. However, these plants are by no means peculiar to this sea, as they are found in great quantities in the Persian Gulf, along the coast of Africa, and those of Provence and Catalonia.

The bottom of many parts of the sea, near America, presents a very different, though a very beautiful, appearance. This is

1 Phil. Trans. vol. iv. part. ii. p. 192.

covered with vegetables, which make it look as green as a meadow, and beneath are seen thousands of turtles, and other sea-animals feeding thereon.

In order to extend our knowledge of the sea to greater depths, recourse has been had to the plummet; which is generally made of a lump of lead of about forty pounds weight, fastened to a cord.[2] This, however, only answers in moderate depths; for when a deep sea is to be sounded, the matter of which the cord is composed, being lighter than the water, floats upon it, and when let down to a considerable depth, its length so increases its surface, that it is often sufficient to prevent the lead from sinking; so that this may be the reason why some parts of the sea are said to have no bottom.

In general, we learn from the plummet, that the bottom of the sea is tolerably even where it has been examined; and that the farther from the shore, the sea is in general the deeper. Notwithstanding, in the midst of a great and unfathomable ocean, we often find an island raising its head, and singly braving its fury. Such islands may be considered as the mountains of the deep; and, could we for a moment imagine the waters of the ocean removed or dried away, we should probably find the inequalities of its bed resembling those that are found at land. Here extensive plains, there valleys, and, in many places, mountains of amazing height. M. Buache has actually given us a map of that part of its bottom, which lies between Africa and America, taken from the several soundings of mariners: in it we find the same uneven surface that we do upon land, the same eminences, and the same depressions. In such an imaginary prospect, however, there would be this difference, that as the tops of land-mountains appear the most barren and rocky, the tops of sea-mountains would be found the most verdant and fruitful.

The plummet, which thus gives us some idea of the inequalities of the bottom, leaves us totally in the dark as to every other particular; recourse, therefore, has been had to divers: these, either being bred up in this dangerous way of life, and accustomed to remain sometime under water without breathing, or assisted by means of a diving-bell, have been able to return some

2 Boyle, vol. ii. p. 5.

confused and uncertain accounts of the places below. In the great diving-bell improved by Dr Halley, which was large enough to contain five men, and was supplied with fresh air by buckets, that alternately rose and fell, they descended fifty fathom. In this huge machine, which was let down from the mast of the ship, the doctor himself went down to the bottom, where, when the sea was clear, and especially when the sun shone, he could see perfectly well to write or read, and much more to take up any thing that was underneath: at other times, when the water was troubled and thick, it was dark as night below, so that he was obliged to keep a candle lighted at the bottom. But there is one thing very remarkable, that the water which from above was usually seen of a green colour, when looked at from below, appeared to him of a very different one, casting a redness upon one of his hands, like that of damask roses:[1]—a proof of the sea's taking its colour not from any thing floating in it, but from the different reflections of the rays of light. Upon the whole, the accounts we have received from the bottom, by this contrivance, are but few. We learn from it, and from divers in general, that while the surface of the sea may be deformed by tempests, it is usually calm and temperate below;[2] that some divers, who have gone down when the weather was calm, and came up when it was tempestuous, were surprised at their not perceiving the change at the bottom. This, however, must not be supposed to obtain with regard to the tides, and the currents, as they are seen constantly shifting their bottom; taking their bed with great violence from one place, and depositing it upon another. We are informed, also, by divers, that the sea grows colder in proportion as they descend to the bottom; that as far as the sun's rays pierce, it is influenced by their warmth; but lower, the cold becomes almost intolerable. A person of quality, who had been himself a diver, as Mr Boyle informs us, declared, that though he seldom descended above three or four fathoms, yet he found it so much colder than near the top, that he could not well endure it; and that being let down in a great diving-bell, although the water could not immediately touch him, he found the air extremely cold upon his first arrival at the bottom.

1 Newton's Optics, p. 56. 2 Boyle, vol. iii. p 242.

From divers also we learn that the sea, in many places, is filled with rocks at bottom; and that among their clefts, and upon their sides, various substances sprout forward, which are either really vegetables, or the nests of insects, increased to some magnitude. Some of these assume the shape of beautiful flowers; and, though soft when taken up, soon harden, and are kept in the cabinets of the curious.

But of all those divers who have brought us information from the bottom of the deep, the famous Nicola Pesce, whose performances are told us by Kircher, is the most celebrated. I will not so much as pretend to vouch for the veracity of Kircher's account, which he assures us he had from the archives of the kings of Sicily; but it may serve to enliven a heavy chapter. "In the times of Frederic, king of Sicily, there lived a celebrated diver, whose name was Nicholas, and who, from his amazing skill in swimming, and his perseverance under water, was surnamed the *Fish*. This man had from his infancy been used to the sea; and earned his scanty subsistence by diving for corals and oysters; which he sold to the villagers on shore. His long acquaintance with the sea, at last brought it to be almost his natural element. He frequently was known to spend five days in the midst of the waves, without any other provisions than the fish which he caught there, and ate raw. He often swam over from Sicily to Calabria, a tempestuous and dangerous passage, carrying letters from the king. He was frequently known to swim among the gulfs of the Lipari islands, no way apprehensive of danger.

"Some mariners out at sea, one day observed something at some distance from them which they regarded as a sea monster; but, upon its approach, it was known to be Nicholas, whom they took into their ship. When they asked him whither he was going in so stormy and rough a sea, and at such a distance from land, he showed them a packet of letters, which he was carrying to one of the towns of Italy exactly done up in a leather bag, in such a manner as that they could not be wetted by the sea. He kept them thus company for some time on their voyage, conversing and asking questions; and after eating a hearty meal with them, he took his leave, and jumping into the sea, pursued his voyage alone.

"In order to aid these powers of enduring in the deep, nature seemed to have assisted him in a very extraordinary manner; for the spaces between his fingers and toes were webbed as in a goose; and his chest became so very capacious, that he could take in at one inspiration, as much breath as would serve him for a whole day.

"The account of so extraordinary a person did not fail to reach the king himself, who, actuated by the general curiosity, ordered that Nicholas should be brought before him. It was no easy matter to find Nicholas, who generally spent his time in the solitudes of the deep; but at last, however, after much searching, he was found, and brought before his majesty. The curiosity of this monarch had been long excited by the accounts he had heard of the bottom of the gulf of Charybdis; he therefore conceived that it would be a proper opportunity to have more certain information; and commanded our poor diver to examine the bottom of this dreadful whirlpool: as an incitement to his obedience, he ordered a golden cup to be flung into it. Nicholas was not insensible of the danger to which he was exposed: dangers best known only to himself; and he therefore presumed to remonstrate; but the hopes of the reward, the desire of pleasing the king, and the pleasure of showing his skill, at last prevailed. He instantly jumped into the gulf, and was swallowed as instantly up in its bosom. He continued for three quarters of an hour below; during which time the king and his attendants remained upon shore anxious for his fate; but he at last appeared, buffeting upon the surface, holding the cup in triumph in one hand, and making his way good among the waves with the other. It may be supposed he was received with applause, upon his arrival on shore; the cup was made the reward of his adventure; the king ordered him to be taken proper care of; and, as he was somewhat fatigued and debilitated by his labour, after a hearty meal he was put to bed, and permitted to refresh himself by sleeping.

"When his spirits were thus restored, he was again brought to satisfy the king's curiosity with a narrative of the wonders he had seen; and his account was to the following effect:—He would never, he said, have obeyed the king's commands, had he been apprised of half the dangers that were before him. There were four things, he said, that rendered the gulf dreadful, not only to men, but even to the fishes themselves: first, the force of the water bursting up from the bottom, which requires great strength to resist; secondly, the abruptness of the rocks, that on every side threatened destruction; thirdly, the force of the whirlpool, dashing against those rocks; and fourthly, the number and magnitude of the polypus fish, some of which appeared as large as a man, and which every where sticking against the rocks, projected their fibrous arms to entangle him. Being asked how he was able so readily to find the cup that had been thrown in, he replied that it happened to be flung by the waves into the cavity of a rock, against which he himself was urged in his descent. This account, however, did not satisfy the king's curiosity: being requested to venture once more into the gulf for further discoveries, he at first refused; but the king, desirous of having the most exact information possible of all things to be found in the gulf, repeated his solicitations; and to give them still greater weight, produced a larger cup than the former, and added also a purse of gold. Upon these considerations, the unfortunate Pessacola once again plunged into the whirlpool, and was never heard of more."

CHAP. XVIII.

A SUMMARY ACCOUNT OF THE MECHANICAL PROPERTIES OF AIR.

Having described the earth and the sea, we now ascend into that fluid which surrounds them both; and which, in some measure, supports and supplies all animated nature. As upon viewing the bottom of the ocean from its surface, we see an infinity of animals moving therein, and seeking food; so, were some superior being to regard the earth at a proper distance, he might consider us in the same light; he might from his superior station behold a number of busy little beings, immersed in the aerial fluid that everywhere surrounds them, and sedulously employed in procuring the means of subsistence. This fluid, though too fine for the gross perception of its inhabitants, might to his nicer organs of sight be very visible; and while he at once saw into its operations, he might smile at the varieties of human conjecture concerning it; he might readily discern, perhaps, the heigh. above the surface of the earth to which this fluid atmosphere reaches; he might exactly determine the peculiar form of its parts which gives it the spring or elasticity with which it is endued: he might distinguish which of its parts were pure incorruptible air and which only made for a little time to assume the appearance, so as to be quickly returned back to the element from whence it came. But as for us, who are immersed at the bottom of this gulf, we must be contented with a more confined knowledge; and, wanting a proper point of prospect, remain satisfied with a combination of the effects.

One of the first things that our senses inform us of, is that although the air is too fine for our sight, it is very obvious to our touch. Although we cannot see the wind contained in a bladder, we can very readily feel its resistance; and though the hurricane may want colour, we often fatally experience that it does not want force. We have equal experience of the air's spring or elasticity; the bladder when pressed, returns again, upon the pressure being taken away; a bottle, when filled, often bursts from the spring of air which is included.

So far the slightest experience reaches; but, by carrying experiment a little farther, we learn, that air also is heavy: a round glass vessel being emptied of its air, and accurately weighed, has been found lighter than when it was weighed with the air in it. Upon computing the superior weight of the full vessel, a cubic foot of air is found to weigh something more than an ounce.

From this experiment, therefore, we learn, that the earth, and all things upon its surface, are every where covered with a ponderous fluid, which rising very high over our heads must be proportionably heavy. For instance, as in the sea, a man at the depth of twenty feet sustains a greater weight of water, than a man at the depth of but ten feet; so will a man at the bottom of a valley have a greater weight of air over him, than a man on the top of a mountain.

From hence we may conclude, that we sustain a very great weight of air; and although, like men walking at the bottom of the sea, we cannot feel the weight which presses equally round us, yet the pressure is not the less real. As in morals we seldom know the blessings that surround us, till we are deprived of them; so here we do not perceive the weight of the ambient fluid till a part of it is taken away. If, by any means, we contrive to take away the pressure of the air from any one part of our bodies, we are soon made sensible of the weight upon the other parts. Thus, if we clap our hand upon the mouth of a vessel from whence the air has been taken away, there will thus be air on one side and none on the other; upon which we shall instantly find the hand violently sucked inwards; which is nothing more than the weight of the air upon the back of the hand that forces it into the space which is empty below.

As, by this experiment, we perceive that the air presses with great weight upon every thing on the surface of the earth, so by other experiments we learn the exact weight with which it presses. First, if the air be exhausted out of any vessel, a drinking vessel, for instance,[1] and this vessel be set with the mouth downwards in water, the water will rise up into the empty space, and fill the inverted glass; for the external air will, in this case, press up the water where there is no weight to resist; as, one part of a bed being pressed, makes the other parts, that have no weight upon them, rise. In this case, as was said, the water being pressed without, will rise in the glass; and would continue to rise (if the empty glass were tall enough) thirty-two feet high. In fact, there have been pipes made purposely for this experiment, of above thirty-two feet high, in which, upon being exhausted, the water has always risen to the height of thirty-two feet; there it has always rested, and never ascended higher. From this, therefore, we learn, that the weight of the air which presses up the water, is equal to a pillar or column of water which is thirty-two feet high; as it is just able to raise such a column and no more. In other words, the surface of the earth is every where covered with a weight of air, which is equivalent to a covering of thirty-two feet deep of water; or to a weight of twenty-nine inches and a half of quicksilver, which is known to be just as heavy as the former.

Thus we see that the air, at the surface of the earth, is just as heavy as thirty-two feet of water, or twenty-nine inches and a half of quick-silver; and it is easily found by computation,

[1] This may be done by burning a bit of paper in the same, and then quickly turning it down upon the water.

that to raise water thirty-two feet, will require a weight of fifteen pounds upon every square inch. Now, if we are fond of computations, we have only to calculate how many square inches are in the surface of an ordinary human body, and allowing every inch to sustain fifteen pounds, we may amaze ourselves at the weight of air we sustain. It has been computed, and found, that our ordinary load of air amounts to within a little of forty thousand pounds: this is wonderful! but wondering is not the way to grow wise.

Notwithstanding this be our ordinary load, and our usual supply, there are, at different times, very great variations. The air is not, like water, equally heavy at all seasons; but sometimes is lighter, and sometimes more heavy. It is sometimes more compressed, and sometimes more elastic or springy, which produces the same effects as an increase of its weight. The air, which at one time raises water thirty-two feet in the tube, and quicksilver twenty-nine inches, will not at another raise the one to thirty feet, or the other to twenty-six inches. This makes, therefore, a very great difference in the weight we sustain; and we are actually known, by computation, to carry at one time four thousand pounds of air more than at another.

The reason of this surprising difference in the weight of air, is either owing to its pressure from above, or to an increase of vapour floating in it. Its increased pressure is the consequence of its spring or elasticity, which cold and heat sensibly affect, and are continually changing.

This elasticity of the air is one of its most amazing properties; and to which it should seem nothing can set bounds. A body of air that may be contained in a nut shell, may easily, with heat, be dilated into a sphere of unknown dimensions. On the contrary, the air contained in a house, may be compressed into a cavity not larger than the eye of a needle. In short, no bounds can be set to its confinement or expansion; at least, experiment has hitherto found its attempts indefinite. In every situation, it retains its elasticity; and the more closely we compress it, the more strongly does it resist the pressure. If to the increasing the elasticity on one side by compression, we increase it on the other side by heat, the force of both soon becomes irresistible; and a certain French philosopher[1] supposed that air

1 Monsieur Amontons.

thus confined and expanding, was sufficient for the explosion of a world.

Many instruments have been formed to measure and determine these different properties of the air; and which serve several useful purposes. The barometer serves to measure its weight; to tell us when it is heavier, and when lighter. It is composed of a glass tube or pipe, of about thirty inches in length, closed up at one end: this tube is then filled with quicksilver; this done, the maker clapping his finger upon the open end, inverts the tube, and plunges the open end, finger and all, into a basin of quicksilver, and then takes his finger away; now the quicksilver in the tube will, by its own weight, endeavour to descend into that in the basin; but the external air, pressing on the surface of the quicksilver in the basin without, and no air being in the tube at top, the quicksilver will continue in the tube being pressed up, as was said, by the air, on the surface of the basin below. The height at which it is known to stand in the tube, is usually about twenty-nine inches when the air is heavy; but not above twenty-six when the air is very light. Thus, by this instrument, we can with some exactness determine the weight of the air; and, of consequence, tell before-hand the changes of the weather. Before fine dry weather, the air is charged with a variety of vapours, which float in it unseen, and render it extremely heavy, so that it presses up the quicksilver; or in other words, the barometer rises. In moist, rainy weather, the vapours are washed down or there is not heat sufficient for them to rise, so that the air is then sensibly lighter, and presses up the quicksilver with less force; or, in other words, the barometer is seen to fall. Our constitutions seem also to correspond with the changes of the weather-glass; they are braced, strong, and vigorous, with a large body of air upon them; they are languid, relaxed, and feeble when the air is light, and refuses to give our fibres their proper tone.

But although the barometer thus measures the weight of the air with exactness enough for the general purposes of life, yet it is often affected with a thousand irregularities that no exactness in the instrument can remedy, nor no theory account for. When high winds blow, the quicksilver generally is low: it rises higher in cold weather than in warm; and is usually higher at morning and evening than at mid-day: it generally descends lower after rain than it was before it. There are also frequent changes in the air, without any sensible alteration in the barometer.

As the barometer is thus used in predicting the changes of the weather, so is it also serviceable in measuring the heights of mountains, which mathematicians cannot so readily do: for, as the higher we ascend from the surface of the earth the air becomes lighter, so the quicksilver in the barometer will descend in proportion. It is found to sink at the rate of the tenth part of an inch for every ninety feet we ascend; so that in going up a mountain, if I find the quicksilver fallen an inch, I conclude, that I am got upon an ascent of near nine hundred feet high. In this there has been found, some variation; into a detail of which, it is not the business of a natural historian to enter.

In order to determine the elasticity of air, the wind-gun has been invented, which is an instrument variously made; but in all upon the principle of compressing a large quantity of air into a tube, in which there is an ivory ball, and then giving the compressed elastic air free power to act, and drive the ball as directed. The ball, thus driven, will pierce a thick board; and will be as fatal, at small distances, as if driven with gunpowder. I do not know whether ever the force of this instrument has been assisted by means of heat; certain I am, that this, which could be very easily contrived by means of phosphorus, or any other hot substance applied to the barrel, would give such a force as I doubt whether gunpowder itself could produce.

The air-pump is an instrument contrived to exhaust the air from round a vessel adapted to that purpose, called a receiver. This method of exhausting, is contrived in the simple instrument, by a piston, like that of a syringe, going down into the vessel, and thus pushing out its air; which, by means of a valve, is prevented from returning into the vessel again. But this, like all other complicated instruments, will be better understood by a minute inspection, than an hour's description: it may suffice here to observe, that by depriving animals, and other substances, of all air, it shows us what the benefits and effects of air are in sustaining life, or promoting vegetation.

The digester is an instrument of still more extraordinary effects, than any of the former; and sufficiently discovers the amazing force of air, when its elasticity is augmented by fire. A common tea-kettle if the spout were closed up, and the lid put firmly down, would serve to become a digester, if strong enough. But the instrument used for this purpose is a strong metal pot, with a lid to screw close on, so that, when down, no air can get in or return; into this pot meat and bones are put, with a small quantity of water, and then the lid screwed close: a lighted lamp is put underneath, and, what is very extraordinary, (yet equally true,) in six or eight minutes the whole mass, bones and all, are dissolved into a jelly; so great is the force and elasticity of the air contained within, struggling to escape, and breaking in pieces all the substances with which it is mixed. Care, however, must be taken not to heat this instrument too violently: for then the inclosed air would become irresistible, and burst the whole, with, perhaps, a fatal explosion.

There are numberless other useful instruments made to depend on the weight, the elasticity, or the fluidity, of the air, which do not come within the plan of the present work; the design of which is not to give an account of the inventions that have been made for determining the nature and properties of air, but a mere narrative of its effects. The description of the pump, the forcing-pump, the fire-engine, the steam-engine, the syphon, and many others, belong not to the naturalist, but the experimental philosopher: the one gives a history of Nature, as he finds she presents herself to him; and he draws the obvious picture: the other pursues her with close investigation, tortures her by experiment to give up her secrets, and measures her latent qualities with laborious precision. Much more, therefore, might be said of the mechanical effects ot air, and of the conjectures that have been made respecting the form of its parts; how some have supposed them to resemble little hoops, coiled up in a spring; others, like fleeces of wool; others, that the parts are endued with a repulsive quality, by which, when squeezed together, they endeavour to fly off, and recede from each other. We might have given the disputes relative to the height to which this body of air extends above us, and concerning which there is no agreement. We might have inquired how much of the air we breathe is elementary, and not reducible to any other substance; and of what density it would become, if it were supposed to be continued down to the centre of the earth. At that place we might, with the help of figures, and a bold imagination, have shown it twenty thousand times heavier than its bulk of gold. We might also prove it millions of times purer than upon earth, when raised to the surface of the atmosphere. But these speculations do not belong to natural history; and they have hitherto produced no great advantages in that branch of science to which they more properly appertain.*

* Atmospherical air was long considered as a simple elementary body. But it is now known to consist of at least four distinct substances, namely, oxygen, azote, carbonic acid, and aqueous vapour. The first two substances must be considered as its essential constituents, and constitute in fact almost the whole of it. The other two are variable in their proportion, and exist only in minute quantities, which it is difficult to appreciate. The first knowledge of the composition of the atmosphere must have been after the period of the discovery of oxygen gas by Dr Priestley, in 1774. Lavoisier, indeed, in his posthumous works, appears to insinuate a knowledge of it in 1772. But this claim cannot be admitted, as he gives no hint of any such knowledge in his volume of essays published after that period, and as he was entirely unacquainted with oxygen gas when Priestley showed him the way to prepare it at Paris, about the end of 1774. It is very probable that Lavoisier became acquainted with the composition of atmospherical air not very long after that period; though some years elapsed before he made it known to the public. Whether he preceded Scheele in his knowledge of this important fact, we do not exactly know. But there is no doubt whatever, that Scheele's investigations were carried on without any assistance from abroad, and that it was in consequence of the publication of his Treatise on Air and Fire, that the chemical world became acquainted with the nature and composition of atmospherical air. This important work was printed at Upsal, in 1777, with an introduction by Bergmann, and translated into English by Dr Foster, in 1789. The experiments of Priestley, indeed, would have warranted the conclusions respecting the composition of atmospherical air drawn by Scheele; but those of Dr Priestley were different and more complicated. In Scheele's first experiments, he estimated the bulk of oxygen gas in air at 30 per cent. But in the year 1779, he published a set of experiments continued for a whole year, in order to ascertain whether the bulk of oxygen in air be constant, or varies with the season of the year. He found it in general remarkably constant, and amounting to 27 per cent. The smallest bulk was 24, and the greatest observed was 30 per cent. Dr Priestley had made similar experiments, and had estimated the bulk of the oxygen at $\frac{1}{5}$th of the air, or 20 per cent. Mr Lavoisier's experiments, which were very numerous and varied, almost coincided with those of Scheele. He considered air as composed of 27 parts by bulk of oxygen, and 73 of azote. Mr Cavendish's experiments were published in the Philosophical Transactions for 1783. He proved decisively, that the proportion of the azote and oxygen in the atmosphere does not vary; and by a very careful analysis, concluded that 100 parts of air in bulk are composed of

79.16	azote
20.84	oxygen
100.00	

This opinion was not at first acceded to by chemists, misled by the previous

CHAP. XIX.

AN ESSAY TOWARDS A NATURAL HISTORY OF THE AIR.

A LATE eminent philosopher has considered our atmosphere as one large chymical vessel, in which an infinite number of various operations are constantly performing. In it all the bodies of the earth are continually sending up a part of their substance by

conclusions of Scheele and Lavoisier; and it was not till towards the commencement of the 19th century, that the true proportion of these constituents was generally known. The experiments of Berthollet in Egypt and in Paris, seem to have led the way to it. These were almost immediately confirmed by those of Davy, Beddoes, and many other chemists. At present it is universally admitted, that atmospheric air never varies in its composition; that it is the same in all places, and in all seasons; and that it consists in bulk of

79 azote
21 oxygen
100

proportions almost exactly the same with those originally settled by Mr Cavendish.

Oxygen gas is undoubtedly the most important of the constituents of the atmosphere, and indeed one of the most remarkable substances in nature, and highly worthy of the investigation of the chemist. Dr Priestley, its original discoverer, gave it the name of *dephlogisticated air*, Scheele called it *empyreal air*, Lavoisier called it at first *highly respirable air*, then *vital air*, and at last *oxygen gas*, because he considered it as the acidifying principle. It possesses the mechanical properties of common air; combustibles burn in it with great brilliancy; and animals can breathe it much longer than the same quantity of common air. If the specific gravity of common air be reckoned 1.000, that of oxygen gas, according to the experiments of Kirwin and Lavoisier, is 1.103; according to Davy, 1.127; according to Fourcroy, Vauquelin, and Seguin, 1.087; and according to Allen and Pepys, 1.090. These results do not differ much from each other, except that of Mr Davy. His oxygen was obtained from the black oxide of manganese, and might perhaps contain a little carbonic acid gas. If we exclude his, the average of the other three is 1.093. This may be considered as near the truth as can well be attained. Rating its specific gravity at 1.093, 100 cubic inches of it, at the temperature of 60° when the barometer stands at 30 inches, will weigh $33\frac{1}{3}$ grains troy.

Azotic gas, the other constituent of atmospherical air, is chiefly recognised by its negative qualities. It possesses the mechanical properties of air; it does not support combustion; and no animal can breathe it without death. It constitutes the base of nitric acid, and is one of the constituents of ammonia. There is reason to consider it as a compound body, but hitherto chemists have not been able to ascertain its constituents; though several extraordinary phenomena, observed during the decomposition of ammonia by Davy and evaporation, to mix in this great alembic, and to float a while in common. Here minerals, from their lowest depths, ascend in noxious or in warm vapours, to make a part of the general mass; seas, rivers, and subterranean springs, furnish their copi-

Berzilius, cannot well be accounted for, without supposing hydrogen to be a constituent of it. The specific gravity of azotic gas, according to Kirwan, is 0.985, that of air being 1.000; while, according to Lavoisier and Davy, it is 0.978. This last estimate we are disposed to consider as most correct. If so, 100 cubic inches of it, at the temperature of 60° when the barometer stands at 30 inches, weigh 29.83 grains troy. Reckoning the specific gravity of oxygen gas 1.093, and that of azotic gas 0.978, and supposing atmospherical air to be composed of 79 parts of azote and 21 oxygen by bulk, it follows, that 100 parts of it in weight are composed of

77.43 azote
22.57 oxygen

100.00

The third constituent of the atmosphere is carbonic acid gas. Its presence in the atmosphere was recognised as soon as Dr Black had ascertained the cause of the difference between mild and caustic alkalies: for it was known, that a caustic alkali soon becomes mild by exposure to the air. Dr Black ascertained, that the *mildness* is owing to the absorption of carbonic acid. From the observations of Saussure we learn, that this gas exists in the atmosphere on the summit of Mount Blanc, which is nearly 16,000 feet above the level of the sea; for lime-water soon deposited its lime in the state of carbonate, when exposed upon the summit of that mountain, (Saussure's *Voyages*, iv. 199.) Humboldt found it in a quantity of air brought down by Garnerin from a height of 4280 feet, to which he had ascended in an air-balloon. (*Jour. de Phys.* xlvii. 202.) It appears, therefore, to constitute a part of every portion of the atmosphere to which we have access. As this acid gas is produced in great quantities by combustion, respiration, fermentation, and many other of the most common processes of nature, one would be disposed to believe, at first view, that its quantity must be constantly increasing. But this does not appear to be the case; it must therefore be decomposed and separated from air as fast as it is formed. It is of so deleterious a nature, that, if it were to accumulate to any extent, it would render air incapable of supporting life. A candle will not burn in air contaminated with one-ninth of carbonic acid gas. The quantity of this gas in air is small. Many attempts have been made to ascertain it; but the process is so difficult, that absolute precision cannot be looked for. It was long believed that the carbonic acid present in the atmosphere amounted to one *per cent.* Humboldt made many experiments on the subject, and concluded from them, that its bulk varied from one *per cent.* to half a *per cent.* But this determination is certainly excessive. According to the experiments of Mr Dalton, a quantity of air, equal in bulk to 102,400 grains of water, contains a quantity of carbonic acid just capable of saturating 125 grains of lime-water; 70 measures of carbonic acid gas would produce the same effect: Hence he concludes, that the atmosphere contains $\frac{1}{1400}$th part of its bulk of carbonic acid gas. (*Phil. Mag.* xxiii 354.) This quantity we consider as rather below the truth. Mr Cavendish ous supplies; plants receive and return their share; and animals, that by living upon, consume this general store, are found to give it back in great quantities when they die.[1] The air therefore, that we breathe, and upon which we subsist, bears

has shown, that lime-water is not capable of depriving air completely of carbonic acid gas: Hence a portion would still remain in Mr Dalton's experiment. Perhaps we shall not err far if we state the bulk of carbonic acid gas in the atmosphere at $\frac{1}{1000}$th part.

The 4th constituent of the atmosphere is water in the state of vapour. That water forms a constituent part of the atmosphere, has been known in all ages, and indeed is demonstrated by the rain and dew which is continually falling, and by the great quantity of moisture which sulphuric acid, potash, and other bodies, absorb when exposed to the atmosphere. The quantity of moisture in the atmosphere has been observed to vary greatly at different times, and various instruments have been invented to measure that quantity. These instruments are called *hygrometers*. The most ingenious of them are those of Leslie, Saussure, and De Luc. It was at first supposed, that the water in the atmosphere was still in the state of water, and that it was held in solution in air precisely as salts are dissolved in water. But it has been at last established by satisfactory experiments, that the water in the atmosphere is in the state of vapour. To De Luc, Saussure, and Dalton, we are chiefly indebted for these experiments. As to the quantity of water which exists in the atmosphere, it depends upon a variety of circumstances. Saussure found that a cubic foot of air, saturated with moisture at 66°, contains about 8 grains troy of water, or $\frac{1}{67}$th of its weight. Supposing air always saturated with moisture, the quantity always increases with the temperature, because the elasticity of aqueous vapour increases with the temperature. Hence, in cold weather, the quantity of vapour in air is always small; whereas, in warm weather, it is often considerable. In the torrid zone the aqueous vapour in the atmosphere is capable of supporting from 0.6 to 1 inch of mercury. In Britain it is hardly ever capable of supporting 0.6 inch of mercury; but in summer it is often capable of supporting 0.5 inch, while in winter it often does not exceed 0.1 inch. From these facts it follows, that the weight of water present in the atmosphere varies from $\frac{1}{60}$ to $\frac{1}{300}$ of the whole. Mr Dalton supposes, that the medium quantity of vapour held in solution at once in the atmosphere, may amount to $\frac{1}{70}$th of its bulk.

These four bodies, oxygen, azote, carbonic acid, and vapour, are the only known constituents of the atmosphere. It cannot be doubted, that other bodies are occasionally present in it. The dreadful effects of marshy situations upon the health of the inhabitants, and the fatal rapidity with which certain diseases are propagated, cannot well be accounted for, without supposing that certain substances which produce a deleterious effect on the animal economy, are occasionally present in the atmosphere. But hitherto no method has been discovered of ascertaining the presence of these bodies, and subjecting them to examination. They are too subtile for our apparatus, and altogether escape the cognizance of our senses. It has been ascertained,

1 Boyle, vol. ii. p. 593.

very little resemblance to that pure elementary body which was described in the last chapter; and which is rather a substance that may be conceived, than experienced to exist. Air, such as we find it, is one of the most compounded bodies in all nature.

however, that certain acid fumes, as those of the muriatic acid, nitric acid, and above all, of the oxymuriatic acid, have the property of destroying these miasmata, or at least of preventing them from producing deleterious effects on the animal economy.

If the atmosphere were of uniform density, it would be easy to ascertain with the utmost accuracy, the height to which it extends: for the height of the atmosphere would obviously be to the height of the mercury in the barometer, as the specific gravity of common air is to the specific gravity of mercury. By making the calculation on this supposition, it will be found that the height of the atmosphere is a little more than 5 miles. As the air, however, gradually diminishes in density, the atmosphere must reach to a much greater distance from the earth than 5 miles. It appears from the duration of twilight, that at the height of $44\frac{1}{2}$ miles, the atmosphere is sufficiently dense to intercept the light of the sun, and reflect it to the earth. We are therefore entitled to conclude that it extends to a much greater height.

When a ray of light enters the atmosphere, it is bent from its course by the same cause which refracts the rays of light when they pass through any dense medium, such as glass or water. The refraction sustained by light at its first entrance into the atmosphere must be very small, from the extreme rarity of the air. The deviation, however, will gradually increase as it penetrates the denser strata, and the ray will describe a path increasing in curvature as it approaches the earth. From this property of the atmosphere, the apparent altitude of the sun, moon, and stars, is greater than their real elevation, and they appear to be raised above the horizon when they are actually below it. The refraction of the atmosphere near the earth's surface is liable to very considerable anomalies. A very extraordinary phenomenon arising from this cause has been described by Mr Vince. The castle of Dover concealed by the hill which lies between it and Ramsgate appeared, on the 6th of August, 1806, as if it had been brought over and placed on the side of the hill next to Ramsgate. This phenomenon must have arisen from some variation of density in the intermediate air. Phenomena of the same class with the preceding have been illustrated experimentally by the ingenious Dr Wollaston. See *Edinburgh Transactions*, vol. vi. p. 245; and *Phil. Trans.* 1778, p. 357; 1798. But while the solar rays traverse the earth's atmosphere, they suffer another change from the resisting medium which they encounter. When the sun or any of the heavenly bodies are considerably elevated above the horizon, their light is transmitted to the earth without any perceptible change; but when these bodies are near the horizon, their light must pass through a long tract of air, and is considerably modified before it reaches the eye of the observer. The momentum of the red or greatest refrangible rays, being greater than the momentum of the violet, or least refrangible rays, the former will force their way through the resisting medium, while the latter will be either reflected or absorbed. A white beam of light, therefore, will be deprived of a portion of its blue rays by its horizontal passage through

Water may be reduced to a fluid every way resembling air, by heat; which, by cold, becomes water again. Every thing we see gives off its parts to the air, and has a little floating atmosphere of its own round it. The rose is encompassed with a sphere of its own odorous particles; while the night-shade infects the air with a scent of a more ungrateful nature. The perfume of musk flies off in such abundance, that the quantity remaining becomes sensibly lighter by the loss. A thousand substances that escape all our senses we know to be there; the powerful emanations of the load-stone, the effluvia of electricity, the rays of light, and the insinuations of fire. Such are the various substances through which we move, and which we are constantly taking in at every pore, and returning again with imperceptible discharge!

This great solution, or mixture of all earthly bodies, is continually operating upon itself; which, perhaps, may be the cause of its unceasing motion: but it operates still more visibly upon such grosser substances as are exposed to its influence; for

the atmosphere, and the resulting colour will be either orange or red, according to the quantity of the least refrangible rays that have been stopt in their course. Hence the rich and brilliant hue with which nature is gilded by the setting sun; hence the glowing red which tinges the morning and evening clouds; and hence the sober purple of twilight which they assume when their ruddy glare is tempered by the reflected azure of the sky.

We have already seen, that the red rays penetrate through the atmosphere, while the blue rays, less able to surmount the resistance which they meet, are reflected or absorbed in their passage. It is to this cause that we must ascribe the colour of the sky, and the bright azure which tinges the mountains of the distant landscape. As we ascend in the atmosphere, the deepness of the blue tinge gradually dies away; and to the aeronaut who has soared above the denser strata, or to the traveller who has ascended the Alps or the Andes, the sky appears of a deep black, while the blue rays find a ready passage through the attenuated strata of the atmosphere. It is owing to the same cause that the diver at the bottom of the sea, is surrounded with the red light which has pierced through the superincumbent fluid, and that the blue rays are reflected from the surface of the ocean. Were it not for the reflecting power of the air, and of the clouds which float in the lower regions of the atmosphere, we should be involved in total darkness by the setting of the sun, and by every cloud that passes over his disc. It is to the multiplied reflections which the light of the sun suffers in the atmosphere, that we are indebted for the light of day, when the earth is enveloped with impenetrable clouds. From the same cause arises the sober hue of the morning and evening twilight, which increases as we recede from the equator till it blesses with perpetual day the inhabitants of the polar regions.

scarcely any substance is found capable of resisting the corroding qualities of the air. The air, say the chemists, is a chaos furnished with all kinds of salts and menstruums; and, therefore, it is capable of dissolving all kinds of bodies. It is well known, that copper and iron are quickly covered, and eaten with rust, and that, in the climates near the equator, no art can keep them clean. In those dreary countries, the instruments, knives, and keys, that are kept in the pocket, are nevertheless quickly incrusted; and the great guns, with every precaution, after some years become useless. Stones, as being less hard, may be readily supposed to be more easily soluble. The marble of which the noble monuments of Italian antiquity are composed, although in one of the finest climates in the world, show the impressions which have been made upon them by the air. In many places they seem worm-eaten by time; and in others, they appear crumbling into dust. Gold alone seems to be exempted from this general state of dissolution; it is never found to contract rust though exposed never so long: the reason of this seems to be, that sea-salt, which is the only menstruum capable of acting upon and dissolving gold, is but very little mixed with the air; for salt being a very fixed body, and not apt to volatilize, and rise with heat, there is but a small proportion of it in the atmosphere. In the elaboratories and shops, however, where salt is much used, and the air is impregnated with it, gold is found to rust as well as other metals.

Bodies of a softer nature are obviously destroyed by the air.[1] Mr Boyle says, that silks brought to Jamaica, will, if there exposed to the air, rot, even while they preserve their colour; but if kept therefrom, they both retain their strength and gloss. The same happens in Brazil, where their clothes, which are black, soon turn of an iron colour; though in the shops, they preserve their proper hue.[2] In these tropical climates also, such are the putrescent qualities of the air, that white sugar will sometimes be full of maggots. Drugs and plasters lose their virtue, and become verminous. In some places they are obliged to expose their sweetmeats by day in the sun, otherwise the night-air would quickly cause them to putrify. On the contrary, in the cold arctic regions, animal substances, during the winter

1 Buffon, vol. iii. p. 62 2 Ibid. vol. iii. p. 68.

are never known to putrefy; and meat may be kept for months without any salt whatsoever. This experiment happily succeeded with the eight Englishmen that were accidentally left upon the inhospitable coasts of Greenland, at a place where seven Dutchmen had perished but a few years before; for killing some rein-deer for their subsistence, and having no salt to preserve the flesh, to their great surprise they soon found it did not want any, as it remained sweet during their eight month's continuance upon that shore.

These powers with which air is endued over unorganized substances, are exerted in a still stronger manner over plants, animals of an inferior nature, and lastly over man himself. Most of the beauty and the luxuriance of vegetation, is well known to be derived from the benign influence of the air; and every plant seems to have its favourite climate, not less than its proper soil. The lower ranks of animals also seem formed for their respective climates, in which only they can live. Man alone seems the child of every climate, and capable of existing in all. However, this peculiar privilege does not exempt him from the influences of the air; he is as much subject to its malignity as the meanest insect or vegetable.

With regard to plants, air is so absolutely necessary for their life and preservation, that they will not vegetate in an exhausted receiver. All plants have within them a quantity of air, which supports and agitates their juices. They are continually imbibing fresh nutriment from the air, to increase this store, and to supply the wants which they sustain from evaporation. When, therefore, the external air is drawn from them, they are no longer able to subsist. Even that quantity of air which they before were possessed of, escapes through their pores, into the exhausted receiver; and as this continues to be pumped away, they become languid, grow flaccid, and die. However, the plant or flower thus ceasing to vegetate, is kept, by being secured from the external air, a much longer time sweet than it would have continued had it been openly exposed.

That air which is so necessary to the life of vegetables, is still more so to that of animals; there are none found, how seemingly torpid soever, that do not require their needful supply. Fishes themselves will not live in water from whence the air is exhausted; and it is generally supposed that they die in frozen ponds, from the want of this necessary to animal existence. Many have been the animals that idle curiosity has tortured in the prison of a receiver, merely to observe the manner of their dying. We shall, from a thousand instances, produce that of the viper, as it is known to be one of the most vivacious reptiles in the world; and as we shall feel but little compassion for its tortures. Mr Boyle took a new caught viper, and shutting it up into a small receiver, began to pump away the air.[1] "At first, upon the air's being drawn away, it began to swell; sometime after he had done pumping, it began to gape, and open its jaws; being thus compelled to open its jaws, it once more resumed its former lankness; it then began to move up and down within, as if to seek for air, and after a while foamed a little, leaving the foam sticking to the inside of the glass; soon after, the body and neck grew prodigiously tumid, and a blister appeared upon its back; an hour and a half after, the receiver was exhausted, the distended viper moved, and gave manifest signs of life; the jaws remained quite distended; as it were from beneath the epiglottis, came the black tongue, and reached beyond it; but the animal seemed, by its posture, not to have any life; the mouth also was grown blackish within; and in this situation it continued for twenty-three hours. But upon the air being re-admitted, the viper's mouth was presently closed, and soon after opened again; and for some time those motions continued, which argued the remains of life." Such is the fate of the most insignificant or minute reptile that can be thus included. Mites, fleas, and even the little eels that are found swimming in vinegar, die for want of air. Not only these, but the eggs of these animals will not produce in vacuo, but require air to bring them to perfection.

As in this manner air is necessary to their subsistence, so also is must be of a proper kind, and not impregnated with foreign mixtures. That fictitious air which is pumped from plants or fluids, is generally, in a short time, fatal to them. Mr Boyle has given us many experiments to this purpose. After having shown that all vegetable and most mineral substances, properly prepared, may afford air, by being placed in an exhausted receiver, and this in such quantities, that some have thought it a new sub-

1 Boyle's Physico-Mechan. Exper. passim.

tance, made by the alteration which the mineral or plant has undergone by the texture of its parts being loosened in the operation—having shown, I say, that this air may be drawn in great quantities from vegetable, animal. or mineral substances, such as apples, cherries, amber burned, or hartshorn[2]—he included a frog in artificial air, produced from paste; in seven minutes space it suffered convulsions, and at last lay still, and being taken out, recovered no motion at all, but was dead. A bird inclosed in artificial air, from raisins, died in a quarter of a minute, and never stirred more. A snail was put into the receiver, with air of paste; in four minutes it ceased to move, and was dead, although it had survived in vacuo for several hours: so that factitious air proved a greater enemy to animals than even a vacuum itself.

Air also may be impregnated with fumes that are instantly fatal to animals. The fumes of hot iron, copper, or any other heated metal, blown into the place where an animal is confined, instantly destroy it. We have already mentioned the vapours in the grotto Del Cane suffocating a dog. The ancients even supposed, that these animals, as they always ran with their noses to the ground, were the first that felt any infection. In short, it should seem that the predominance of any one vapour, from any body, how wholesome soever in itself, becomes infectious; and that we owe the salubrity of the air to the variety of its mixture.

But there is no animal whose frame is more sensibly affected by the changes of the air than man. It is true, he can endure a greater variety of climates than the lower orders generally are able to do; but it is rather by the means which he has discovered of obviating their effects, than by the apparent strength of his constitution. Most other animals can bear cold or hunger better, endure greater fatigues in proportion, and are satisfied with shorter repose. The variations of the climate, therefore, would probably affect them the less, if they had the same means or skill in providing against the severities of the change. However this be, the body of man is an instrument much more nicely sensible of the variations of the air, than any of those which his own art has produced; for his frame alone seems to

2 Boyle's Physico-Mechan. vol. ii. p. 598

unite all their properties, being invigorated by the weight of the air, relaxed by its moisture, enfeebled by its heat, and stiffened by its frigidity.*

But it is chiefly by the predominance of some peculiar vapour, that the air becomes unfit for human support. It is often found, by dreadful experience, to enter into the constitution, to mix with its juices, and to putrefy the whole mass of blood. The nervous system is not less affected by its operations; palsies and vertigoes are caused by its damps; and a still more fatal train of distempers by its exhalations. In order that the air should be wholesome, it is necessary, as we have seen, that it should

* It is surprising the degree of heat the human body is capable of bearing. This seems to be connected with the action of the skin, and no doubt depending upon it; for the human body evidently has the power of bearing a very high temperature, without any change in the temperature of the body itself. Accurate experiments upon this subject (for it is needless to mention the inaccurate trials of Boerhaave) were first made by M. Tillet, at Paris, in 1764. The subject was resumed by Dr Fordyce, in 1775, and there are two curious papers in the Philosophical Transactions, giving an account of the phenomena which were observed. Dr Fordyce heated a room by means of flues running along the floor, and by means of boiling water, to the temperature of about 120o; he then stripped himself to the shirt, and went into the room. The temperature of his body continued at about 100°, but his pulse increased considerably in rapidity, beating 126 times in a minute. Streams of water condensed upon his body, and ran down to the floor. This was the vapour of the hot water by means of which the room was heated, condensed by the action of the comparatively cold surface of his body. Dr Fordyce invited the Hon. Captain Phipps, Sir Joseph Banks, Dr Solander, and Sir Charles Blagden, to repeat and verify these experiments. These gentlemen attended two several days, and during the last of these days there were also present Lord Seaforth, Sir George Home, Mr Dundas, and Mr Nooth The room was heated by means of a large iron cocle placed in the centre, and heated red hot. The thermometer, in some of their trials, rose to 260°. This degree of heat they found they could bear for a considerable time without any great inconvenience, both when dressed and when naked. The temperature of the body continued at 100°, the pulse was greatly quickened, increasing to 144 beats in a minute. The perspiration was very violent, and, no doubt, together with the imperfect conducting power of air, occasioned that equability of temperature which the body preserved. To prove that the heat of the air was really as great as they stated, and that there was no error in their thermometer, they introduced eggs and beaf-steaks, which were perfectly roasted in a short time. Water introduced, remained stationary at 140°, the evaporation preventing any farther increase; but when this evaporation was stopped, by covering its surface with oil or melted wax, the water soon heated so as to boil briskly. Experiments attended with nearly a similar result, were made at the same time by Dr Dobson, at Liverpool.

not be of one kind, but the compound of several substances; and the more various the composition, to all appearance, the more salubrious. A man, therefore, who continues in one place, is not so likely to enjoy this wholesome variety, as he who changes his situation; and, if I may so express it, instead of waiting for a renovation of air, walks forward to meet its arrival. This mere motion, independent even of the benefits of exercise, becomes wholesome, by thus applying a great variety of that healthful fluid by which we are sustained.

A thousand accidents are found to increase these bodies of vapour, that make one place more or less wholesome than another. Heat may raise them in too great quantities; and cold may stagnate them. Minerals may give off their effluvia in such proportion as to keep away all other kind of air; vegetables may render the air unwholesome by their supply; and animal putrefaction seems to furnish a quantity of vapour, at least as noxious as any of the former. All these united, generally make up the mass of respiration, and are, when mixed together, harmless; but any one of them, for a long time singly predominant, becomes at length fatal.

The effects of heat in producing a noxious quality in the air are well known. Those torrid regions under the Line are always unwholesome. At Senegal, I am told, the natives consider forty as a very advanced time of life, and generally die of old age at fifty. At Carthagena,[1] in America, where the heat of the hottest day ever known in Europe is continual, where, during their winter-season, these dreadful heats are united with a continual succession of thunder, rain, and tempests, arising from their intenseness, the wan and livid complexions of the inhabitants might make strangers suspect that they were just recovered from some dreadful distemper: the actions of the natives are conformable to their colour; in all their motions there is somewhat relaxed and languid: the heat of the climate even affects their speech, which is soft and slow, and their words generally broken. Travellers from Europe retain their strength and ruddy colour in that climate, possibly for three or four months; but afterwards suffer such decays in both, that they are no longer to be distinguished from the inhabitants by their complexion.

1 Ulloa, vol. i. p. 42.

However, this languid and spiritless existence is frequently drawled on sometimes even to eighty. Young persons are generally most affected by the heat of the climate, which spares the more aged; but all, upon their arrival on the coasts, are subject to the same train of fatal disorders. Few nations have experienced the mortality of these coasts so much as our own: in our unsuccessful attack upon Carthagena, more than three parts of our army were destroyed by the climate alone; and those that returned from that fatal expedition, found their former vigour irretrievably gone. In our more fortunate expedition, which gave us the Havannah, we had little reason to boast of our success; instead of a third, not a fifth part of the army were left survivors of their victory, the climate being an enemy that even heroes cannot conquer.

The distempers that thus proceed from the cruel malignity of those climates, are many: that, for instance, called the *Chapotonadas*, carries off a multitude of people; and extremely thins the crews of European ships, whom gain tempts into those inhospitable regions. The nature of this distemper is but little known, being caused in some persons by cold, in others by indigestion. But its effects are far from being obscure; it is generally fatal in three or four days: upon its seizing the patient, it brings on what is there called the *black vomit*, which is the sad symptom after which none are ever found to recover. Some, when the vomit attacks them, are seized with a delirium, that, were they not tied down, they would tear themselves to pieces, and thus expire in the midst of this furious paroxysm. This disorder, in milder climates, takes the name of the *bilious fever*, and is attended with milder symptoms, but very dangerous in all.

There are many other disorders incident to the human body, that seem the offspring of heat; but to mention no other, tha very lassitude which prevails in all the tropical climates, may be considered as a disease. The inhabitants of India,[1] says a modern philosopher, sustain an unceasing languor, from the heats of their climate, and are torpid in the midst of profusion. For this reason, the great Disposer of nature has clothed their country with trees of an amazing height, whose shade might defend them from the beams of the sun; and whose continual fresh-

1 Linnæi Amænitates, vol. v. p. 444.

ness might, in some measure, temperate their fierceness. From these shades, therefore, the air receives refreshing moisture, and animals a cooling protection. The whole race of savage animals retire in the midst of the day, to the very centre of the forests, not so much to avoid their enemy man, as to find a defence against the raging heats of the season. This advantage which arises from shades in torrid climates, may probably afford a solution for that extraordinary circumstance related by Boyle, which he imputes to a different cause. In the island of Ternate, belonging to the Dutch, a place that had been long celebrated for its beauty and healthfulness, the clove-trees grew in such plenty, that they in some measure lessened their own value: for this reason, the Dutch resolved to cut down the forests, and thus to raise the price of the commodity: but they had soon reason to repent of their avarice; for such a change ensued, by cutting down the trees, that the whole island from being healthy and delightful, having lost its charming shades, became extremely sickly, and has actually continued so to this day. Boerhaave considered heat so prejudicial to health, that he was never seen to go near a fire.

An opposite set of calamities are the consequence, in climates where the air is condensed by cold. In such places, all that train of distempers which are known to arise from obstructed perspiration, are very common;[2] eruptions, boils, scurvy, and a loathsome leprosy, that covers the whole body with a scurf, and white putrid ulcers. These disorders also are infectious; and, while they thus banish the patient from society, they generally accompany him to the grave. The men of those climates seldom attain to the age of fifty; but the women, who do not lead such laborious lives, are found to live longer.

The autumnal complaints which attend a wet summer, indicate the dangers of a moist air. The long continuance of an east wind also, shows the prejudice of a dry one. Mineral exhalations, when copious, are every where known to be fatal; and although we probably owe the increase and luxuriance of vegetation to a moderate degree of their warmth, yet the natives of those countries where there are mines in plenty, but too often experience the noxious effects of their vicinity. Those trades

2 Krantz's History of Greenland, vol. i. p. 235.

also that deal in the preparations of metals of all kinds, are always unwholesome; and the workmen, after some time, are generally seen to labour under palsies, and other nervous complaints. The vapours from some vegetable substances are well known to be attended with dangerous effects. The shade of the manchineel tree, in America, is said to be fatal, as was that of the juniper, if we may credit the ancients. Those who walk through fields of poppies, or in any manner prepare those flowers for making opium, are very sensibly affected with the drowsiness they occasion. A physician of Mr Boyle's acquaintance, causing a large quantity of black hellebore to be pounded in a mortar, most of the persons who were in the room, and especially the person who pounded it, were purged by it, and some of them strongly. He also gathered a certain plant in Ireland, which the person who beat it in a mortar, and the physician who was standing near, were so strongly affected by, that their hands and faces swelled to an enormous size, and continued tumid for a long time after.

But neither mineral nor vegetable steams are so dangerous to the constitution, as those proceeding from animal substances, putrefying either by disease or death. The effluvia that comes from diseased bodies, propagate that frightful catalogue of disorders which are called *infectious.* The parts which compose vegetable vapours and mineral exhalations, seem gross and heavy, in comparison of these volatile vapours, that go to great distances, and have been described as spreading desolation over the whole earth. They fly every where; penetrate every where; and the vapours that fly from a single disease, soon render it epidemic.

The plague is the first upon the list in this class of human calamities. From whence this scourge of man's presumption may have its beginning, is not well known: but we well know that it is propagated by infection. Whatever be the general state of the atmosphere, we learn from experience, that the noxious vapours, though but singly introduced at first, taint the air by degrees; every person infected tends to add to the growing malignity; and as the disorder becomes more general, the putrescence of the air becomes more noxious, so that the symptoms are aggravated by continuance. When it is said that the origin of this disorder is unknown, it implies, that the air seems to be but little employed in first producing it. There are some countries, even in the midst of Africa, that we learn have never been infected with it; but continue for centuries unmolested. On the contrary, there are others, that are generally visited once a year, as in Egypt, which, nevertheless, seems peculiarly blessed with the serenity and temperature of its climate. In the former countries, which are of vast extent, and many of them very populous, every thing should seem to dispose the air to make the plague continual among them. The great heats of the climate, the unwholesomeness of the food, the sloth and dirt of the inhabitants, but, above all, the bloody battles which are continually fought among them, after which heaps of dead bodies are left unburied, and exposed to putrefaction. All these, one might think, would be apt to bring the plague among them; and yet, nevertheless, we are assured by Leo Africanus, that in Numidia the plague is not known once in a hundred years; and that in Negroland, it is not known at all. This dreadful disorder, therefore, must have its rise, not from any previous disposition of the air, but from some particular cause, beginning with one individual, and extending the malignity by communication, till at last the air becomes actually tainted by the generality of the infection.

The plague which spread itself over the whole world, in the year 1346, as we are told by Mezeray, was so contagious, that scarcely a village, or even a house, escaped being infected by it. Before it had reached Europe, it had been for two years travelling from the great kingdom of Cathay, where it began by a vapour most horridly fœtid: this broke out of the earth like a subterranean fire, and upon the first instant of its eruption consumed and desolated above two hundred leagues of that country, even to the trees and stones.

In that great plague which desolated the city of London, in the year 1665, a pious and learned schoolmaster of Mr Boyle's acquaintance, who ventured to stay in the city, and took upon him the humane office of visiting the sick and the dying, who had been deserted by better physicians, averred, that being once called to a poor woman who had buried her children of the plague, he found the room where she lay so little, that it scarcely could hold any more than the bed whereon she was stretched. However, in this wretched abode, beside her, in an open coffin her husband lay, who had some time before died of the same disease; and whom she, poor creature, soon followed. But what showed the peculiar malignity of the air, thus suffering from animal putrefaction, was, that the contagious steams had produced spots on the very wall of their wretched apartment: and Mr Boyle's own study, which was contiguous to a pest-house, was also spotted in the same frightful manner. Happily for mankind this disorder, for more than a century, has not been known in our island: and for this last age, has abated much of its violence, even in those countries where it is most common. Diseases, like empires, have their revolutions; and those which for a while were the scourge of mankind, sink unheard of, to give place to new ones, more dreadful, as being less understood.

For this revolution in disorders, which has employed the speculation of many, Mr Boyle accounts in the following manner: "Since," says he, "there want not causes in the bowels of the earth, to make considerable changes amongst the materials that nature has plentifully treasured up in those magazines, and as those noxious steams are abundantly supplied to the surface, it may not seem improbable, that in this great variety some may be found capable of affecting the human frame in a particular manner, and thus of producing new diseases. The duration of these may be greater or less, according to the lastingness of those subterraneous causes that produced them. On which account, it need be no wonder that some diseases have but a short duration, and vanish not long after they appear; whilst others may continue longer, as having under ground more settled and durable causes to maintain them."

From the recital of this train of mischiefs produced by the air upon minerals, plants, animals, and man himself, a gloomy mind may be apt to dread this indulgent nurse of nature as a cruel and inexorable stepmother: but it is far otherwise; and, although we are sometimes injured, yet almost all the comforts and blessings of life spring from its propitious influence. It would be needless to observe, that it is absolutely necessary for the support of our lives; for of this every moment's experience assures us. But how it contributes to this support, is not so readily comprehended. All allow it to be a friend, to whose benefits we are constantly obliged; and yet, to this hour, philosophers are divided as to the nature of the obligation. The dispute is, whether the air is only useful by its weight to force our juices into circulation:[1] or, whether, by containing a peculiar spirit, it mixes with the blood in our vessels, and acts like a spur to their industry.[2] Perhaps it may exert both these useful offices at the same time. Its weight may give the blood its progressive motion, through the larger vessels of the body; and its admixture with it, cause those contractions of all the vessels, which serve to force it still more strongly forward, through the minutest channels of the circulation. Be this as it may, it is well known, that that part of our blood which has just received the influx of the air in our bodies, is of a very different colour from that which has almost performed its circuit. It has been found, that the arterial blood, which has been immediately mixed with the air in the lungs, and, if I may so express it, is just beginning its journey through the body, is of a fine florid scarlet colour; while, on the contrary, the blood of the veins, that is returning from having performed its duty, is of a blackish crimson hue. Whence this difference of colour should proceed, is not well understood; we only know the fact, that this florid colour is communicated by the air; and we are well convinced, that this air has been admitted into the blood for very useful purposes.

Beside this vital principle in animals, the air also gives life and body to flame. A candle quickly goes out in an exhausted receiver; for having soon consumed the quantity of air, it then expires for want of a fresh supply. There has been a flame contrived that will burn under water; but none has yet been found that will continue to burn without air. Gunpowder, which is the most catching and powerful fire we know, will not go off in an exhausted receiver; nay, if a train of gunpowder be laid, so as that one part may be fired in the open air, yet the other part in vacuo will remain untouched, and unconsumed. Wood also set on fire, immediately goes out; and its flame ceases upon removing the air; for something is then wanting to press the body of the fire against that of the fuel, and to prevent the too speedy diffusion of the flame. We frequently see cooks and others, whose business it is to keep up strong fires, take proper precautions to exclude the beams of the sun from shining upon them, which effectually puts them out. This they are apt to ascribe

1 Keil. Robinson. 2 Whytt upon vital and involuntary motions.

to a wrong cause; namely, the operation of the light: but the real fact is, that the warmth of the sun-beams lessens and dissipates the body of the air that goes to feed the flame; and the fire, of consequence, languishes for want of a necessary supply.

The air, while it thus kindles fire into flame, is, notwithstanding, found to moderate the rays of light, to dissipate their violence, and to spread an uniform lustre over every object. Were the beams of the sun to dart directly upon us, without passing through this protecting medium, they would either burn us up at once, or blind us with their effulgence. But by going through the air, they are reflected, refracted, and turned from their direct course, a thousand different ways; and thus are more evenly diffused over the face of nature.

Among the other necessary benefits the air is of to us, one of the principal is, its conveyance of sound. Even the vibrations of a bell, which have the loudest effect that we know of, cease to be heard when under the receiver of an air-pump. Thus all the pleasures we receive from conversation with each other, or from music, depend entirely upon the air.*

* Every sound is rendered stronger or weaker, and may be heard at a greater or less distance, according to the density or rarity of that elastic fluid by which it is propagated. According to Mr Hawksbee, who has made deep researches into this branch of philosophy, when air has acquired twice its common density, it transmits sound twice as far as common air; whence he reasonably concludes, that sound increases, not only in direct proportion to the density of the air, but in proportion to the square of this density. If sound was propagated in an elastic fluid more dense than the air, it would be carried proportionably farther. M. Brisson has proved this, by putting a sonorous body into carbonic acid gas, the density of which is about one-third more than that of atmospheric air; the consequence was, that at that time, and in that situation, the sound was very considerably increased. For this reason the dryness of the air, which increases its density, has a considerable effect in rendering sound louder and more audible. Sound is also much increased by the reverberation of the pulses of the air from those surrounding bodies against which they strike; whence it happens, music is so much louder in a close apartment than in the open air.

A knowledge of the progression of sound is not a subject of mere sterile curiosity, but is in several instances useful; for by this we are enabled to determine the distance of ships or other moving bodies. Suppose, for example, a vessel fires a gun, the sound of which is heard five seconds after the flash is seen; as sound moves 1142 English feet in one second, this number multiplied by five, gives the distance of 5710 feet. The same principle has been already mentioned as applicable in storms of lightning and thunder.

The waves or pulses of sound being reflexible in their course, when they

Odours likewise are diffused only by the means of air; without this fluid to swim in, they would for ever remain torpid in their respective substances; and the rose would affect us with as little sensations of pleasure, as the thorn on which it grew.

meet with an extended solid body of a regular surface, an ear placed in the passage of these reflected waves, will perceive a sound similar to the original sound, but which will seem to proceed from a body situated in a similar position and distance behind the place of reflection,* as the real sounding body is before it. This reflected sound is commonly called an *Echo*, which, however, cannot take place at less than fifty-five feet; because it is necessary that the distance should be such, and the reverberated or reflected sound so long in arriving, that the ear may distinguish clearly between that and the original sound.

It is in general known, that caverns, grottoes, mountains, and ruined buildings, return this image of sound. Image we may call it, for in every respect it resembles the image of a visible object reflected from a polished surface. Our figures are often represented in a mirror without seeing them ourselves, while those standing on one side are alone sensible of the reflection. To be capable of seeing the reflected image of ourselves, we must be directly in a line with the image. Just so it is in an echo; we must stand in the line in which the sound is reflected, or the repetition will be lost to us, while it may, at the same time, be distinctly heard by others who stand at a small distance to one side of us. There is a very extraordinary echo at a ruined fortress near Louvain, in Flanders. If a person sing, he only hears his own voice, but then he hears it with surprising variations, sometimes louder, sometimes softer, now more near, then more distant. There is an account in the Memoirs of the French Academy, of a similar echo near Rouen. The building which returns it is a semicircular court-yard; yet all the buildings of the same form do not produce the same effects. We find some music halls excessively adapted for sounds, while others, built upon the same plan, in a different place, are found to resist the tones, instead of enlarging them, in a very disagreeable manner.

As we know the distance of places by the length of time a sound takes to travel from them, so we may judge of the distance of an echo by the length of the interval between our voice and its repetition. The most deliberate echoes, as they are called, are ever the most distant; while, on the contrary, those that are very near, return their sound so very quick as to have the interval almost imperceptible: when this is the case, and the echo is so very near, the voice is said to be increased and not echoed; however, in fact, the increase is only made by the swiftly pursuing repetition. Our theatres and concert-rooms are best fitted for music or speaking, when they enlarge the sound to the greatest pitch at the smallest interval: for a repetition which does not begin the word till the speaker has finished it, throws all the sounds into confusion. Thus the theatre at the Hay-market, in London, enlarges the sound very much; but then at a long interval after the singer or speaker. The old theatre at Drury-lane, before it was altered, enlarged the sound but

* Sound is reflected in the same direction as light from a mirror; that is, the angle of reflection is equal to the angle of incidence.

Those who are willing to augment the catalogue of the benefits we receive from this element, assert also, that tastes themselves would be insipid, were it not that the air presses their parts upon the nerves of the tongue and palate, so as to produce their grateful effects. Thus, continue they, upon the tops of high mountains, as on the Peak of Teneriffe, the most poignant bodies, as pepper, ginger, salt, and spice, have no sensible taste, for want of their particles being thus sent home to the sensory. But we owe the air sufficient obligations, not to be studious of admitting this among the number; in fact, all substances have their taste, as well on the tops of mountains, as in the bottom of the valley; and I have been one of many, who have ate a very savoury dinner on the Alps.

It is sufficient, therefore, that we regard the air as the parent of health and vegetation; as a kind dispenser of light and warmth; and as the conveyer of sounds and odours. This is an element of which avarice will not deprive us; and which power cannot monopolize. The treasures of the earth, the verdure of the fields, and even the refreshments of the stream, are too often seen going only to assist the luxuries of the great; while the less fortunate part of mankind stand humble spectators of their encroachments. But the air no limitations can bound, nor any landmarks restrain. In this benign element, all mankind can boast an equal possession; and for this we all have equal obligations to Heaven. We consume a part of it, for our own sustenance, while we live; and, when we die, our putrefying bodies give back the supply, which, during life, we had accumulated from the general mass.

in a small degree; but then the repetition was extremely quick in its pursuit, and the sounds, when heard, were therefore heard distinctly. Deigo lise, the great musical composer, used to say, that an echo was the best school-mistress; for let a man's own music be ever so good, by playing to an echo she would teach him to improve it.

Reflected sounds may be magnified by much the same contrivances as are used in optics respecting light: hence it follows, that sounds uttered at one focus of an elliptical cavity, are heard much magnified in the other focus. The whispering gallery at St Paul's Cathedral, in London, is of this description; a whisper uttered at one side of the dome is reflected to the other, and may be very distinctly heard. The speaking and ear trumpets are constructed on this principle The best form for these instruments is a hollow parabolic conoid, with a small orifice at the top or apex, to which the mouth is applied when the sound is to be magnified, or the ear when the hearing is to be facilitated.

CHAP. XX.

OF WINDS, REGULAR AND IRREGULAR.

Wind is a current of air. Experimental philosophers produce an artificial wind, by an instrument called an *æolipile.* This is nothing more than a hollow copper ball, with a long pipe ; a tea-kettle might be readily made into one, if it were entirely closed at the lid, and the spout left open . through this spout it is to be filled with water, and then set upon the fire, by which means it produces a violent blast, like wind, which continues while there is any water remaining in the instrument. In this manner water is converted into a rushing air ; which, if caught as it goes out, and left to cool, is again quickly converted into its former element. Besides this, as was mentioned in the former chapter, almost every substance contains some portions of air. Vegetables, or the bodies of animals left to putrefy, produce it in a very copious manner. But it is not only seen thus escaping from bodies, but it may be very easily made to enter into them. A quantity of air may be compressed into water, so as to be intimately blended with it. It finds a much easier admission into wine, or any fermented liquor : and an easier still into spirits of wine. Some salts suck up the air in such quantities, that they are made sensibly heavier thereby, and often are melted by its moisture. In this manner, most bodies being found either capable of receiving or affording it, we are not to be surprised at those streams of air that are continually fleeting round the globe.—Minerals, vegetables, and animals, contribute to increase the current ; and are sending off their constant supplies. These, as they are differently affected by cold or heat, by mixture or putrefaction, all yield different quantities of air at different times; and the loudest tempests, and most rapid whirlwinds, are formed from their united contributions.

The sun is the principal instrument in rarefying the juices of plants, so as to give an escape to their imprisoned air ; it is also equally operative in promoting the putrefaction of animals. Mineral exhalations are more frequently raised by subterranean heat. The moon, the other planets, the seasons, are all combined in producing these effects in a smaller degree. Mountains give a direction to the courses of the air. Fires carry a current of air along their body. Night and day alternately chill and warm the earth, and produce an alternate current of its vapours. These, and many other causes, may be assigned for the variety and the activity of the winds, their continual change, and uncertain duration.

With us on land, as the wind proceeds from so many causes, and meets such a variety of obstacles, there can be but little hopes of ever bringing its motions to conform to theory; or of foretelling how it may blow a minute to come. The great Bacon, indeed, was of opinion, that by a close and regular history of the winds, continued for a number of ages together, and the particulars of each observation reduced to general maxims, we might at last come to understand the variations of this capricious element; and that we could foretell the certainty of a wind with as much ease as we now foretell the return of an eclipse. Indeed, his own beginnings in this arduous undertaking seem to speak the possibility of its success; but, unhappily for mankind, this investigation is the work of ages, and we want a Bacon to direct the process.

To be able, therefore, with any plausibility, to account for the variations of the wind upon land, is not to be at present expected; and to understand any thing of their nature, we must have recourse to those places where they are more permanent and steady. This uniformity and steadiness we are chiefly to expect upon the ocean. There, where there is no variety of substances to furnish the air with various and inconstant supplies, where there are no mountains to direct the course of its current, but where all is extensively uniform and even; in such a place, the wind arising from a simple cause, must have but one simple motion. In fact, we find it so. There are many parts of the world where the winds, that with us are so uncertain, pay their stated visits. In some places they are found to blow one way by day, and another by night; in others, for one half of the year they go in a direction contrary to their former course: but, what is more extraordinary still, there are some places where the winds never change, but for ever blow the same way. This is particularly found to obtain between the tropics in the Atlantic and Æthiopic oceans; as well as in the great Pacific sea.

Few things can appear more extraordinary to a person who has never been out of our variable latitudes, than this steady wind, that for ever sits in the sail, sending the vessel forward; and as effectually preventing its return. He who has been taught to consider that nothing in the world is so variable as the winds, must certainly be surprised to find a place where there is nothing more uniform. With us their inconstancy has become a proverb; with the natives of those distant climates they may talk of a friend or a mistress as fixed and unchangeable as the winds, and mean a compliment by the comparison. When our ships are once arrived into the proper latitudes of the great Pacific ocean, the mariner forgets the helm, and his skill becomes almost useless: neither storms nor tempests are known to deform the glassy bosom of that immense sheet of waters; a gentle breeze, that for ever blows in the same direction, rests upon the canvas, and speeds the navigator. In the space of six weeks, ships are thus known to cross an immense ocean, that takes more than so many months to return. Upon returning, the trade-wind, which has been propitious, is then avoided; the mariner is generally obliged to steer into the northern latitudes, and to take the advantage of every casual wind that offers, to assist him into port. This wind, which blows with such constancy one way, is known to prevail not only in the Pacific ocean, but also in the Atlantic, between the coasts of Guinea and Brazil; and, likewise, in the Æthiopic ocean. This seems to be the great universal wind, blowing from the east to the west, that prevails in all the extensive oceans, where the land does not frequently break the general current. Were the whole surface of the globe an ocean, there would probably be but this one wind, for ever blowing from the east, and pursuing the motions of the sun westward. All the other winds seem subordinate to this; and many of them are made from the deviations of its current. To form, therefore, any conception relative to the variations of the wind in general, it is proper to begin with that which never varies.

There have been many theories to explain this invariable motion of the winds; among the rest we cannot omit that of Dr Lyster, for its strangeness. "The sea," says he, "in those latitudes, is generally covered over with green weeds, for a great extent; and the air produced from the vegetable perspiration of these, produces the trade-wind." The theory of Cartesius was not quite so absurd. He alleged that the earth went round faster than its atmosphere at the equator; so that its motion, from west to east, gave the atmosphere an imaginary one from east to west; and thus an east wind was eternally seen to prevail. Rejecting those arbitrary opinions, conceived without force, and asserted without proof, Dr Halley has given one more plausible; which seems to be the reigning system of the day.

To conceive his opinion clearly, let us for a moment suppose the whole surface of the earth to be an ocean, and the air encompassing it on every side, without motion. Now it is evident, that that part of the air which lies directly under the beams of the sun, will be rarified; and if the sun remained for ever in the same place, there would be a great vacuity in the air, if I may so express it, beneath the place where the sun stood. The sun moving forward from east to west, this vacuity will follow too, and still be made under it. But while it goes on to make new vacuities, the air will rush in to fill up those the sun has already made; in other words, as it is still travelling forward, the air will continually be rushing in behind, and pursue its motions from east to west. In this manner the air is put into motion by day; and by night the parts continue to impel each other till the next return of the sun, that gives a new force to the circulation.

In this manner is explained the constant east wind that is found blowing round the globe, near the equator. But it is also known, that as we recede from the equator on either side, we come into a trade-wind, that continually blows from the poles, from the north on one side, or the south on the other, both directing towards the equator. This also proceeds from a similar cause with the former; for the air being more rarified in those places over which the sun more directly darts its rays, the currents will come both from the north and the south, to fill up the intermediate vacuity.

These two motions, namely, the general one from east to west, and the more particular one from both the poles, will account for all the phenomena of trade-winds; which, if the whole surface of the globe were sea, would undoubtedly be constant, and for ever continue to blow in one direction. But there are a thousand circumstances to break these air-currents into smaller ones; to drive them back against their general course; to raise or depress them; to condense them into storms, or to whirl them in eddies. In consequence of this, regard must be often had to the nature of the soil, the position of the high mountains, the course of the rivers, and even to the luxuriance of vegetation.

If a country, lying directly under the sun, be very flat and sandy, and if the land be low and extensive, the heat occasioned by the reflection of the sunbeams produces a very great rarefaction of the air. The deserts of Africa, which are conformable to this description, are scarcely ever fanned by a breath of wind by day; but the burning sun is continually seen blazing in intolerable splendour above them. For this reason, all along the coasts of Guinea, the wind is always perceived blowing in upon the land, in order to fill up the vacuity caused by the sun's operation. In those shores, therefore, the wind blows in a contrary direction to that of its general current; and is constantly found setting in from the west.

From the same cause it happens, that those constant calms, attended with deluges of rain, are found in the same part of the ocean. For this tract being placed in the middle, between the westerly winds blowing on the coast of Guinea, and the easterly trade-winds that move at some distance from shore, in a contrary direction, the tendency of that part of the air that lies between these two opposite currents is indifferent to either, and so rests between both in torpid serenity; and the weight of the incumbent atmosphere, being diminished by the continual contrary winds blowing from hence, it is unable to keep the vapours suspended that are copiously borne thither; so that they fall in continual rains.

But it is not to be supposed, that any theory can account for all the phenomena of even those winds that are known to be most regular. Instead of a complete system of the trade-winds, we must rather be content with an imperfect history. These,[1] as was said, being the result of a combination of effects, assume as great a variety as the causes producing them are various.

Besides the great general wind above mentioned, in those parts of the Atlantic that lie under the temperate zone, a north wind prevails constantly during the months of October, November, December, and January. These, therefore, are the most favour-

1 Buffon, vol. ii. p. 230.

able months for embarking for the East-Indies, in order to take the benefit of these winds, for crossing the Line: and it has been often found by experience, that those who had set sail five months before, were not in the least farther advanced in their voyage, than those who waited for the favourable wind. During the winter, off Nova Zembla, and the other arctic countries, a north wind reigns almost continually. In the Cape de Verd islands, a south wind prevails during the month of July. At the Cape of Good Hope, a north-west wind blows during the month of September. There are also regular winds, produced by various causes, upon land. The ancient Greeks were the first who observed a constant breeze, produced by the melting of the snows, in some high neighbouring countries. This was perceived in Greece, Thrace, Macedonia, and the Ægean sea. The same kind of winds are now remarked in the kingdom of Congo, and the most southern parts of Africa. The flux and reflux of the sea also produces some regular winds, that serve the purposes of trade; and, in general, it may be observed, that wherever there is a strong current of water, there is a current of air that seems to attend it.

Besides these winds that are found to blow in one direction, there are, as was said before, others that blow for certain months of the year one way, and the rest of the year the contrary way; these are called the *Monsoons*, from a famous pilot of that name, who first used them in navigation with success.* In all that

* Varenii Geographia Generalis, cap. 20. The term *Monsoon* is otherwise derived from *moussin*, a Malay word, signifying "season." It is in the Indian Ocean alone that the famous *monsoons*, or half yearly winds, seem to destroy the uniformity of the general atmospheric movement. No doubt, however, they might be made to accord with it, provided we knew all the circumstances which influence them. We exhibit the facts in the first place. From the 10th degree of south latitude to the tropic of Capricorn, and beyond it, the general east or south-east trade wind prevails over all the Indian Ocean, sometimes in summer extending as far as the 2d and 3d degrees of south latitude. On this side the 10th degree, we first meet with the *monsoons* or periodical half yearly winds. North of the equator, from April to October, a violent *south-west* wind prevails, accompanied with tempests, storms, and rain; while a soft and pleasant *north-east* wind blows during the other six months. Between the second and twelfth parallels of south latitude, the winds blow generally from *north-west* during the winter six months, from *south-west* in summer.

During winter, then, the constitution of the atmosphere exhibits the following principal circumstances: North-east winds north of the line; north-west part of the ocean that lies between Africa and India, the east winds begin at the month of January, and continue till about the commencement of June. In the month of August or September, the contrary direction takes place: and the west wind;

winds south of it, to the 10th parallel; and finally, the east and south-east trade-winds. In *summer*, the phenomena are less contradictory: South-west winds from the 10th parallel to the northern limits; trade-winds south of the 10th parallel.

These general tendencies are subject to variations, depending on the figure and elevation of coasts, on straits, and currents of the sea. The north-west and south-west monsoons are weaker and more variable in the Bay of Bengal, more steady and violent in the gulf of Arabia. Both those monsoons grow broader to the west, ranging in this direction over the whole tract of sea that lies between Africa and Madagascar. In the seas extending between China, the kingdom of Siam, Sumatra, and the equator, those monsoons are felt likewise; but here, excepting local variations, they are almost entirely *north* and *south*. They extend as far as the Philippine Islands, and though with much inconstancy, even to Japan. Between the equator, the islands of Java, and New Guinea, the monsoons are nearly similar to those of the Chinese Sea, in regard to their direction, which merely varies a little to the north-west in the north monsoon, and a little to the south-west in the south monsoon. But they do not begin till six weeks after those of the Chinese Seas.

Some other striking circumstances still remain to be noticed. The monsoons do not change, or, as sailors express it, do not break, of a sudden. Their change, which usually takes place fifteen days or four weeks *after the equinoxes*, is announced by the decay of the existing monsoon, by calms and squalls in rapid succession, by storms, waterspouts, tornadoes, and by Indian hurricanes, called *taifouns*, particularly terrible from the explosions of electric matter accumulated by the monsoon. The beginnings of the subsequent monsoon are, at first, liable to variations, till finally it establishes an absolute dominion.

Navigators assert, that on quitting the region where a monsoon prevails, one is sure, in ordinary circumstances, to fall in with a very strong and impetuous wind, blowing from a quarter directly opposite: They must naturally have observed this phenomenon with much care, since the calms and whirlwinds it occasions are productive of great danger. It can hardly be explained, except by admitting, with Halley, the existence of two currents,—one above, composed of warm and rarified air; another below, composed of the column of cold and condensed air. This hypothesis will become almost a settled truth, if we observe how small is the elevation to which the monsoon extends—a fact clearly exhibited in the peninsula on this side the Ganges, where the monsoons are arrested for several months by the mountain chain of the Gauts (not certainly of extraordinary height); so that the coast of Coromandel, and that of Malabar, have always their dry and their rainy seasons, at opposite periods of the year.

According to the preceding description, it is the *south-west monsoon* alone which presents any phenomena directly contrary to the general movement of the atmosphere; for the north-east monsoon is in conformity with it, and prevail for three or four months. The interval between these winds, that is to say, from the end of June to the beginning of August, there is no fixed wind; but the sea is usually tossed by violent tempests, proceeding from the north. These winds are always subject to their greatest variations, as they approach the land; so that on one side of the great peninsula of India, the coasts are, for near half the year, harassed by violent hurricanes and northern tempests: while, on the opposite side, and all along the coasts of Coromandel, these dreadful tempests are wholly unknown. At Java and Ceylon, a west wind begins to reign in the month of September; but at fifteen degrees of

the north-west wind south of the line seems not to be altogether constant, and may perhaps arise from nothing more than a compound movement, or a higher current of air. What then is the origin of this half-yearly wind, which in summer blows from south and south-west, over all the Indian ocean? The sagacity of physical geographers has long been exercised by this question. We give the explanation of which Halley laid the ground-work, and which appears to us the most plausible.

The monsoons always change some time after the equinoxes; they constantly blow towards that hemisphere in which the sun is found. The action of this luminary on the atmosphere, is, therefore, plainly one of their causes. When its rays, reflected from the mountains of Thibet, scorching the plains of Bengal, and the valleys of the kingdom of Siam, rarefy and dissipate the atmosphere, the cold air becomes violently attracted from the regions about the south pole. The sun's action is seconded by the marine current, which proceeds from the south polar seas to those of India. This current must bring with it a column of vapours, continually disengaging themselves from its surface. The absence of a northern marine current must farther be added; we can even imagine, that the mountains of Thibet, and the whole central platform of Asia, may arrest and preserve the cold air, which would otherwise proceed from Siberia towards India.

But why does not this polar wind prevail south of the equator also? For the same reason which renders the aquatic polar current inconsiderable there. The general movement of the ocean being opposed by no obstacle, has too much force to be modified by the polar current. A similar result happens in the atmosphere, at all times intimately connected with the ocean, which feeds and modifies it. But on leaving New Holland between us and the Pacific Ocean, the general movement of the Indian sea must evidently more and more abandoned to its individual force, and that force must soon be overcome by the polar current, which, after being long deflected or concealed by the general movement of the ocean, now re-appears in all its energy. The polar column of water now fills the atmosphere with cold particles, which, by their gravity, determine the whole atmospheric mass to flow towards the equator, more strongly and more directly than it would have flowed otherwise. It is possible, moreover, that higher currents may exist in the atmosphere, and descend towards the earth at the time when the monsoons commence.

south latitude, this wind is found to be lost, and the great general trade-wind from the east is perceived to prevail. On the contrary, at Cochin, in China, the west wind begins in March; so that these monsoons prevail, at different seasons, throughout the Indies. So that the mariner takes one part of the year to go from Java to the Moluccas; another from Cochin to Molucca; another from Molucca to China; and still another to direct him from China to Japan.

There are winds also that may be considered as peculiar to certain coasts; for example, the south wind is almost constant upon the coasts of Chili and Peru; western winds almost constantly prevail on the coast of Terra Magellanica, and in the environs of the Straits le Maire. On the coasts of Malabar, north and north-west winds prevail continually; along the coast of Guinea, the north-west wind is also very frequent; and, at a distance from the coasts, the north-east is always found prevailing. From the beginning of November to the end of December, a west wind prevails on the coasts of Japan; and, during the whole winter, no ships can leave the port of Cochin, on account of the impetuosity of the winds that set upon the coast. These blow with such vehemence, that the ports are entirely choked up with sand, and even boats are not able to enter. However, the east winds that prevail for the other half of the year, clear the mouths of their harbours from the accumulations of the preceding winter, and set the confined ships at liberty. At the straits of Babelmandel, there is a south wind that periodically returns, and which is always followed by a north-east.

Besides winds thus peculiar to certain coasts, there are others found to prevail on all the coasts, in warm climates, which during one part of the day, blow from the shore, and during another part of it blow from the sea. The sea-breeze, in those countries, as Dampier observes, commonly rises in the morning about nine, proceeding slowly in a fine small black curl, upon the surface of the water, and making its way to refresh the shore. It is gentle at first, but increases gradually till twelve, then insensibly sinks away, and is totally hushed at five. Upon its ceasing, the land-breeze begins to take its turn, which increases gradually till twelve at night, and is succeeded in the morning by the sea-breeze again. Without all doubt, nothing could be more fortunate for the inhabitants of the warm countries where those breezes blow, than this alternate refreshment, which they feel at those seasons, when it is most wanted. The heat on some coasts would be insupportable, were it not for such a supply of air, when the sun has rarified all that which lay more immediately under the coast. The sea-breeze temperates the heat of the sun by day; and the land-breeze corrects the malignity of the dews and vapours by night. Where these breezes, therefore, prevail, and they are very common, the inhabitants enjoy a share of health and happiness unknown to those that live much farther up the country, or such as live in similar latitudes without this advantage. The cause of these obviously seems to arise from the rarefaction of the air by the sun, as their duration continues with its appearance, and alters when it goes down. The sun, it is observed, equally diffusing his beams upon land and sea, the land being a more solid body than the water, receives a greater quantity of heat, and reflects it more strongly. Being thus, therefore, heated to a greater degree than the waters, it, of consequence, drives the air from land out to sea; but its influence being removed, the air returns to fill up the former vacuity. Such is the usual method of accounting for this phenomenon; but, unfortunately, these sea and land breezes are visitants that come at all hours. On the coasts of Malabar,[1] the land-breezes begin at midnight, and continue till noon; then the sea-breezes take their turn, and continue till midnight. While again, at Congo, the land-breezes begin at five, and continue till nine the next day.

But if the cause of these be so inscrutable, that are, as we see, tolerably regular in their visitations, what shall we say to the winds of our own climate, that are continually shifting, and incapable of rest? Some general causes may be assigned, which nothing but particular experience can apply. And in the first place, it may be observed, that clouds and heat, and in short, whatever either increases the density or the elasticity of the air, in any one place, will produce a wind there: for the increased activity of the air thus pressing more powerfully on the parts of it that are adjacent, will drive them forward, and thus go on, in a current, till the whole comes to an equality.

1 Buffon, vol. ii. p. 252.

In this manner, as a denser air produces a wind, on one hand; so will any accident, that contributes to lighten the air, produce it on the other: for a lighter air may be considered as a vacuity, into which the neighbouring air will rush: and hence it happens, that when the barometer marks a peculiar lightness in the air, it is no wonder that it foretells a storm.

The winds upon large waters are generally more regular than those upon land. The wind at sea generally blows with an even steady gale; the wind at land puffs by intervals, increasing its strength, and remitting it, without any apparent cause. This, in a great measure, may be owing to the many mountains, towers, or trees, that it meets in its way, all contributing either to turn it from its course, or interrupt its passage.

The east wind blows more constantly than any other, and for an obvious reason: all other winds are, in some measure, deviations from it, and partly may owe their origin thereto. It is generally, likewise, the most powerful, and for the same reason.

There are often double currents of the air. While the wind blows one way, we frequently see the clouds move another. This is generally the case before thunder; for it is well known that the thunder cloud always moves against the wind: the cause of this surprising appearance has hitherto remained a secret. From hence we may conclude, that weathercocks only inform us of that current of the air which is near the surface of the earth; but are often erroneous with regard to the upper regions, and, in fact, Derham has often found them erroneous.

Winds are generally more powerful on elevated situations than on the plain, because their progress is interrupted by fewer obstacles. In proportion as we ascend the heights of a mountain, the violence of the weather seems to increase, until we have got above the region of storms, where all is usually calm and serene. Sometimes, however, the storms rise even to the tops of the highest mountains; as we learn from those who have been on the Andes, and as we are convinced by the deep snows that crown even the highest.

Winds blowing from the sea are generally moister, and more attended with rains, than those which blow over extensive tracts of land; for the sea gives off more vapours to the air, and these are rolled forward upon land by the wind's blowing from thence.[1] For this reason our easterly winds that blow from the continent are dry in comparison of those that blow from the surface of the ocean, with which we are surrounded on every other quarter.

In general the winds are more boisterous in spring and autumn than at other seasons: for that being the time of high tides, the sea may communicate a part of its motions to the winds. The sun and moon, also, which then have a greater effect upon the waters, may also have some influence upon the winds: for there being a great body of air surrounding the globe, which, if condensed into water, would cover it to the depth of thirty-two feet, it is evident that the sun and moon will, to a proportionable degree, affect the atmosphere, and make a tide of air. This tide will be scarcely perceivable, indeed; but, without doubt, it actually exists; and may contribute to increase the vernal and autumnal storms, which are then known to prevail.

Upon narrowing the passage through which the air is driven, both the density and the swiftness of the wind is increased. For, as currents of water flow with greater force and rapidity by narrowing their channels; so also will a current of air driven through a contracted space, grow more violent and irresistible. Hence we find those dreadful storms that prevail in the defiles of mountains, where the wind, pushing from behind through a narrow channel, at once increases in speed and density, levelling or tearing up every obstacle that rises to obstruct its passage.

Winds reflected from the sides of mountains and towers, are often found to be more forceful than those in direct progression. This we frequently perceive near lofty buildings, such as churches or steeples, where winds are generally known to prevail, and that much more powerfully than at some distance. The air in this case, by striking against the side of the building, acquires additional density, and, therefore, blows with more force.

These different degrees of density, which the air is found to possess, sufficiently show that the force of the winds do not depend upon their velocity alone; so that those instruments called *anemometers*, which are made to measure the velocity of the wind, will by no means give us certain information of the

1 Derham's Physico-Theol.

force of the storm. In order to estimate this with exactness, we ought to know its density; which also these are not calculated to discover. For this reason we often see storms, with very powerful effects, that do not seem to show any great speed; and, on the contrary, we see these wind-measurers go round with great swiftness, when scarcely any damage has followed from the storm.

Such is the nature and the inconstancy of the irregular winds, with which we are best acquainted. But their effects are much more formidable in those climates near the tropics, where they are often found to break in upon the steady course of the trade-winds, and to mark their passage with destruction. With us the tempest is but rarely known, and its ravages are registered as an uncommon calamity; but in the countries that lie between the tropics, and for a good space beyond them, its visits are frequent, and its effects are anticipated. In these regions the winds vary their terrors; sometimes involving all thing in a suffocating heat; sometimes mixing all the elements of fire, air, earth, and water, together; sometimes, with a momentary swiftness, passing over the face of the country, and destroying all things in their passage; and sometimes raising whole sandy deserts in one country, to deposite them upon some other. We have little reason, therefore, to envy these climates the luxuriance of their soil, or the brightness of their skies. Our own muddy atmosphere, that wraps us round in obscurity, though it fails to gild our prospects with sunshine, or our groves with fruitage, nevertheless answers the call of industry. They may boast of a plentiful, but precarious, harvest; while with us, the labourer toils in a certain expectation of a moderate, but a happy, return.

In Egypt,[2] a kingdom so noted for its fertility, and the brightness of its atmosphere, during summer, the south winds are so hot, that they almost stop respiration; besides which, they are charged with such quantities of sand, that they sometimes darken the air as with a thick cloud.*

2 Buffon, vol. ii. p. 258.

* The most destructive wind of Egypt is what is called the *Kamsin*, which generally prevails in March, April, and May. Denon thus describes it: "The Kamsin is equally terrible by the frightful spectacle which it exhibits when present, and by the consequences which follow its ravages. We had already passed with security one half of the season in which it usually

These sands are so fine, and driven with such violence, that they penetrate every where, even into chests, be they shut never so closely. If these winds happen to continue for any length of time, they produce epidemic diseases, and are often followed by a great mortality. It is also found to rain but very seldom in that country: however, the want of showers is richly compensated by the copiousness of their dews, which greatly tend to promote vegetation.

In Persia, the winter begins in November, and continues till March. The cold at that time is intense enough to congeal the water; and snow falls in abundance upon their mountains.

appears: when, in the evening of the 18th of May, I felt myself entirely overcome by a suffocating heat; it seemed as if the fluctuation of the air was suddenly suspended. I was struck on my arrival with my companions at the bank of the Nile, with a new appearance of Nature all around me; this was a kind of light and colours which I had not before seen. The sun, without being concealed, had lost its rays; it had even less lustre to the eye than the moon, and gave a pale light without shade; the waters of the Nile no longer reflected its rays, but appeared in agitation; every thing had changed its usual aspect; it was now the flat shore that seemed luminous, and the air dull and opaque; the yellow horizon showed the trees on its surface of a dirty blue; flocks of birds were flying off before the cloud: and frighted animals ran loose in the country, followed by the inhabitants, who vainly attempted to collect them together again. We could now easily conceive the dreadful situation of those who are surprised with such a phenomenon of nature, when crossing the exposed and naked deserts; where, as it stands upon record, many thousands have been overwhelmed and lost in the shoals of sand raised by the Kamsin winds. The next day an astonishing mass of dust, attended with similar appearances, travelled along the desert of Libya: it followed the chain of the mountains, and when we flattered ourselves that we were entirely rid of this pestilence, the west wind brought it back, and once more overwhelmed us with this scorching torrent; the light of the sun could pierce with difficulty through this dense vapour; all the elements appeared to be in disorder; rain was mixed with whirlwinds of fire, wind, and dust, and, in this time of confusion, the trees, and all the other productions of nature, seemed to be again plunged in the horrors of chaos. If the desert of Liyba had sent us these clouds of dust, those on the east, on the contrary, had been inundated with water; for the merchants who came from the borders of the Red Sea, told us, that in the valleys, they had the water up to the middle of their legs. When this destructive scourge sets in from the desert, the inundation of sand often overwhelms the country, changes its fertility to barrenness, drives the labourer from his house, whose walls it covers up, and leaves no other mark of vegetable life but the tops of a few palm-trees, which adds still more to the dreary aspect of destruction. Thus the desert is constantly encroaching on the fertile land; and, were the waters of the Nile to discontinue its inundations, the whole vale of Egypt would eventually become a desert or bed of sand."

During the months of March and April, winds arise, that blow with great force, and seem to usher in the heats of summer. These return again, in autumn, with some violence; without, however, producing any dreadful effects. But during their summer, all along the coasts of the Persian Gulf, a very dangerous wind prevails, which the natives call the *Sameyel,* still more dreadful and burning than that of Egypt, and attended with instant and fatal effects. This terrible blast, which was, perhaps, the pestilence of the ancients, instantly kills all those that it involves in its passage. What its malignity consists in, none can tell, as none have ever survived its effects, to give information.* It frequently, as I am told, assumes a visible form, and darts, in a kind of bluish vapour, along the surface of the country. The natives, not only of Persia, but of Arabia, talk of its effects with terror; and their poets have not failed to heighten them with the assistance of imagination. They have described it as under the conduct of a minister of vengeance, who governs its terrors, and raises or depresses it, as he thinks proper.[2] These deadly winds are also known along the coasts of India, at Negapatam, Masulipatam, and Petapoli. But, luckily for mankind, the shortness of their duration diminishes the injuries that might ensue from their malignity.

The Cape of Good Hope, as well as many islands in the West-Indies, are famous for their hurricanes, and that extraordinary kind of cloud which is said to produce them. This cloud, which is the forerunner of an approaching hurricane, appears, when first seen, like a small black spot, on the verge of the horizon; and is called, by sailors, *the bull's eye,* from being seen so minute at a vast distance.† All this time a perfect calm reigns over the sea and land, while the cloud grows gradually broader as it approaches. At length, coming to the place where its fury is to fall, it invests the whole horizon with darkness.

* It is said of this wind, that if it happens to meet with a shower of rain in its course, and blows across it, it is at once deprived of its noxious quality, and becomes mild and innocent. It is also said, that it was never known to pass the walls of a city. Its fatal effects probably proceed from a certain portion of extremely putrid vapours with which it is charged, by blowing over some very putrid and stagnant lake.

2 Herbelot, Bibliotheque Oriental.

† The *water spout* or *syphon,* is a no less dangerous phenomenon. An account of it will be found in the succeeding chapter.

During all the time of its approach, a hollow murmur is heard in the cavities of the mountains; and beasts and animals, sensible of its approach, are seen running over the fields, to seek for shelter. Nothing can be more terrible than its violence when it begins. The houses in those countries, which are made of timber, the better to resist its fury, bend to the blast like osiers, and again recover their rectitude. The sun, which but a moment before blazed with meridian splendour, is totally shut out; and a midnight darkness prevails, except that the air is incessantly illuminated with gleams of lightning, by which one can easily see to read. The rain falls, at the same time, in torrents; and its descent has been resembled to what pours from the spouts of our houses after a violent shower. These hurricanes are not less offensive to the sense of smelling also, and never come without leaving the most noisome stench behind them. If the seamen also lay by their wet clothes, for twenty-four hours, they are all found swarming with little white maggots, that were brought with the hurricane. Our first mariners, when they visited these regions, were ignorant of its effects, and the signs of its approach; their ships, therefore, were dashed to the bottom at the first onset; and numberless were the wrecks which the hurricane occasioned. But, at present, being forewarned of its approach, they strip their masts of all their sails, and thus patiently abide its fury. These hurricanes are common in all the tropical climates. On the coasts of Guinea they have frequently three or four in a day, that thus shut out the heavens for a little space; and, when past, leave all again in former splendour. They chiefly prevail, on that coast, in the intervals of the trade-winds; the approach of which clears the air of its meteors, and gives these mortal showers that little degree of wholesomeness which they possess. They chiefly obtain there during the months of April and May; they are known, at Loango, from January to April; on the opposite coast of Africa, the hurricane season begins in May; and, in general, whenever a trade-wind begins to cease, these irregular tempests are found to exert their fury.

All this is terrible:—but there is a tempest known in those climates, more formidable than any we have hitherto been describing, which is called, by the Spaniards, a *Tornado.* As the former was seen arriving from one part of the heavens, this making a line of destruction; so the winds in this seem to blow from every quarter, and settle upon one destined place, with such fury, that nothing can resist their vehemence. When they have all met, in their central spot, then the whirlwind begins with circular rapidity. The sphere every moment widens, as it continues to turn, and catches every object that lies within its attraction. This also, like the former, is preceded by a flattering calm; the air is every where hushed, and the sea is as smooth as polished glass: however, as its effects are more dreadful than those of the ordinary hurricane, the mariner tries all the power of his skill to avoid it; which, if he fails of doing, there is the greatest danger of his going to the bottom. All along the coasts of Guinea, beginning about two degrees north of the Line, and so downward, lengthwise, for about a thousand miles, and as many broad, the ocean is unnavigable, on account of these tornadoes. In this torrid region there reigns unceasing tornadoes, or continual calms; among which, whatever ship is so unhappy as to fall, is totally deprived of all power of escaping. In this dreadful repose of all the elements, the solitary vessel is obliged to continue, without a single breeze to assist the mariner's wishes, except those whirlwinds, which only serve to increase his calamity. At present, therefore, this part of the ocean is totally avoided; and, although there may be much gold along the coasts of that part of Africa, to tempt avarice, yet there is something, much more dreadful than the fabled dragon of antiquity, to guard the treasure. As the internal parts of that country are totally unknown to travellers, from their burning sand and extensive deserts; so here we find a vast tract of ocean, lying off its shores, equally unvisited by the mariner.

But of all these terrible tempests that deform the face of nature, and repress human presumption, the sandy tempests of Arabia and Africa are the most terrible,* and strike the imagi-

* In his travels to discover the source of the Nile, Mr Bruce observed the astonishing phenomenon of moving pillars of sand, which are probably the effects of a number of whirlwinds in those torrid regions. In relating the particulars of his journey across a part of the deserts of Africa, he observes, "We were here at once surprised and terrified with a sight surely one of the most magnificent in the world. In that vast expanse of desert, from west and to the north-west of us, we saw a number of prodigious pillars of sand at different distances, at times moving with great celerity, and at others stalking on with a majestic slowness; at intervals we thought they

nation most strongly. To conceive a proper idea of these, we are by no means to suppose them resembling those whirlwinds of dust that we sometimes see scattering in our air, and sprinkling their contents upon our roads or meadows. The sand-

were coming in a very few minutes to overwhelm us; and small quantities of sand did actually more than once reach us. Again they would retreat, so as to be almost out of sight, their tops reaching to the very clouds. There the tops often separated from the bodies, and these once disjoined, dispersed in the air, and did not appear more. Sometimes they were broken near the middle, as if struck with a large cannon shot: about noon they began to advance with considerable swiftness upon us, the wind being very strong at north. Eleven of them ranged alongside of us, about the distance of three miles. The greatest diameter of the largest appeared to me at that distance as if it would measure ten feet. They retired from us with a wind at south-east, leaving an impression upon my mind to which I can give no name, though surely one ingredient in it was fear, with a considerable deal of wonder and astonishment. It was in vain to think of flying; the swiftest horse, or fastest sailing ship could be of no use to carry us out of this danger; and the full persuasion of this rivetted me as if to the spot where I stood, and let the camels gain on me so much in my state of lameness, that it was with some difficulty I could overtake them. The same phenomenon occurred again in the course of a few days. The same appearance of moving pillars of sand presented themselves to us this day, in form and disposition like those we had seen at Waadi Halboub, only they seemed to be more in number and less in size. They came several times in a direction close upon us; that is, I believe within less than two miles. They began immediately after sun-rise like a thick wood, and almost darkened the sun; his rays shining through them for near an hour, gave them an appearance of pillars of fire. Our people now became desperate, the Greeks shrieked out, and said it was the day of judgment. Ismael pronounced it to be hell, and the Tucorories that the world was on fire. I asked Idris if ever he had before seen such a sight? He said he had often seen them as terrible, though never worse; but what he feared most was the extreme redness of the air, which was a sure presage of the coming of the simoom. I begged and entreated Idris that he would not say one word of that in the hearing of the people, for they had already felt it at Imhansara, on their way from Ras el Feel to Teawa, and again at the Acaba of Gerri, before we came to Chendi, and they were already nearly distracted at the apprehension of finding it here.

On the 16th, at half-past ten in the forenoon, we left El Mout, standing in the direction close upon Syene. At eleven o'clock, while we contemplated with pleasure the rugged top of Chiggne, to which we were fast approaching, and where we were to solace ourselves with plenty of good water, Idris cried out with a loud voice, Fall upon your faces, for here is the simoom. I saw from the south-east a haze come, in colour like the purple part of the rainbow, but not so compressed or thick. It did not occupy twenty yards in breadth, and was about twelve feet high from the ground. It was a kind of blush upon the air, and it moved very rapidly, for I scarce could turn to fall upon the ground with my head to the northward, when I felt the heat of its current plainly upon my face. We all lay flat upon the ground, till Idris told storm of Africa exhibits a very different appearance. As the sand of which the whirlwind is composed is excessively fine, and almost resembles the parts of water, its motion entirely resembles that of a fluid; and the whole plain seems to float onward, like a slow inundation. The body of sand thus rolling, is deep enough to bury houses and palaces in its bosom: travellers who are crossing those extensive deserts perceive its approach at a distance; and in general have time to avoid it, or turn out of its way, as it generally extends but to a moderate breadth. However, when it is extremely rapid, or very extensive, as sometimes is the case, no swiftness, no art, can avail; nothing then remains but to meet death with fortitude, and submit to be buried alive with resignation.

It is happy for us of Britain that we have no such calamity to fear:* for from this even some parts of Europe are not entirely

us it was blown over. The meteor or purple haze which I saw, was indeed past, but the light air that still blew was of heat to threaten suffocation. For my part, I found distinctly in my breast that I had imbibed a part of it; nor was I free of an asthmatic sensation till I had been some months in Italy, at the baths of Poretta, near two years afterwards.

* One of the most dreadful storms which this island ever experienced was that which took place on the 27th Nov. 1703. This tempest was preceded by a strong west wind which set in about the middle of the month; and every day, and almost every hour, increased in force until the 24th, when it blew furiously, occasioned much alarm, and some damage was sustained. On the 25th, and through the night following, it continued with unusual violence. On the morning of Friday, the 26th, it raged so fearfully that only few people had courage to venture aboad. Towards evening it rose still higher; the night setting in with excessive darkness added general horror to the scene, and prevented any from seeking security abroad from their homes, had that been possible. The extraordinary power of the wind created a noise, hoarse and dreadful, like thunder, which carried terror to every ear, and appalled every heart. There were also appearances in the heavens that resembled lightning. "The air," says a writer at the time, "was full of meteors and fiery vapours; yet," he adds, "I am of opinion, that there was really no lightning, in the common acceptation of the term; for the clouds, that flew with such violence through the air, were not to my observation such as are usually freighted with thunder and lightning; the hurries nature was then in, do not consist with the system of thunder." Some imagined the tempest was accompanied with an earthquake. "Horror and confusion seized upon all, whether on shore or at sea: no pen can describe it, no tongue can express it, no though can conceive it, unless theirs who were in the extremity of it; and who, being touched with a due sense of the sparing mercy of their Maker, retain the deep impressions of his goodness upon their minds though the danger be past. To venture abroad was to rush into instant death, and to stay within afforded no other prospect than that of being buried under the ruins of a falling habi-

free. We have an account given us in the history of the French Academy, of a miserable town in France, that is constantly in danger of being buried under a similar inundation; with which I will take leave to close this chapter. "In the neighbourhood of St

tation. Some in their distraction did the former, and met death in the streets; others the latter, and in their own houses received their final doom." One hundred and twenty-three persons were killed by the falling of dwellings; amongst these were the bishop of Bath and Wells (Dr Richard Kidder) and his lady, by the fall of part of the episcopal palace of Wells: and lady Penelope Nicholas, sister to the bishop of London, at Horsley, in Sussex. Those who perished in the waters, in the floods of the Severn and the Thames on the coast of Holland, and in ships blown away and never heard of afterwards, are computed to have amounted to eight thousand.

All ranks and degrees were affected by this amazing tempest, for every family that had any thing to lose lost something: land, houses, churches, corn, trees, rivers, all were disturbed or damaged by its fury; small buildings were for the most part wholly swept away, "as chaff before the wind." Above eight hundred dwelling-houses were laid in ruins. Few of those that resisted escaped from being unroofed, which is clear from the prodigious increase in the price of tiles, which rose from twenty-one shillings to six pounds the thousand. About two thousand stacks of chimneys were blown down in and about London. When the day broke, the houses were mostly stripped, and appeared like so many skeletons. The consternation was so great that trade and business were suspended, for the first occupation of the mind was so to repair the houses, that families might be preserved from the inclemency of the weather in the rigorous season. The streets were covered with brickbats, broken tiles, signs, bulks, and pent-houses.

The lead which covered one hundred churches, and many public buildings, was rolled up, and hurled in prodigious quantities to distances almost incredible; spires, and turrets of many others were thrown down. Innumerable stacks of corn and hay were blown away, or so torn and scattered as to receive great damage.

Multitudes of cattle were lost. In one level in Gloucestershire, on the banks of the Severn, fifteen thousand sheep were drowned. Innumerable trees were torn up by the roots; one writer says, that he himself numbered seventeen thousand in part of the county of Kent alone, and that, tired with counting, he left off reckoning.

The damage in the city of London alone, was computed at near two millions sterling. At Bristol, it was about two hundred thousand pounds. In the whole, it was supposed, that the loss was greater than that produced by the great fire of London, 1666, which was estimated at four millions.

The greater part of the navy was at sea, and if the storm had not been at its height at full flood, and in a spring-tide, the loss might have been nearly fatal to the nation. It was so considerable, that fifteen or sixteen men of war were cast away, and more than two thousand seamen perished. Few merchantmen were lost: for most of those that were driven to sea were safe Rear-admiral Beaumont, with a squadron then lying in the Downs, perished with his own and several other ships on the Goodwin Sands.

The ships lost by the storm were estimated at three hundred. In the river

Paul de Leon, in Lower Brittany,[1] there lies a tract of country along the sea-side, which, before the year 1666, was inhabited, but now lies deserted, by reason of the sands which cover it, to the height of twenty feet; and which every year advance more and

Thames, only four ships remained between London-bridge and Limehouse, the rest being driven below, and lying there miserably beating against one another. Five hundred wherries, three hundred ship-boats, and one hundred lighters and barges were entirely lost; and a much greater number received considerable damage. The wind blew from the western seas, which preventing many ships from putting to sea, and driving others into harbour, occasioned great numbers to escape destruction.

The Eddystone lighthouse near Plymouth was precipitated in the surrounding ocean, and with it Mr Winstanley, the ingenious architect by whom it was contrived, and the people who were with him.—"Having been frequently told that the edifice was too slight to withstand the fury of the winds and waves, he was accustomed to reply contemptuously, that he only wished to be in it when a storm should happen. Unfortunately his desire was gratified. Signals of distress were made, but in so tremendous a sea no vessel could live, or would venture to put off for their relief."*

The amazing strength and rapidity of the wind, are evidenced by the following well authenticated circumstances. Near Shaftesbury a stone of near four hundred pounds weight, which had lain for some years fixed in the ground, fenced by a bank with a low stone wall upon it, was lifted up by the wind, and carried into a hollow way, distant at least seven yards from the place. This is mentioned in a sermon preached by Dr Samuel Stennett in 1788. Dr Andrew Gifford, in a sermon preached at Little Wylde-street, on the 27th of November, 1734, says, that "in a country town, a large stable was at once removed off its foundation, and instantly carried quite across the highway, over the heads of five horses and the man that was then feeding them, without hurting any one of them, or removing the rack and manger, both of which remained for a considerable time to the admiration of every beholder." Dr Gifford, in the same sermon, gives an account of "several remarkable deliverances." One of the most remarkable instances of this kind occurred at a house in the Strand, in which were no less than fourteen persons: "Four of them fell with a great part of the house, &c. three stories, and several two: and though buried in the ruins, were taken out unhurt; of these, three were children; one that lay by itself, in a little bed near its nurse; another in a cradle; and the third was found hanging (as it were wrapp'd up) in some curtains that hitch'd by the way; neither of whom received the least damage. In another place, as a minister was crossing a court near his house, a stone from the top of a chimney, upwards of one hundred and forty pounds weight, fell close to his heels, and cut between his footsteps four inches deep into the ground. Soon after, upon drawing in his arm, which he had held out on some occasion, another stone, of near the same weight and size, brushed by his elbow, and fell close to his foot, which must necessarily, in the eye of reason, have killed him, had it fallen while it was

1 Histoire de l'Academie des Sciences, an. 1722.

* Belsham's Hist. of G. Britain.

more inland, and gain ground continually. From the time mentioned above, the sand has buried more than six leagues of the country inward; and it is now but half a league from the town of St Paul: so that, in all appearance, the inhabitants must be obliged to abandon it entirely. In the country that has been overwhelmed, there are still to be seen the tops of some steeples peeping through the sand, and many chimneys that still remain above this sandy ocean. The inhabitants, however, had sufficient time to escape; but being deprived of their little

extended." In the Poultry, where two boys were lying in a garret, a huge stack of chimneys fell in, which making its way through that and all the other floors to the cellar, it was followed by the bed with the boys asleep in it, who first awaked in that gloomy place of confusion without the least hurt.

So awful a visitation produced serious impressions on the government, and a day of fasting and humiliation was appointed by authority. The introductory part of the proclamation, issued by queen Anne for that purpose, claims attention from its solemn import.

"WHEREAS, by the late most terrible and dreadful storms of wind, with which it hath pleased Almighty God to afflict the greatest part of this our kingdom, on Friday and Saturday, the twenty-sixth and twenty-seventh days of November last, some of our ships of war, and many ships of our loving subjects, have been destroyed and lost at sea, and great numbers of our subjects serving on board the same have perished, and many houses and other buildings of our good subjects have been either wholly thrown down and demolished or very much damnified and defaced, and thereby several persons have been killed, and many stacks of corn and hay thrown down and scattered abroad, to the great damage and impoverishment of many others, especially the poorer sort, and great numbers of timber and other trees have by the said storm been torn up by the roots in many parts of this our kingdom: a calamity of this sort so dreadful and astonishing, that the like hath not been seen or felt in the memory of any person living in this our kingdom, and which loudly calls for the deepest and most solemn humiliation of us and our people: therefore out of a deep and pious sense of what we and all our people have suffered by the said dreadful wind and storms, (which we most humbly acknowledge to be a token of the divine displeasure, and that it was the infinite mercy of God that we and our people were not thereby wholly destroyed,) We have resolved, and do hereby command, that a General Public Fast be observed," &c.

This public fast was accordingly observed, throughout England, on the nineteenth of January following, with great seriousness and devotion, by all orders and denominations. The protestant dissenters, notwithstanding their objections to the interference of the civil magistrate in matters of religion, deeming this to be an occasion wherein they might unite with their countrymen in openly bewailing the general calamity, rendered the supplication universal, by opening their places of worship; and every church and meeting-house was crowded.

all they had no other resource but begging for their subsistence. This calamity chiefly owes its advancement to a north or an east wind, raising the sand, which is extremely fine, in such great quantities, and with such velocity, that M. Deslands, who gave the account, says, that while he was walking near the place, during a moderate breeze of wind, he was obliged, from time to time, to shake the sand from his clothes and his hat, on which it was lodged in great quantities, and made them too heavy to be easily borne. Still further, when the wind was violent it drove the sand across a little arm of the sea, into the town of Roscoff, and covered the streets of that place two feet deep; so that they have been obliged to carry it off in carts. It may also be observed, that there are several particles of iron mixed with the sand, which are readily affected by the loadstone. The part of the coast that furnishes these sands is a tract of about four leagues in length, and is upon a level with the sea at high-water. The shore lies in such a manner as to leave its sands subject only to the north and east winds, that bear them farther up the shore. It is easy to conceive how the same sand that has at one time been borne a short way inland, may by some succeeding and stronger blast be carried up much higher; and thus the whole may continue advancing forward, deluging the plain, and totally destroying its fertility. At the same time the sea, from whence this deluge of sand proceeds, may furnish it in inexhaustible quantities. This unhappy country, thus overwhelmed in so singular a manner, may well justify what the ancients and the moderns have reported concerning those tempests of sand in Africa, that are said to destroy villages, and even armies, in their bosom."*

* In Sicily a wind is known by the name of the *Sirocco*, so called because it is supposed to blow from Syria. Its medium heat is calculated at 112 degrees: it is fatal to vegetation, and destructive to mankind, and especially to strangers; it depresses the spirits in an unusual degree; it suspends the powers of digestion, so that those who venture to eat a heavy supper, while this wind prevails, are commonly found dead in their beds the next morning, of what is called an indigestion. The sick at that afflicting period commonly sink under the pressure of their diseases; and it is customary in the morning, after this wind has continued a whole night, to inquire who is dead.

CHAP. XXI.

OF METEORS AND SUCH APPEARANCES AS RESULT FROM A COMBINATION OF THE ELEMENTS.

In proportion as the substances of nature are more compounded and combined, their appearances become more inexplicable and amazing. The properties of water have been very nearly ascertained. Many of the qualities of air, earth, and fire, have been discovered and estimated; but when these come to be united by nature, they often produce a result which no artificial combinations can imitate; and we stand surprised, that although we are possessed of all those substances which nature makes use of, she shows herself a much more various operator than the most skilful chemist ever appeared to be. Every cloud that moves, and every shower that falls, serves to mortify the philosopher's pride, and to show him hidden qualities in air and water, that he finds it difficult to explain. Dews, hail, snow, and thunder, are not less difficult for being more common. Indeed, when we reflect on the manner in which nature performs any one of these operations, our wonder increases. To see water, which is heavier than air, rising in air, and then falling in a form so very different from that in which it rose; to see the same fluid at one time descending in the form of hail, at another in that of snow; to see two clouds, by dashing against each other, producing an electrical fire, which no watery composition that we know of can effect; these, I say, serve sufficiently to excite our wonder; and still the more in proportion as the objects are ever pressing on our curiosity. Much, however, has been written concerning the manner in which nature operates in these productions; as nothing is so ungrateful to mankind as hopeless ignorance.

And first, with regard to the manner in which water evaporates, and rises to form clouds, much has been advanced, and many theories devised.* All water,[1] say some, has a quantity

* See Note upon Evaporation, at page 139.

1 Spectacle de la Nature, vol. ii.

of air mixed with it; and the heat of the sun, darting down, disengages the particles of this air from the grosser fluid; the sun's rays being reflected back from the water, carry back with them those bubbles of air and water, which, being lighter than the condensed air, will ascend till they meet with a more rarefied air; and they will then stand suspended. Experience, however, proves nothing of all this. Particles of air or fire; are not thus known to ascend with a thin coat of water; and, in fact, we know that the little particles of steam are solid drops of water. But, besides this, water is known to evaporate more powerfully in the severest frost, than when the air is moderately warm.[2] Dr Hamilton, therefore, of the university of Dublin, rejecting this theory, has endeavoured to establish another. According to him, as aqua fortis is a menstruum that dissolves iron, and keeps it mixed in the fluid; as aqua regia is a menstruum that dissolves gold; or as water dissolves salts to a certain quantity, so air is a menstruum that corrodes and dissolves a certain quantity of water, and keeps it suspended above. But however ingenious this may be, it can hardly be admitted: as we know by Mariotte's experiment,[3] that if water and air be inclosed together, instead of the air's acting as a menstruum upon the water, the water will act as a menstruum upon the air, and take it all up. We know also, that of two bodies, that which is most fluid and penetrating, is most likely to be the menstruum of the other; but water is more fluid and penetrating than air, and therefore the most likely of the two to be the menstruum. We know that all bodies are more speedily acted upon, the more their parts are brought into contact with the menstruum that dissolves them; but water inclosed with compressed air, is not the more diminished thereby.[4] In short, we know, that cold, which diminishes the force of other menstruums, is often found to promote evaporation. In this variety of opinion and uncertainty of conjecture, I cannot avoid thinking that a theory of evaporation may be formed upon very simple and obvious principles, and embarrassed, as far as I can conceive, with very few objections.

We know that a repelling power prevails in nature, not less

2 Memoires de l'Academie des Sciences, an. 1705.
3 Mariotte, de la Nature de l'Air, p. 97, 106.
4 See Boyle's Works, vol. ii. p. 619.

than an attractive one. This repulsion prevails strongly between the body of fire and that of water. If I plunge the end of a red-hot bar of iron into a vessel of water, the fluid rises, and large drops of it fly up in all manner of directions, every part bubbling and steaming until the iron be cold. Why may we not for a moment compare the rays of the sun, darted directly upon the surface of the water, to so many bars of red-hot iron, each bar indeed infinitely small, but not the less powerful? In this case, wherever a ray of fire darts, the water, from its repulsive quality, will be driven on all sides; and, of consequence, as in the case of the bar of iron, a part of it will rise. The parts thus rising however, will be extremely small; as the ray that darts is extremely so. The assemblage of the rays darting upon the water in this manner, will cause it to rise in a light thin steam above the surface; and as the parts of the steam are extremely minute, they will be lighter than air, and consequently float upon it. There is no need for supposing them bubbles of water filled with fire; for any substance, even gold itself, will float on air, if its parts be made small enough; or, in other words, if its surface be sufficiently increased. This water, thus disengaged from the general mass, will be still farther attenuated and broken by the reflected rays, and consequently, more adapted for ascending.

From this plain account, every appearance in evaporation may be easily deduced. The quantity of heat increases evaporation, because it raises a greater quantity of steam. The quantity of wind increases evaporation; for, by waving the surface of the water, it thus exposes a greater surface to the evaporating rays. A dry frost, in some measure, assists the quantity of evaporation; as the quantity of rays are found to be no way diminished thereby. Moist weather alone prevents evaporation; for the rays being absorbed, refracted, and broken, by the intervening moisture, before they arrive at the surface, cannot produce the effect; and the vapour will rise in a small proportion.

Thus far we have accounted for the ascent of vapours; but to account for their falling again, is attended with rather more difficulty. We have already observed, that the particles of vapour, disengaged from the surface of the water, will be broken and attenuated in their ascent, by the reflected, and even the direct rays, that happen to strike upon their minute surfaces. They will, therefore, continue to ascend, till they rise above the operation of the reflected rays, which reaches but to a certain height above the surface of the earth. Being arrived at this region, which is cold for want of reflected heat, they will be condensed, and suspended in the form of clouds. Some vapours that ascend to great heights, will be frozen into snow; others, that are condensed lower down, will put on the appearance of a mist, which we find the clouds to be, when we ascend among them, as they hang along the sides of a mountain. These clouds of snow and rain, being blown about by winds, are either entirely scattered and dispersed above, or they are still more condensed by motion, like a snow-ball, that grows more large and solid as it continues to roll. At last, therefore, they will become too weighty for the air which first raised them to sustain; and they will descend with their excesses of weight, either in snow or rain. But as they will fall precipitately, when they begin to descend, the air, in some measure, will resist the falling; for as the descending fluid gathers velocity in its precipitation, the air will increase its resistance to it, and the water will, therefore, be thus broken into rain; as we see, that water which falls from the tops of houses, though it begins in a spout, separates into drops before it has got to the bottom. Were it not for this happy interposition of the air, between us and the water falling from a considerable height above us, a drop of rain might fall with dangerous force, and a hailstone might strike us with fatal rapidity.

In this manner, evaporation is produced by day; but when the sun goes down, a part of that vapour which his rays had excited, being no longer broken and attenuated by the reflecting rays, it will become heavier than the air, even before it has reached the clouds; and it will, therefore, fall back in dews,* which differ only from rain in descending before they have had

* It has been observed with surprise, that when a number of bodies are exposed together to dew, some are quite wetted with it, while others remain dry. This circumstance probably depends upon the goodness of the body as a conductor of heat. Good conductors will part with their heat more readily, and will therefore evaporate the dew again, whereas it will remain upon bad conductors, which will not so easily part with their heat. If this explanation be the true one, it follows that bodies exposed to the dew and dry, must have a lower temperature than those which remain moist.

time to condense into a visible form. Hail, the Cartesians say, is a frozen cloud, half melted, and frozen again in its descent. A hoar-frost is but a frozen dew. Lightning we know to be an electrical flash, produced by the opposition of two clouds; and thunder to be the sound proceeding from the same, continued by an echo reverberated among them. It would be to very little purpose to attempt explaining exactly how these wonders are effected; we have as little insight into the manner in which these meteors are found to operate upon each other; and therefore we must be contented with a detail rather of their effects than their causes.

In our own gentle climate, where nature wears the mildest and kindest aspect, every meteor seems to befriend us. With us, rains fall in refreshing showers, to enliven our fields, and to paint the landscape with a more vivid beauty. Snows cover the earth, to preserve its tender vegetables from the inclemency of the departing winter. The dews descend with such an imperceptible fall as no way injures the constitution. Even thunder is seldom injurious; and it is often wished for by the husbandman to clear the air, and to kill the numberless insects that are noxious to vegetation. Hail is the most injurious meteor that is known in our climate; but it seldom visits us with violence, and then its fury is but transient.

One of the most dreadful storms we hear of,[1] was that of Hertfordshire, in the year 1697. It began by thunder and lightning, which continued for some hours, when suddenly a black cloud came forward, against the wind, and marked its passage with devastation. The hailstones which it poured down, being measured, were found to be many of them fourteen inches round, and consequently as large as a bowling-green ball. Wherever it came, every plantation fell before it; it tore up the ground, split great oaks, and other trees, without number; the fields of rye were cut down, as if levelled with a scythe; wheat, oats, and barley, suffered the same damage. The inhabitants found but a precarious shelter, even in their houses, their tiles and windows being broke by the violence of the hail-stones, which, by the force with which they came, seemed to have descended from a great height. The birds, in this universal wreck, vainly tried

1 Phil. Trans. vol. ii. p. 148.

to escape by flight; pigeons, crows, rooks, and many more of the smaller and feebler kinds were brought down. An unhappy young man, who had not time to take shelter, was killed; one of his eyes was struck out of his head, and his body was all over black with bruises; another had just time to escape, but not without the most imminent danger, his body being bruised all over. But what is most extraordinary, all this fell within the compass of a mile.

Mezeray, in his history of France, tells us of a shower of hail much more terrible, which happened in the year 1510, when the French monarch invaded Italy. There was, for a time, a horrid darkness, thicker than that of midnight, which continued till the terrors of mankind were changed to still more terrible objects, by thunder and lightning breaking the gloom, and bringing on such a shower of hail, as no history of human calamities could equal. These hailstones were of a bluish colour; and some of them weighed not less than a hundred pounds. A noisome vapour of sulphur attended the storm. All the birds and beasts of the country were entirely destroyed. Numbers of the human race suffered the same fate. But what is still more extraordinary, the fishes found no protection from their native element; but were equal sufferers in the general calamity.

These, however, are terrors that are seldom exerted in our mild climates. They only serve to mark the page of history with wonder; and stand as admonitions to mankind, of the various stores of punishment, in the hands of the Deity, which his power can treasure up, and his mercy can suspend.

In the temperate zones, therefore, meteors are rarely found thus terrible; but between the tropics, and near the poles, they assume very dreadful and various appearances. In those inclement regions, where cold and heat exert their chief power, meteors seem peculiarly to have fixed their residence. They are seen there in a thousand terrifying forms, astonishing to Europeans, yet disregarded by the natives, from their frequency. The wonders of air, fire, and water, are there combined, to produce the most tremendous effects; and to sport with the labour and apprehensions of mankind. Lightnings, that flash without noise; hurricanes, that tear up the earth; clouds, that all at once pour down their contents, and produce an instant deluge; mock suns; northern lights, that illuminate half the hemisphere;

circular rainbows; halos; fleeting balls of fire; clouds reflecting back the images of things on earth, like mirrors; and water-spouts, that burst from the sea, to join with the mists that hang immediately above them. These are but a part of the phenomena that are common in those countries; and from many of which our own climate is, in a great measure, exempted.

The meteors of the torrid zone are different from those that are found near the polar circles; and it may readily be supposed, that in those countries where the sun exerts the greatest force in raising vapours of all kinds, there should be the greatest quantity of meteors. Upon the approach of the winter months, as they are called under the Line, which usually begin about May, the sky, from a fiery brightness, begins to be overcast, and the whole horizon seems wrapt in a muddy cloud. Mists and vapours still continue to rise; and the air, which so lately before was clear and elastic, now becomes humid, obscure, and stifling; the fogs become so thick, that the light of the sun seems in a manner excluded; nor would its presence be known but for the intense and suffocating heat of its beams, which dart through the gloom, and instead of dissipating only serve to increase the mist. After this preparation, there follows an almost continual succession of thunder, rain, and tempests. During this dreadful season, the streets of cities flow like rivers; and the whole country wears the appearance of an ocean. The inhabitants often make use of this opportunity to lay in a stock of fresh water for the rest of the year; as the same cause, which pours down the deluge at one season, denies the kindly shower at another. The thunder which attends the fall of these rains is much more terrible than that we are generally acquainted with. With us, the flash is seen at some distance, and the noise shortly after ensues; our thunder generally rolls in one quarter of the sky, and one stroke pursues another. But here it is otherwise; the whole sky seems illuminated with unremitted flashes of lightning; every part of the air seems productive of its own thunders; and every cloud produces its own shock. The strokes come so thick, that the inhabitants can scarcely mark the intervals; but all is one unremitted roar of elementary confusion. It should seem, however, that the lightning of those countries is not so fatal or so dangerous as with us; since in this case the torrid zone would be uninhabitable.

When these terrors have ceased, with which, however, the natives are familiar, meteors of another kind begin to make their appearance. The intense beams of the sun darting upon stagnant waters, that generally cover the surface of the country, raise vapours of various kinds. Floating bodies of fire, which assume different names, rather from their accidental forms than from any real difference between them, are seen without surprise. The *draco volans*, or flying dragon, as it is called; the *ignis fatuus*,* or wan-

* The *ignis fatuus*, or will-o'-the-wisp, most philosophers are agreed, is caused by some volatile vapour of the phosphoric kind, probably the phosphoric hydrogen gas. The light from putrescent substances, particularly putrid fish, and those sparks emitted from the sea, or sea-water when agitated in the dark, correspond in appearance with this meteor. Sir Isaac Newton defines the *ignis fatuus* to be "a vapour shining without heat," and it is usually visible in damp places, about dunghills, burying-grounds, and other situations which are likely to abound in phosphoric matter. A remarkable *ignis fatuus* was observed by Mr Derham, in some boggy ground between two rocky hills. He was so fortunate as to be able to approach it within two or three yards. It moved with a brisk and desultory motion about a dead thistle, till a slight agitation of the air occasioned, as he supposed, by his near approach to it, caused it to jump to another place; and as he approached, it kept flying before him. He was near enough to satisfy himself that it could not be the shining of glow-worms or other insects—it was one uniform body of light. M. Beccaria mentions two of these luminous appearances, which were frequently observed in the neighbourhood of Bologna, and which emitted a light equal to that of an ordinary faggot. Their motions were unequal, sometimes rising, and sometimes sinking towards the earth; sometimes totally disappearing, though in general they continued hovering about six feet from the ground. They differed in size and figure; and indeed the form of each was fluctuating, sometimes floating like waves and dropping sparks of fire. He was assured that there was not a dark night in the whole year in which they did not appear; nor was their appearance at all effected by the weather, whether cold or hot, snow or rain. They have been known to change their colour from red to yellow; and generally grew fainter as any person approached, vanishing entirely when the observer came very near to them, and appearing again at some distance. Dr Shaw also describes a singular *ignis fatuus*, which he saw in the Holy Land. It was sometimes globular, or in the form of a flame of a candle; and immediately afterwards spread itself so much as to involve the whole company in a pale inoffensive light, and then was observed to contract itself again, and suddenly disappear. In less than a minute, however, it would become visible as before, and run along from one place to another: or would expand itself over more than three acres of the adjacent mountains. The atmosphere at this time, he adds, was thick and hazy. In a superstitious age we cannot wonder that these phenomena have all been attributed to supernatural agency; it is one of the noblest purposes of philosophy to release the mind from the bondage of imaginary terrors; and by explaining the modes in which

dering fire; the *fires of St Helmo*, or the mariner's light; are everywhere frequent: and of these we have numberless descriptions. "As I was riding in Jamaica," says Mr Barbham, "one morning from my habitation, situated about three miles north-west from Jago de la Vega, I saw a ball of fire, appearing to me of the bigness of a bomb, swiftly falling down with a great blaze. At first I thought it fell into the town; but when I came nearer, I saw many people gathered together, a little to the southward, in the savanna, to whom I rode up, to inquire the cause of their meeting: they were admiring, as I found, the ground's being strangely broke up and ploughed by a ball of fire; which, as they said, fell down there. I observed there were many holes in the ground; one in the middle, of the bigness of a man's head, and five or six smaller round about it, of the bigness of one's fist, and so deep as not to be fathomed by such implements as were at hand. It was observed, also, that all the green herbage was burned up, near the holes; and there continued a strong smell of sulphur near the place, for some time after."

Ulloa gives an account of one of a similar kind, at Quito.[1] "About nine at night," says he, "a globe of fire appeared to rise from the side of the mountain Pichinca, and so large, that it spread a light over all the part of the city facing that mountain. The house where I lodged looking that way, I was surprised with an extraordinary light, darting through the crevices of the window-shutters. On this appearance, and the bustle of the people in the street, I hastened to the window, and came in time enough to see it, in the middle of its career; which continued from west to south, till I lost sight of it, being intercepted by a mountain, that lay between me and it. It was round; and its apparent diameter about a foot. I observed it to rise from the sides of Pichinca; although, to judge from its course, it was behind that mountain where this congeries of inflammable matter was kindled. In the first half of its visible course, it emitted a prodigious effulgence, then it began gradually to grow

the Divine Providence disposes the different powers of nature, to elevate our thoughts to *one* First Cause; to teach us to see, "God in all, and all in God."

1 Ulloa, vol. i. p. 41.

dim; so that, upon its disappearing behind the intervening mountain, its light was very faint."

Meteors of this kind are very frequently seen between the tropics; but they sometimes, also, visit the more temperate regions of Europe. We have the description of a very extraordinary one, given us by Montanari, that serves to show to what great heights, in our atmosphere, these vapours are found to ascend. In the year 1676, a great globe of fire was seen at Bononia, in Italy, about three quarters of an hour after sun-set. It passed westward, with a most rapid course, and at the rate of not less than a hundred and sixty miles in a minute, which is much swifter than the force of a cannon-ball, and at last stood over the Adriatic sea. In its course it crossed over all Italy; and, by computation, it could not have been less than thirty-eight miles above the surface of the earth. In the whole line of its course, wherever it approached, the inhabitants below could distinctly hear it, with a hissing noise, resembling that of a firework. Having passed away to sea, towards Corsica, it was heard, at last, to go off with a most violent explosion, much louder than that of a cannon: and, immediately after, another noise was heard, like the rattling of a great cart upon a stony pavement; which was, probably, nothing more than the echo of the former sound. Its magnitude, when at Bononia, appeared twice as long as the moon, one way, and as broad the other; so that, considering its height, it could not have been less than a mile long, and half a mile broad. From the height at which this was seen, and there being no volcano on that quarter of the world from whence it came, it is more than probable that this terrible globe was kindled on some part of the contrary side of the globe, in those regions of vapours which we have been just describing; and thus, rising above the air, and passing in a course opposite to that of the earth's motion, in this manner it acquired its amazing rapidity.*

* Nothing can be a more complete proof of the imperfect state of the science of meteorology, than the discovery of facts, for which not even a conjectural cause in the smallest degree probable can be assigned. Luminous bodies called *meteors*, *fire-balls*, &c. have in all ages been observed in the atmosphere, and many of them have been described by eye-witnesses. One of the most remarkable of these was the meteor which appeared in 1783. It was very luminous, and its diameter could not be less than 1000 yards. It tra-

To these meteors, common enough southward, we will add one more of a very uncommon kind, which was seen by Ulloa, at Quito, in Peru; the beauty of which will, in some measure, serve to relieve us, after the description of those hideous ones

versed Britain and a considerable part of the continent of Europe with very great velocity, and at the height of nearly 60 miles from the surface of the earth. Almost all the meteors observed resembled each other. They were luminous at a great height, moved very swiftly, and disappeared in a very short time. Their disappearance was usually accompanied by a loud explosion like a clap of thunder; and it was almost constantly affirmed, that heavy stony bodies fell from them to the earth. But though several well authenticated accounts of the fall of such stones had been from time to time published, little credit was given to them; nor did they indeed attract the attention of philosophers, till Dr Chladni published a dissertation on the subject in 1794. Two years after, Mr King published a still more complete collection of examples, both ancient and modern; many of them supported by such evidence that it was impossible to reject it. These two dissertations excited considerable attention: but the opinion, that stones had really fallen from the atmosphere, was considered as so extraordinary, and so contrary to what we know of the constitution of the air, that most people hesitated or refused their assent. Meanwhile Mr Howard took a different method of investigating the subject. He not only collected all the recent and well authenticated accounts of the fall of stony bodies, and examined the evidence of their truth, but procured specimens of the stones which were said to have fallen in different places, compared them together, and subjected them to a chemical analysis. The result was, that all these stony bodies differ completely from every other known stone; that they all resemble each other, and that they are all composed of the same ingredients, although found in climates and in soils exceedingly different from each other. The stones when they fall are always hot. They commonly bury themselves some depth under ground. Their size differs from a few ounces to several tons. They are usually roundish, and always covered with a black crust. In many cases they smell strongly of sulphur. The black crust, from the analysis of Howard, consists chiefly of iron. The outer surface of these stones is rough. When broken, they appear of an ash-grey colour, and of a granular texture like a coarse sandstone. The metals found in them are iron, nickel, chromium, and cobalt. Now these constitute the whole of the magnetic metals. Various attempts have been made to account for their appearance. But such is the obscurity of the subject, so little progress have we made in the science of meteorology, that no opinion in the slightest degree probable has hitherto been advanced. It was first supposed that the bodies in question had been thrown out of volcanoes; but the immense distance from all volcanoes at which they have been found, and the absence of all similar stones from volcanic productions, render this opinion untenable. Chladni endeavoured to prove that the meteors from which they fell were bodies floating in space, unconnected with any planetary system, attracted by the earth in their progress, and kindled by their rapid motion through the atmosphere. But this opinion is not susceptible of any direct evidence, and can scarcely be believed, one would think, preceding. "At day break," says he, "the whole mountain of Pambamarca, where we then resided, was encompassed with very thick clouds; which the rising of the sun dispersed so far, as to leave only some vapours, too fine to be seen. On the side opposite to the rising sun, and about ten fathoms distant from the place where we were standing, we saw, as in a looking-glass, each his own image; the head being, as it were, the centre of three circular rainbows, one without the other, and just near enough to each other as that the colours of the internal verged upon those more external; while round all was a circle of white, but with a greater space between. In this manner these circles were erected, like a mirror, before us; and as we moved, they moved, in disposition and order. But, what is most remarkable, though we were six in number, every one saw the phenomenon with regard to himself, and not that relating to others. The diameter of the arches gradually altered, as the sun rose above the horizon; and the whole, after continuing a long time, insensibly faded away. In the beginning, the diameter of the inward iris, taken from its last colour, was about five degrees and a half; and that of the white arch, which surrounded the rest, was not less than sixty-seven degrees. At the beginning of the phenomenon, the arches seemed of an oval or elliptical figure, like the disc of the sun; and afterwards became perfectly circular. Each of these was of a red colour, bordered with an orange; and the

even by Dr Chladni himself. Laplace suggests the probability of their having been thrown off by the volcanoes of the moon: but the meteors which almost always accompany them, and the swiftness of their horizontal motion, militate too strongly against this opinion. The greater number of philosophers consider them, with Mr King and Sir William Hamilton, as concretions actually formed in the atmosphere. This opinion is undoubtedly the most probable of all; but in the present state of our knowledge, it would be absurd to attempt any explanation of the manner in which they are formed. The masses of native iron found in South America, in Siberia, and near Agnam, contain nickel, as has been ascertained by Proust, Howard, and Klaproth, and resemble exactly the iron found in the stones fallen from the atmosphere. We have every reason therefore to ascribe to them the same original: and this accordingly is almost the uniform opinion of philosophers. Klaproth has shown that real native iron is distinguished from meteoric iron by the absence of nickel. Upon the whole, we may consider these stony and metallic masses as fragments of fire-balls which have burst in the atmosphere; but the origin and cause of these fire-balls will perhaps for ages baffle all the attempts of philosophers to explain them.—*See Thomson's System of Chemistry.*

last bordered by a bright yellow, which altered into a straw colour, and this turned to a green; but, in all, the external colour remained red." Such is the description of one of the most beautiful illusions that has ever been seen in nature. This alone seems to have combined all the splendours of optics in one view. To understand the manner, therefore, how this phenomenon was produced, would require a perfect knowledge of optics; which it is not our present province to enter upon. It will be sufficient, therefore, only to observe, that all these appearances arise from the density of the cloud, together with its uncommon and peculiar situation, with respect to the spectator and the sun. It may be observed, that but one of these three rainbows was real, the rest being only reflections thereof. It may also be observed, that whenever the spectator stands between the sun and a cloud of falling rain, a rainbow is seen, which is nothing more than the reflection of the different coloured rays of light from the bosom of the cloud. If, for instance, we take a glass globe, filled with water, and hang it up before us opposite the sun, in many situations it will appear transparent; but if it is raised higher, or sideways, to an angle of forty-five degrees, it will at first appear red; altered a very little higher, yellow; then green, then blue, then violet colour: in short, it will assume successively all the colours of the rainbow; but, if raised higher still, it will become transparent again. A falling shower may be considered as an infinite number of these little transparent globes, assuming different colours, by being placed at their proper heights. The rest of the shower will appear transparent, and no part of it will seem coloured; but such as are at angles of forty-five degrees from the eye, forty-five degrees upward, forty-five degrees on each side, and forty-five degrees downward, did not the plane of the earth prevent us. We therefore see only an arch of the rainbow, the lower part being cut off from our sight by the earth's interposition. However, upon the tops of very high mountains, circular rainbows are seen, because we can see to an angle of forty-five degrees downward, as well as upward, or sideways, and therefore we take in the rainbow's complete circle.

In those forlorn regions round the poles, the meteors, though of another kind, are not less numerous and alarming. When the winter begins, and the cold prepares to set in, the same misty appearance which is produced in the southern climates by the heat, is there produced by the contrary extreme.[1] The sea smokes like an oven, and a fog arises which mariners call the *frost smoke.* This cutting mist commonly raises blisters on several parts of the body; and as soon as it is wafted to some colder part of the atmosphere, it freezes to little icy particles, which are driven by the wind, and create such an intense cold on land, that the limbs of the inhabitants are sometimes frozen, and drop off.

There, also, halos, or luminous circles round the moon, are oftener seen than in any other part of the earth, being formed by the frost smoke; although the air otherwise seems to be clear A lunar rainbow also is often seen there, though somewhat different from that which is common with us; as it appears of a pale white, striped with gray. In these countries also, the aurora borealis streams with peculiar lustre, and variety of colours.* In Greenland it generally arises in the east, and darts

1 Paul Egede's History of Greenland.

* The aurora borealis may with propriety be distinguished into two kinds, the tranquil, and the varying. The tranquil shines with a mild and steady light, very much resembling the clearness of twilight; and preserves, for a considerable time, the form in which it first appears, with little or no variation. The varying aurora is still more remarkable in its appearance, and occasionally exhibits the most brilliant and rapidly diversified forms. In that region of the air which is directly towards the north, or which stretches from the north towards the east or west, there appears at first a cloud in the horizon, which rarely rises to the height of 40 degrees. This cloud is sometimes contiguous to the horizon, sometimes detached from it; in which last case the intermediate sky appears of a bright blue colour. The cloud occupies a portion of the heavens extending in length from 5 to 100 degrees, and sometimes still farther. It is generally white and shining, but sometimes black and thick. Its upper edge is parallel to the horizon, bordered by a long train of light which rises higher in some places than in others. It appears also bent in the form of a bow, or like the segment of a sphere which has its centre considerably beneath the horizon; and sometimes a large white or luminous band is visible skirting the superior edge of the black cloud. The dark part of the cloud becomes white and luminous when the aurora has shone for some time, and after it has sent forth several bright and fiery rays. Then, from the superior edge of the cloud, there issue rays in the form of jets, which are sometimes many, sometimes few in number, sometimes close together, sometimes removed several degrees asunder. These jets diffuse a very brilliant light, as if a luminous or fiery liquor were driven with impetuosity from a syringe. The jet increases in brightness, and has less bulk at the place where it issues from the cloud; while it dilates itself and grows dimmer as it goes farther and farther off. Then there arises from a large open-

its sportive fires, with variegated beauty, over the whole horizon. Its appearance is almost constant in winter; and at those seasons when the sun departs to return no more for half a year, this meteor kindly rises to supply its beams, and affords suffi-

ing in the cloud, a luminous train or column, of which the motion is at first gentle and uniform, and which increases in size as it advances. The dimensions and duration of these columns, however, vary considerably. Their light is sometimes white, sometimes reddish, or even blood colour; and, as they advance, their colours change, till they form a kind of arch in the heavens. When several of these columns, which have issued from different places, encounter each other in the zenith, they intermingle with each other, and form at their junction a small thick cloud, which seems as it were to kindle, and sends forth a light considerably more brilliant than that of any of the separate columns. This light changes to green, blue, and purple; and quitting its original situation, it directs itself towards the south, under the form of a small bright cloud. When no more columns are seen to issue, the cloud assumes the appearance of the morning dawn, and insensibly dissipates itself. The duration of the aurora is very various. Sometimes it is formed and disappears in the course of a few minutes. At other times, it lasts during the whole night, or even for two or three days together. In high northern latitudes, as those of Sweden, Lapland, and Siberia, the aurora borealis are singularly resplendent, and even terrific. They frequently occupy the whole of the heavens, and eclipse the splendour of the stars, planets, and moon, and sometimes even of the sun himself. In the north-eastern districts of Siberia, according to the description of Gmelin, cited and translated by Dr Blagden, (*Phil. Trans.* vol. lxxiv. p. 228,) the aurora is observed to "begin with single bright pillars, rising in the north, and almost at the same time in the north-east, which, gradually increasing, comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally almost cover the whole sky up to the zenith, and produce an appearance as if a vast tent was expanded in the heavens, glittering with gold, rubies, and sapphire. As soon as the phenomena of electricity, and the laws by which they are governed, were tolerably understood, philosophers very naturally had recourse to this agent, as affording a satisfactory explanation of the aurora borealis. The brilliancy o its light, the rapidity of its motions, and the instantaneous changes of form which it underwent, all seemed plainly to point to this powerful element as the cause of these striking phenomena. A small quantity of electricity excited in a highly rarefied atmosphere, or in a medium approaching to a perfect vacuum, will exhibit luminous appearances entirely resembling the aurora borealis, for a very considerable space of time. With respect to the variations of colour which we find in the aurora borealis, these seem fairly ascribable to the different degrees of rarefaction of the air; for the same electricity which appears white in a very rare medium, becomes blue, purple, or red, in a medium of increased density; as is fully evinced by the following experiment. Let an electrical machine and an air pump be so disposed, that while the machine is worked, a succession ot strong sparks shall be communicated from the prime conductor to a metallic knob attached to the top of the receiver of the air pump. Let now the exhaustion of the receiver cient light for all the purposes of existence. However, in the very midst of their tedious nights, the inhabitants are not entirely forsaken. The tops of the mountains are often seen painted with the red rays of the sun; and the poor Greenlander from thence begins to date his chronology. It would appear whimsical to read a Greenland calendar, in which we might be told, That one of their chiefs, having lived forty days, died, at last, of a good old age; and that his widow continued for half a day to deplore his loss, with great fidelity, before she admitted a second husband.

The meteors of the day, in these countries, are not less extraordinary than those of the night: mock suns are often reflected upon an opposite cloud; and the ignorant spectator fancies that there are often three or four real suns in the firmament at the same time. In this splendid appearance the real sun is

proceed, and we shall soon perceive the electricity forcing itself through the air within it, in a visible stream. At first this stream is of a deep purple colour; but, as the exhaustion advances, it changes to blue; and at length to an intense white, with which the whole receiver becomes completely filled.

This experiment would appear to establish the identity of the aurora borealis with electric light; and it may be mentioned as collateral proofs of this identity, that the atmosphere is found, by the electrometer, to abound with electricity when the aurora shines forth; that the aurora, when strong, is accompanied with the whizzing or crackling sound of electricity; and that the magnetic needle is evidently disturbed by the aurora, as well as by the action of an electrical machine, or by the natural electricity of a thunder storm. The course of the aurora is uniformly from the poles towards the equator; and supposing it to consist in a stream of electric light, the following reasons may be assigned for its constantly preserving this course. Extreme cold renders almost all bodies electric, or disposed to accumulate electricity; while heat and moisture occasion a conducting power. Air, when dry and cold, is powerfully electric; and hence the beautiful phenomena of the aurora are confined to the polar regions, and appear by night and not by day, and in winter rather than in summer. The inferior part of the atmosphere, between the tropics, is violently heated during the day time, by the reflection of the sun's rays from the earth, while the superior parts retain their original cold. It is also impregnated with moisture exhaled by the powerful heat which then acts upon the earth. It is therefore in the conducting state, and readily communicates the electricity of the superior regions to the clouds which float in it, or to the body of the earth. Hence the awful electrical phenomena of the tropical regions, exhibited in thunder and lightning, water spouts, whirlwinds, and the most tremendous tempests. The electrical fluid is thus conveyed in great quantities from the upper parts of the atmosphere between the tropics, to the lower stratum, and thence to the earth; and the inferior and warm atmosphere, having once exhausted itself, must necessarily be recruited from the upper and colder region.

always readily known by its superior brightness, every reflection being seen with diminished splendour. The solar rainbow there, is often seen different from ours. Instead of a pleasing variety of colours, it appears of a pale white, edged with a stripe of dusky yellow: the whole being reflected from the bosom of a frozen cloud.

But of all the meteors which mock the imagination with an appearance of reality, those strange illusions that are seen there, in fine serene weather, are the most extraordinary and entertaining. "Nothing," says Crantz, "ever surprised me more, than on a fine warm summer's day, to perceive the islands that lie four leagues west of our shore, putting on a form quite different from what they are known to have. As I stood gazing upon them, they appeared at first infinitely greater than what they naturally are; and seemed as if I viewed them through a large magnifying glass. They were not thus only made larger, but brought nearer to me. I plainly descried every stone upon the land, and all the furrows filled with ice, as if I stood close by. When this illusion had lasted for a while, the prospect seemed to break up, and a new scene of wonder to present itself. The islands seemed to travel to the shore, and represented a wood, or a tall cut hedge. The scene then shifted, and showed the appearance of all sorts of curious figures; as ships with sails, streamers, and flags; antique elevated castles, with decayed turrets: and a thousand forms, for which fancy found a resemblance in nature. When the eye had been satisfied with gazing, the whole group of riches seemed to rise in air, and at length vanish into nothing. At such times the weather is quite serene and clear; but compressed with such subtile vapours, as it is in very hot weather; and these appearing between the eye and the object, give it all that variety of appearances which glasses of different refrangibilites would have done." Mr Crantz observes, that commonly a couple of hours afterwards a gentle west wind and a visible mist follow, which put an end to this *lusus naturæ*.

It were easy to swell this catalogue of meteors with the names of many others, both in our own climate and in other parts of the world. Such as falling stars, which are thought to be no more than unctuous vapours, raised from the earth to small heights, and continuing to shine till that matter which first raised and supported them, being burnt out, they fall back again to the earth with extinguished flame.* Burning spears, which are a peculiar kind of aurora borealis; bloody rains, which are said to be the excrements of an insect, that at that time has been raised into the air. Showers of stones, fishes, and ivy-berries, at first, no doubt, raised into the air by tempests in one country, and falling at some considerable distance, in the manner of rain, to astonish another. But omitting these, of which we know little more than what is thus briefly mentioned, I will conclude this chapter with the description of a water-spout: a most surprising phenomenon, not less dreadful to mariners than astonishing to the observer of nature.

These spouts are seen very commonly in the tropical seas, and sometimes in our own. Those seen by Tournefort, in the Mediterranean, he has described as follows: "The first of these," says this great botanist, "that we saw, was about a musket-shot from our ship. There we perceived the water began to boil, and to rise about a foot above its level. The water was agitated and whitish; and above its surface there seemed to stand a smoke, such as might be imagined to come from wet straw before it begins to blaze. It made a sort of a murmuring sound, like that of a torrent heard at a distance, mixed, at the same time, with a hissing noise like that of a serpent; shortly after we perceived a column of this smoke rise up to the clouds, at the same time whirling about with great rapidity. It appeared to be as thick as one's finger; and the former sound still continued. When this disappeared, after lasting for about eight minutes, upon turning to the opposite quarter of the sky, we perceived another, which began in the manner of the former; presently after, a third appeared in the west; and instantly beside it still another arose. The most distant of these three could not be above a musket-shot from the ship. They all continued like so many heaps of wet straw set on fire, that continued to smoke, and to make

* The shooting or falling star is a common phenomenon, but though so frequently observed, the great distance, and the transient nature of those meteors, added to the entire consumption of their materials, have hitherto frustrated every attempt to ascertain their cause. It is, however, reasonable to suppose, that they are intrinsically the same with the larger meteors, as in most of their properties they perfectly correspond with them.

the same noise as before. We soon after perceived each, with its respective canal, mounting up in the clouds, and spreading where it touched; the cloud, like the mouth of a trumpet, makeing a figure (to express it intelligibly) as if the tail of an animal were pulled at one end by a weight. These canals were of a whitish colour, and so tinged, as I suppose, by the water which was contained in them; for previous to this they were apparently empty, and of the colour of transparent glass. These canals were not straight, but bent in some parts, and far from being perpendicular, but rising in their clouds with a very inclined ascent. But what is very particular, the cloud to which one of them was pointed happening to be driven by the wind, the spout still continued to follow its motion without being broken; and passing behind one of the others, the spouts crossed each other, in the form of a St Andrew's cross. In the beginning they were all about as thick as one's finger, except at the top, where they were broader, and two of them disappeared; but shortly after, the last of the three increased considerably; and its canal, which was at first sc small, soon became as thick as a man's arm, then as his leg, and at last thicker than his whole body. We saw distinctly, through this transparent body, the water which rose up with a kind of spiral motion; and it sometimes diminished a little of its thickness, and again resumed the same, sometimes widening at top, and sometimes at bottom; exactly resembling a gut filled with water, pressed with the fingers to make the fluid rise or fall; and I am well convinced that this alteration in the spout was caused by the wind, which pressed the cloud, and impelled it to give up its contents. After some time its bulk was so diminished as to be no thicker than a man's arm again; and thus swelling and diminishing, it at last became very small. In the end, I observed the sea which was raised above it to resume its level by degrees, and the end of the canal that touched it to become as small as if it had been tied round with a cord; and this continued till the light striking through the cloud took away the view. I still however continued tc look, expecting that its parts would join again, as I had before seen in one of the others, in which the spout was more than once broken, and yet again came together; but I was disappointed, for the spout appeared no more."

Many have been the solutions offered for this surprising appearance. Mr Buffon supposes the spout here described, to proceed from the operation of fire, beneath the bed of the sea; as the waters at the surface are thus seen agitated. However, the solution of Dr Stuart is not divested of probability; who thinks it may be accounted for by suction, as in the application of a cupping-glass to the skin.

Wherever spouts of this kind are seen, they are extremely dreaded by mariners; for if they happen to fall upon a ship, they most commonly dash it to the bottom. But if the ship be large enough to sustain the deluge, they are at least sure to destroy its sails and rigging, and render it unfit for sailing. It is said that vessels of any force usually fire their guns at them, loaden with a bar of iron; and if so happy as to strike them, the water is instantly seen to fall from them with a dreadful noise, though without any farther mischief.

I am at a loss whether we ought to reckon these spouts called *typhons*, which are sometimes seen at land, of the same kind with those so often described by mariners at sea, as they seem to differ in several respects. That, for instance, observed at Hatfield in Yorkshire, in 1687, as it is described by the person who saw it, seems rather to have been a whirlwind than a water-spout. The season in which it appeared was very dry, the weather extremely hot, and the air very cloudy. After the wind had blown for some time with considerable force, and condensed the black clouds one upon another, a great whirling of the air ensued; upon which the centre of the clouds every now and then darted down, in the shape of a thick long black pipe; in which the relater could distinctly view a motion like that of a screw, continually screwing up to itself, as it were, whatever it happened to touch. In its progress it moved slowly over a grove of young trees, which it violently bent in a circular motion. Going forward to a barn, it, in a minute, stript it of all the thatch, and filled the whole air with the same. As it came near the relater, he perceived that its blackness proceeded from a gyration of the clouds, by contrary winds meeting in a point, or a centre; and where the greatest force was exerted, there darting down like an Archimedes's screw, to suck up all that came in its way. Another which he saw some time after was attended with still more terrible effects; levelling or tearing up great oak trees, catching up the birds in its vortex, and dashing them against the ground. In this manner it proceeded, with an audible whirling noise, like that of a mill; and at length dissolved, after having done much mischief.

But we must still continue to suspend our assent as to the nature even of these land spouts, since they have been sometimes found to drop, in a great column of water, at once upon the earth, and produce an instant inundation,[1] which could not readily have happened had they been caused by the gyration of a whirlwind only. Indeed, every conjecture regarding these meteors seems to me entirely unsatisfactory. They sometimes appear in the calmest weather at sea, of which I have been an eye-witness; and therefore these are not caused by a whirlwind. They are always capped by a cloud; and therefore are not likely to proceed from fires at the bottom. They change place; and therefore suction seems impracticable. In short, we still want facts, upon which to build a rational theory; and instead of knowledge, we must be contented with admiration. To be well acquainted with the appearances of nature, even though we are ignorant of their causes, often constitutes the most useful wisdom.

CHAP. XXII.

THE CONCLUSION.

Having thus gone through a particular description of the earth, let us now pause for a moment, to contemplate the great picture before us. The universe may be considered as the palace in which the Deity resides; and this earth as one of its apartments. In this, all the meaner races of animated nature mechanically obey him; and stand ready to execute his commands without hesitation. Man alone is found refractory; he is the only being endued with a power of contradicting these mandates. The Deity was pleased to exert superior power in creating him a superior being; a being endued with the choice of good and evil; and capable, in some measure, of co-operating with his own intentions. Man, therefore, may be considered as a limited

1 Phil. Trans. vol. iv. p. ii. 108.

creature, endued with powers imitative of those residing in the Deity. He is thrown into a world that stands in need of his help; and has been granted a power of producing harmony from partial confusion.

If, therefore, we consider the earth as allotted for our habitation, we shall find that much has been given us to enjoy, and much to amend; that we have ample reasons for our gratitude, and still more for our industry. In those great outlines of nature, to which art cannot reach, and where our greatest efforts must have been ineffectual, God himself has finished these with amazing grandeur and beauty. Our beneficent Father has considered those parts of nature as peculiarly his own; as parts which no creature could have skill or strength to amend: and therefore made them incapable of alteration, or of more perfect regularity. The heavens and the firmament show the wisdom and the glory of the workman. Astronomers, who are best skilled in the symmetry of systems, can find nothing there that they can alter for the better. God made these perfect, because no subordinate being could correct their defects.

When, therefore, we survey nature on this side, nothing can be more splendid, more correct, or amazing. We there behold a Deity residing in the midst of a universe, infinitely extended every way, animating all, and cheering the vacuity with his presence! We behold an immense and shapeless mass of matter, formed into worlds by his power, and dispersed at intervals, to which even the imagination cannot travel! In this great theatre of his glory, a thousand suns, like our own, animate their respective systems, appearing and vanishing at Divine command. We behold our own bright luminary fixed in the centre of its system, wheeling its planets in times proportioned to their distances, and at once dispensing light, heat, and action. The earth also is seen with its two-fold motion; producing, by the one, the change of seasons; and by the other, the grateful vicissitudes of day and night. With what silent magnificence is all this performed! with what seeming ease! The works of art are exerted with interrupted force; and their noisy progress discovers the obstructions they receive: but the earth, with a silent steady rotation, successively presents every part of its bosom to the sun; at once imbibing nourishment and light from that parent of vegetation and fertility.

But not only provisions of heat and light are thus supplied, but its whole surface is covered with a transparent atmosphere, that turns with its motion, and guards it from external injury. The rays of the sun are thus broken into a genial warmth; and, while the surface is assisted, a gentle heat is produced in the bowels of the earth, which contributes to cover it with verdure. Waters also are supplied in healthful abundance, to support life, and assist vegetation. Mountains arise, to diversify the prospect, and give a current to the stream. Seas extend from one continent to the other, replenished with animals that may be turned to human support; and also serving to enrich the earth with a sufficiency of vapour. Breezes fly along the surface of the fields, to promote health and vegetation. The coolness of the evening invites to rest; and the freshness of the morning renews for labour.

Such are the delights of the habitation that has been assigned to man! Without any one of these, he must have been wretched; and none of these could his own industry have supplied. But while many of his wants are thus kindly furnished on the one hand, there are numberless inconveniences to excite his industry on the other. This habitation, though provided with all the conveniences of air, pasturage, and water, is but a desert place, without human cultivation. The lowest animal finds more conveniences in the wilds of nature than he who boasts himself their lord. The whirlwind, the inundation, and all the asperities of the air, are peculiarly terrible to man, who knows their consequences, and, at a distance, dreads their approach. The earth itself, where human art has not pervaded, puts on a frightful gloomy appearance. The forests are dark and tangled; the meadows overgrown with rank weeds; and the brooks stray without a determined channel. Nature that has been kind to every lower order of beings, has been quite neglectful with regard to him; to the savage uncontriving man the earth is an abode of desolation, where his shelter is insufficient, and his food precarious.

A world thus furnished with advantages on one side, and inconveniences on the other, is the proper abode of reason, is the fittest to exercise the industry of a free and a thinking creature. These evils, which art can remedy, and prescience guard against, are a proper call for the exertion of his faculties; and they tend still more to assimilate him to his Creator. God beholds with pleasure that being which he has made, converting the wretchedness of his natural situation into a theatre of triumph; bringing all the headlong tribes of nature into subjection to his will; and producing that order and uniformity upon earth, of which his own heavenly fabric is so bright an example.

PART II.

OF ANIMALS

CHAP. I.

A COMPARISON OF ANIMALS WITH THE INFERIOR RANKS OF CREATION.

HAVING given an account of the earth in general, and the advantages and inconveniences with which it abounds, we now come to consider it more minutely. Having described the habitation, we are naturally led to inquire after the inhabitants. Amidst the infinitely different productions which the earth offers, and with which it is every where covered, animals hold the first rank; as well because of the finer formation of their parts, as of their superior power. The vegetable, which is fixed to one spot, and obliged to wait for its accidental supplies of nourishment, may be considered as the prisoner of nature. Unable to correct the disadvantages of its situation, or to shield itself from the dangers that surround it, every object that has motion may be its destroyer.

But animals are endowed with powers of motion and defence. The greatest part are capable, by changing place, of commanding nature; and of thus obliging her to furnish that nourishment which is most agreeable to their state. Those few that are fixed to one spot, even in this seemingly helpless situation, are, nevertheless, protected from external injury by a hard shelly covering; which they often can close at pleasure, and thus defend themselves from every assault. And here, I think, we may draw the line between the animal and vegetable kingdoms. Every animal, by some means or other, finds protection from injury; either from its force or courage, its swiftness or cunning. Some are protected by hiding in convenient places; and others by taking refuge in a hard resisting shell. But vegetables are totally unprotected; they are exposed to every assailant, and patiently submissive in every attack. In a word, an animal is an organized being, that is, in some measure, provided for its own security; a vegetable is destitute of every protection.

But though it is very easy, without the help of definitions, to distinguish a plant from an animal, yet both possess many properties so much alike, that the two kingdoms, as they are called, seem mixed with each other. Hence, it frequently puzzles the naturalist to tell exactly where animal life begins, and vegetative terminates; nor indeed is it easy to resolve, whether some objects offered to view be of the lowest of the animal, or the highest of the vegetable races. The sensitive plant, that moves at the touch, seems to have as much perception as the fresh-water polypus, that is possessed of a still slower share of motion. Besides, the sensitive plant will not re-produce upon cutting in pieces, which the polypus is known to do; so that the vegetable production seems to have the superiority. But, notwithstanding this, the polypus hunts for its food, as most other animals do. It changes its situation; and therefore possesses a power of choosing its food, or retreating from danger. Still, therefore, the animal kingdom is far removed above the vegetable; and its lowest denizen is possessed of very great privileges, when compared with the plants with which it is often surrounded.

However, both classes have many resemblances, by which they are raised above the unorganized and inert masses of nature. Minerals are mere inactive, insensible bodies, entirely motionless of themselves, and waiting some external force to alter their formsor their properties. But it is otherwise with animals and vegetables; these are endued with life and vigour; they have their state of improvement and decay; they are capable of reproducing their kinds; they grow from seeds in some, and from cuttings in others; they seem all possessed of sensation, in a greater or less degree; they both have their enmities and affections; and as some animals are, by nature, impelled to violence, so some plants are found to exterminate all others, and make a wilderness of the places round them. As the lion makes a desert of the forest where it resides, thus no other plant will grow under the shade of the manchineel-tree. Thus, also, that plant, in the West-Indies, called *caraguata*, clings round whatever tree it happens to approach: there it quickly gains the ascendant; and loading the tree with a verdure not its own, keeps away that nourishment designed to feed the trunk; and, at last, entirely destroys its supporter. As all animals are ultimately supported upon vegetables, so vegetables are greatly propagated by being made a part of animal food. Birds distribute the seeds wherever they fly, and quadrupeds prune them into great luxuriance. By these means the quantity of food, in a state of nature, is kept equal to the number of the consumers; and, lest some of the weaker ranks of animals should find nothing for their support, but all the provisions be devoured by the strong, different vegetables are appropriated to different appetites. If, transgressing this rule, the stronger rank should invade the rights of the weak, and, breaking through all regard to appetite, should make an indiscriminate use of every vegetable, nature then punishes the transgression, and poison marks the crime as capital.

If, again, we compare vegetables and animals, with respect to the places where they are found, we shall find them bearing a still stronger similitude. The vegetables that grow in a dry and sunny soil, are strong and vigorous, though not luxuriant; so also are the animals of such a climate. Those, on the contrary, that are the joint product of heat and moisture, are luxuriant and tender; and the animals assimilating to the vegetable food, on which they ultimately subsist, are much larger in such places than in others. Thus, in the internal parts of South America and Africa, where the sun usually scorches all above, while inundations cover all below, the insects, reptiles, and other animals, grow to a prodigious size: the earth-worm of America is often a yard in length, and as thick as a walking cane; the boiguacu, which is the largest of the serpent kind, is sometimes forty feet in length; the bats in those countries, are as big as a rabbit; the toads are bigger than a duck; and their spiders are as large as a sparrow. On the contrary, in the cold frozen regions of the north, where vegetable nature is stinted of its growth, the few animals in those climates partake of the diminution; all the wild animals, except the bear, are much smaller than in milder countries; and such of the domestic kinds as are carried thither, quickly degenerate, and grow less. Their very insects are of the minute kinds, their bees and spiders being not half so large as those in the temperate zone.

The similitude between vegetables and animals is no where more obvious than in those that belong to the ocean, where the nature of one is admirably adapted to the necessities of the other. This element, it is well known, has its vegetables, and its insects that feed upon them, in great abundance. Over many tracts of the sea, a weed is seen floating, which covers the surface, and gives the resemblance of a green and extensive meadow. On the under side of these unstable plants, millions of little animals are found adapted to their situation. For as their ground, if I may so express it, lies over their heads, their feet are placed upon their backs; and as land animals have their legs below their bodies, these have them above. At land also, most animals are furnished with eyes to see their food; but at sea, almost all the reptile kinds are without eyes, which might only give them prospects of danger at a time when unprovided with the means of escaping it.[1]

Thus, in all places, we perceive an obvious similitude between the animals and the vegetables of every region. In general, however, the most perfect races have the least similitude to the vegetable productions on which they are ultimately fed; while, on the contrary, the meaner the animal, the more local it is found to be, and the more it is influenced by the varieties of the soil where it resides. Many of the more humble reptile kinds are not only confined to one country, but also to a plant; nay, even to a leaf. Upon that they subsist; increase with its vegetation, and seem to decay as it declines. They are merely the circumscribed inhabitants of a single vegetable: take them from that, and they instantly die; being entirely assimilated to the plant they feed on, assuming its colour, and even its medicinal properties. For this reason there are infinite numbers of the meaner animals that we have never an opportunity of seeing in this part of the world; they are incapable of living separate from their kindred vegetables, which grow only in a certain climate.

Such animals as are formed more perfect, lead a life of less dependence; and some kinds are found to subsist in many parts of the world at the same time. But, of all the races of animated

1 Linnæi Amænitates, vol. v. p. 68.

nature, man is the least affected by the soil where he resides, and least influenced by the variations of vegetable sustenance: equally unaffected by the luxuriance of the warm climates, or the sterility of the poles, he has spread his habitations over the whole earth; and finds subsistence as well amidst the ice of the north as the burning deserts under the Line. All creatures of an inferior nature, as has been said, have peculiar propensities to peculiar climates; they are circumscribed to zones, and confined to territories, where their proper food is found in the greatest abundance; but man may be called the animal of every climate, and suffers but very gradual alterations from the nature of any situation.

As to animals of a meaner rank, whom man compels to attend him in his migrations, these being obliged to live in a kind of constraint, and upon vegetable food often different from that of their native soil, they very soon alter their natures with the nature of their nourishment, assimilate to the vegetables upon which they are fed, and thus assume very different habits as well as appearances. Thus man, unaffected himself, alters and directs the nature of other animals at his pleasure; increases their strength for his delight, or their patience for his necessities.

This power of altering the appearances of things, seems to have been given him for very wise purposes. The Deity, when he made the earth, was willing to give his favoured creature many opponents, that might at once exercise his virtues, and call forth his latent abilities. Hence we find, in those wide uncultivated wildernesses, where man, in his savage state, owns inferior strength, and the beasts claim divided dominion, that the whole forest swarms with noxious animals and vegetables; animals as yet undescribed, and vegetables which want a name. In those recesses, nature seems rather lavish than magnificent in bestowing life. The trees are usually of the largest kinds, covered round with parasite plants, and interwoven at the tops with each other. The boughs, both above and below, are peopled with various generations; some of which have never been upon the ground, and others have never stirred from the branches on which they were produced. In this manner millions of minute and loathsome creatures pursue a round of uninterrupted existence, and enjoy a life scarcely superior to vegetation. At the same time, the vegetables in those places are of the larger kinds, while the animal race is of the smaller: but man has altered this disposition of nature; having, in a great measure, levelled the extensive forests, cultivated the softer and finer vegetables, destroyed the numberless tribes of minute and noxious animals, and taken every method to increase a numerous breed of the larger kinds. He thus has exercised a severe control; unpeopled nature, to embellish it, and diminished the size of the vegetable, in order to improve that of the animal kingdom.

To subdue the earth to his own use, was, and ought to be, the aim of man; which was only to be done by increasing the number of plants, and diminishing that of animals: to multiply existence *alone*, was that of the Deity. For this reason, we find, in a state of nature, that animal life is increased to the greatest quantity possible; and, we can scarcely form a system that could add to its numbers. First, plants, or trees, are provided by nature of the largest kinds; and, consequently, the nourishing surface is thus extended. In the second place, there are animals peculiar to every part of the vegetable, so that no part of it is lost. But the greatest possible increase of life would still be deficient, were there not other animals that lived upon animals; and these are, themselves, in turn, food for some other greater and stronger set of creatures. Were all animals to live upon vegetables alone, thousands would be extinct that now have existence, as the quantity of their provision would shortly fail. But, as things are wisely constituted, one animal now supports another; and thus, all take up less room than they would by living on the same food; as, to make use of a similar instance, a greater number of people may be crowded into the same space, if each is made to bear his fellow upon his shoulders.

To diminish the number of animals and increase that of vegetables, has been the general scope of human industry; and if we compare the utility of the kinds, with respect to man, we shall find, that of the vast variety in the animal kingdom, but very few are serviceable to him; and, in the vegetable, but very few are entirely noxious. How small a part of the insect tribes, for instance, are beneficial to mankind, and what numbers are injurious! In some countries they almost darken the air: a candle cannot be lighted without their instantly flying upon it, and putting out the flame.[1] The closest recesses are no safeguard

1 Ulloa's Description of Guayaquil.

from their annoyance; and the most beautiful landscapes of nature only serve to invite their rapacity. As these are injurious, from their multitudes, so most of the larger kinds are equally dreadful to him from their courage and ferocity. In the most uncultivated parts of the forest these maintain an undisputed empire; and man invades their retreats with terror. These are dreadful; and there are still more which are utterly useless to him, that serve to take up the room which more beneficial creatures might possess; and incommode him rather with their numbers than their enmities. Thus, in a catalogue of land-animals, that amounts to more than twenty thousand, we can scarcely reckon up a hundred that are any way useful to him; the rest being either all his open or his secret enemies, immediately attacking him in person, or intruding upon that food he has appropriated to himself. Vegetables, on the contrary, though existing in greater variety, are but few of them noxious. The most deadly poisons are often of great use in medicine; and even those plants that only seem to cumber the ground, serve for food to the race of animals which he has taken into friendship or protection. The smaller tribes of vegetables, in particular, are cultivated, as contributing either to his necessities or amusement; so that vegetable life is as much promoted by human industry, as animal life is controlled and diminished.

Hence it was not without a long struggle, and various combinations of experience and art that man acquired his present dominion. Almost every good that he possesses was the result of the contest; for, every day, as he was contending, he was growing more wise: and patience and fortitude were the fruits of his industry.

Hence, also, we see the necessity of some animals living upon each other, to fill up the plan of Providence; and we may, consequently, infer the expediency of man's living upon all. Both animals and vegetables seem equally fitted to his appetites; and, were any religious or moral motives to restrain him from taking away life, upon any account, he would only thus give existence to a variety of beings made to prey upon each other; and, instead of preventing, multiply mutual destruction.

CHAP. II.

OF THE GENERATION OF ANIMALS.

Before we survey animals in their state of maturity, and performing the functions adapted to their respective natures, method requires that we should consider them in the more early periods of their existence. There has been a time when the proudest and the noblest animal was a partaker of the same imbecility with the meanest reptile; and, while yet a candidate for existence, equally helpless and contemptible. In their incipient state, all are upon a footing; the insect and the philosopher being equally insensible, clogged with matter, and unconscious of existence. Where then are we to begin with the history of those beings, that make such a distinguished figure in the creation? Or, where lie those peculiar characters in the parts that go to make up animated nature—that mark one animal as destined to creep in the dust, and another to glitter on the throne?

This has been a subject that has employed the curiosity of all ages, and the philosophers of every age have attempted the solution. In tracing nature to her most hidden recesses, she becomes too minute or obscure for our inspection; so that we find it impossible to mark her first differences, to discover the point where animal life begins, or the cause that conduces to set it in motion. We know little more than that the greatest number of animals require the concurrence of a male and female to reproduce their kind; and that these distinctly and invariably are found to beget creatures of their own species. Curiosity has, therefore, been active in trying to discover the immediate result of this union; how far either sex contributes to the bestowing animal life, and whether it be to the male or female, that we are most indebted for the privilege of our existence.

Hippocrates has supposed that fecundity proceeded from the mixture of the seminal liquor of both sexes, each of which equally contributes to the formation of the incipient animal. Aristotle, on the other hand, would have the seminal liquor in the male alone to contribute to this purpose, while the female supplied the proper nourishment for its support. Such were the opinions of these fathers of philosophy; and these continued to be adopted by the naturalists and schoolmen of succeeding ages, with blind veneration. At length Steno and Harvey, taking anatomy for their guide, gave mankind a nearer view of nature just advancing into animation. These perceived, in all such animals as produced their young alive, two glandular bodies, near the womb, resembling that ovary, or cluster of small eggs, which is found in fowls; and from the analogy between both, they gave these also the name of ovaria. These, as they resembled eggs, they naturally concluded had the same offices; and, therefore, they were induced to think that all animals, of what kind soever, were produced from eggs. At first, however, there was some altercation raised against this system: for, as these ovaria were separate from the womb, it was objected that they could not be any way instrumental in replenishing that organ, with which they did not communicate. But, upon more minute inspection, Falopius, the anatomist, perceived two tubular vessels depending from the womb, which, like the horns of a snail, had a power of erecting themselves, of embracing the ovaria, and of receiving the eggs, in order to be fecundated by the seminal liquor. This discovery seemed, for a long time after, to fix the opinions of philosophers. The doctrine of Hippocrates was re-established, and the chief business of generation was ascribed to the female. This was for a long time the established opinion of the schools; but Leuwenhoeck, once more, shook the whole system, and produced a new schism among the lovers of speculation. Upon examining the seminal liquor of a great variety of male animals with microscopes, which helped his sight more than that of any o t his successors, he perceived therein infinite numbers of little living creatures, like tadpoles, very brisk, and floating in the fluid with a seeming voluntary motion. Each of these, therefore, was thought to be the rudiments of an animal, similar to that from which it was produced; and this only required a reception from the female, together with proper nourishment, to complete its growth. The business of generation was now, therefore, given back to the male a second time, by many; while others suspended their assent, and chose rather to confess ignorance than to embrace error.[1]

In this manner has the dispute continued for several ages,

1 Bonet Considerations sur les Corps Organisees.

some accidental discovery serving, at intervals, to renew the debate, and revive curiosity. It was a subject where speculation could find much room to display itself; and Mr Buffon, who loved to speculate, would not omit such an opportunity of giving scope to his propensity. According to this most pleasing of all naturalists, the microscope discovers that the seminal liquor, not only of males, but of females also, abounds in these moving little animals which have been mentioned above, and that they appear equally brisk in either fluid. These he takes not to be real animals, but organical particles, which being simple, cannot be said to be organized themselves, but go to the composition of all organized bodies whatsoever; in the same manner as a tooth, in the wheel of a watch, cannot be called either the wheel or the watch, and yet contributes to the sum of the machine. These organical particles are, according to him, diffused throughout all nature, and to be found not only in the seminal liquor, but in most other fluids in the parts of vegetables, and all parts of animated nature. As they happen, therefore, to be differently applied, they serve to contribute a part of the animal, or the vegetable, whose growth they serve to increase, while the superfluity is thrown off in the seminal liquor of both sexes, for the reproduction of other animals or vegetables of the same species. These particles assume different figures, according to the receptacle into which they enter; falling into the womb, they unite into a fœtus; beneath the bark of a tree they pullulate into branches; and, in short, the same particles that first formed the animal in the womb, contribute to increase its growth when brought forth.[2]

To this system it has been objected, that it is impossible to conceive organical substances without being organized; and that, if divested of organization themselves, they could never make an organized body, as an infinity of circles could never make a triangle. It has been objected, that it is more difficult to conceive the transformation of these organical particles, than even that of the animal, whose growth we are inquiring after; and this system, therefore, attempts to explain one obscure thing by another still more obscure.

But an objection, still stronger than these, had been advanced

2 Mr Buffon.

by an ingenious countryman of our own; who asserts, that these little animals, which thus appear swimming and sporting in almost every fluid we examine with a microscope, are not real living particles, but some of the more opaque parts of the fluid that are thus increased in size, and seem to have a much greater motion than they have in reality. For the motion being magnified with the object, the smallest degree of it will seem very considerable; and a being almost at rest may, by these means, be apparently put into violent action. Thus, for instance, if we look upon the sails of a windmill moving at a distance, they appear to go very slow; but, if we approach them, and thus magnify their bulk to our eye, they go round with great rapidity. A microscope, in the same manner, serves to bring our eye close to the object, and thus to enlarge it; and not only increase the magnitude of its parts, but of its motion. Hence, therefore, it would follow, that these organical particles, that are said to constitute the bulk of living nature, are but mere optical illusions; and the system founded on them must, like them, be illusive.

These, and many other objections, have been made to this system; which, instead of enlightening the mind, serve only to show, that too close a pursuit of nature very often leads to uncertainty. Happily, however, for mankind, the most intricate inquiries are generally the most useless. Instead, therefore, of balancing accounts between the sexes, and attempting to ascertain to which the business of generation most properly belongs, it will be more instructive, as well as amusing, to begin with animal nature, from its earliest retirements, and evanescent outlines, and pursue the incipient creature through all its changes in the womb, till it arrives into open day.

The usual distinction of animals, with respect to their manner of generation, has been into the oviparous and viviparous kinds; or in other words, into those that bring forth an egg, which is afterwards hatched into life, and those that bring forth their young alive and perfect. In one of these two ways all animals were supposed to have been produced, and all other kinds of generation were supposed imaginary or erroneous. But later discoveries have taught us to be more cautious in making general conclusions, and have even induced many to doubt whether animal life may not be produced merely from putrefaction.[1]

1 Bonet Consid. p. 100.

Indeed the infinite number of creatures that putrid substances seem to give birth to, and the variety of little insects seen floating in liquors, by the microscope, appear to favour this opinion. But however this may be, the former method of classing animals can now by no means be admitted, as we find many animals that are produced neither from the womb nor from the shell, but merely from cuttings ; so that to multiply life in some creatures, it is sufficient only to multiply the dissection. This being the simplest method of generation, and that in which life seems to require the smallest preparation for its existence, I will begin with it, and so proceed to the two other kinds, from the meanest to the most elaborate.

The earth-worm, the millipedes, the sea-worm, and many marine insects, may be multiplied by being cut in pieces ; but the polypus is noted for its amazing fertility ; and from hence it will be proper to take the description. The structure of the polypus may be compared to the finger of a glove, open at one end, and closed at the other. The closed end represents the tail of the polypus, with which it serves to fix itself to any substance it happens to be upon ; the open end may be compared to the mouth ; and, if we conceive six or eight small strings issuing from this end, we shall have a proper idea of its arms, which it can erect, lengthen, and contract, at pleasure, like the horns of a snail. This creature is very voracious, and makes use of its arms as a fisherman does of his net, to catch and entangle such little animals as happen to come within its reach. It lengthens these arms several inches, keeps them separated from each other, and thus occupies a large space in the water in which it resides. These arms, when extended, are as fine as threads of silk, and have a most exquisite degree of feeling. If a small worm happens to get within the sphere of their activity, it is quickly entangled by one of these arms, and, soon after, the other arms come to its aid : these all together shortening, the worm is drawn into the animal's mouth, and quickly devoured, colouring the body as it is swallowed. Thus much is necessary to be observed of this animal's method of living, to show that it is not of the vegetable tribe, but a real animal, performing the functions which other animals are found to perform, and endued with powers that many of them are destitute of. But what is most extraordinary, remains yet to be told ; for, if examined with a microscope, there are seen several little specks, like buds, that seem to pullulate from different parts of its body; and these soon after appear to be young polypi, and, like the large polypus, begin to cast their little arms about for prey, in the same manner. Whatever they happen to ensnare is devoured, and gives a colour not only to their own bodies, but to that of the parent; so that the same food is digested, and serves for the nourishment of both. The food of the little one passes into the large polypus, and colours its body; and this, in its turn, digests and swallows its food to pass into theirs. In this manner every polypus has a new colony sprouting from its body: and these new ones, even while attached to the parent animal, become parents themselves, having a smaller colony also budding from them; all, at the same time, busily employed in seeking for their prey, and the food of any one of them serving for the nourishment, and circulating through the bodies, of all the rest. This society, however, is every hour dissolving; those newly produced are seen at intervals to leave the body of the large polypus, and become, shortly after, the head of a beginning colony themselves.

In this manner the polypus multiplies naturally; but one may take a much readier and shorter way to increase them, and this only by cutting them in pieces. Though cut into thousands of parts, each part still retains its vivacious qualities, and each shortly becomes a distinct and a complete polypus; whether cut lengthways, or crossways, it is all the same; this extraordinary creature seems a gainer by our endeavours, and multiplies by apparent destruction. The experiment has been tried, times without number, and still attended with the same success. Here, therefore, naturalists, who have been blamed for the cruelty of their experiments upon living animals, may now boast of their increasing animal life, instead of destroying it. The production of the polypus is a kind of philosophical generation. The famous Sir Thomas Brown hoped one day to be able to produce children by the same method as trees are produced: the polypus is multiplied in this manner; and every philosopher may thus, if he please, boast of a very numerous, though, I should suppose, a very useless progeny.

This method of generation, from cuttings, may be considered as the most simple kind, and is a strong instance of the little pains Nature takes in the formation of her lower and humbler productions. As the removal of these from inanimate into animal existence is but small, there are but few preparations made for their journey. No organs of generation seem provided, no womb to receive, no shell to protect them in their state of transition. The little reptile is quickly fitted for all the offices of its humbler sphere, and in a very short rime, arrives at the height of its contemptible perfection.

The next generation is of those animals that we see produced from the egg. In this manner all birds, most fishes, and many of the insect tribes, are brought forth. An egg may be considered as a womb detached from the body of the parent animal, in which the embryo is but just beginning to be formed. It may be regarded as a kind of incomplete delivery, in which the animal is disburthened of its young before its perfect formation. Fishes and insects, indeed, most usually commit the care of their eggs to hazard: but birds, which are more perfectly formed, are found to hatch them into maturity by the warmth of their bodies. However, any other heat, of the same temperature, would answer the end as well; for either the warmth of the sun, or of a stove, is equally efficacious in bringing the animal in the egg to perfection. In this respect, therefore, we may consider generation from the egg as inferior to that in which the animal is brought forth alive. Nature has taken care of the viviparous animal in every stage of its existence. That force which separates it from the parent separates it from life; and the embryo is shielded with unceasing protection till it arrives at exclusion. But it is different with the little animal in the egg; often totally neglected by the parent, and always separable from it, every accident may retard its growth, or even destroy its existence. Besides, art or accident, also, may bring this animal to a state of perfection; so that it never can be considered as a complete work of nature, in which so much is left for accident to finish or destroy.

But however inferior this kind of generation may be, the observation of it will afford great insight into that of nobler animals, as we can here watch the progress of the growing embryo in every period of its existence, and catch it in those very moments when it first seems stealing into motion. Malpighi and Haller have been particularly industrious on this subject; and with a patience almost equalling that of the sitting hen, have attended incubation in all its stages. From them, therefore, we have an amazing history of the chicken in the egg, and of its advances into complete formation.

It would be methodically tedious to describe those parts of the egg which are well known and obvious ; such as its shell, its white, and its yolk ; but the disposition of these is not so apparent. Immediately under the shell lies that common membrane or skin, which lines it on the inside, adhering closely to it everywhere, except at the broad end, where a little cavity is left, that is filled with air which increases as the animal within grows larger. Under this membrane are contained two whites, though seeming to us to be only one, each wrapped up in a membrane of its own, one white within the other. In the midst of all is the yolk wrapped up likewise in its own membrane. At each end of this are two ligaments, called *chalazæ*, which are, as it were, the poles of this microcosm, being white dense substances, made from the membranes, and serving to keep the white and the yolk in their places. It was the opinion of Mr Derham that they served also for another purpose ; for a line being drawn from one ligament to the other, would not pass directly through the middle of the yolk, but rather towards one side, and would divide the yolk into two unequal parts, by which means these ligaments serve to keep the smallest side of the yolk always uppermost ; and in this part he supposed the cicatricula, or first speck of life, to reside ; which by being uppermost, and consequently next the hen, would be thus in the warmest situation. But this is rather fanciful than true, the incipient animal being found in all situations, and not particularly influenced by any.[1] The cicatricula, which is the part where the animal first begins to show signs of life, is not unlike a vetch, or a lentil, lying on one side of the yolk, and within its membrane. All these contribute to the little animal's convenience or support : the outer membranes and ligaments preserve the fluids in their proper places ; the white serves as nourishment, and the yolk, with its membranes, after a time becomes a part of the animal's body.[2] This is a description of a hen's egg, and answers to that of all others how large or how small soever.

1 Haller. 2 Ibid.