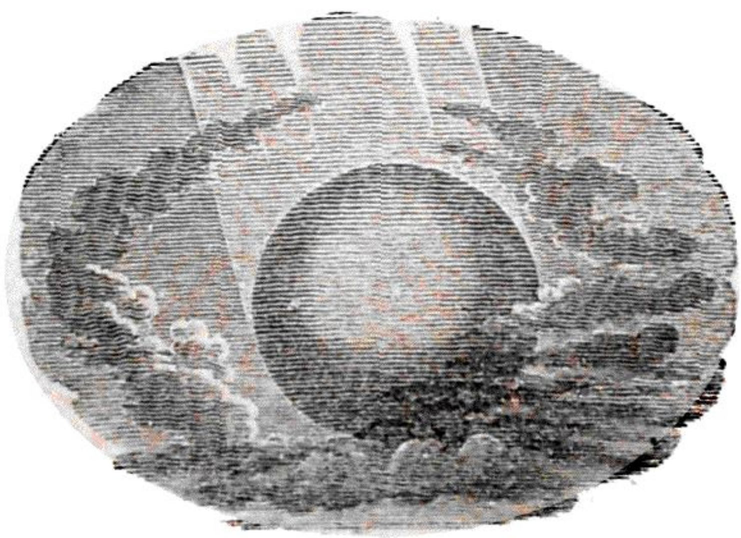
THE EARTH:

ITS PHYSICAL CONDITION AND MOST REMARKABLE PHENOMENA.

BY

W. MULLINGER HIGGINS,

FELLOW OF THE GEOLOGICAL SOCIETY
AND LECTURER ON NATURAL PHILOSOPHY AT GUY'S HOSPITAL.



NEW YORK:

HARPER & BROTHERS, PUBLISHERS,

329 & 331 PEARL STREET.

FRANKLIN SQUARE.

1858.

This Page Blank

CONTENTS.

INTRODUCTORY CHAPTER.

CHAPTER I.

THE EARTH IN RELATION TO THE UNIVERSE.

CHAPTER II.

CELESTIAL APPEARANCES.

CHAPTER III.

THE ATMOSPHERE AND ITS PHENOMENA.

CHAPTER IV.

ATMOSPHERIC PHENOMENA DEPENDANT ON THE DISTRIBUTION OF HEAT.

CHAPTER V.

PHENOMENA DEPENDANT ON THE DISTRIBUTION AND CONDITIONS OF LIGHT.

CHAPTER VI.

PHENOMENA DEPENDANT ON THE DISTRIBUTION OF ELECTRICITY.

CHAPTER VII.

PHENOMENA DEPENDANT ON TERRESTRIAL MAGNETISM.

CHAPTER VIII.

INTERIOR OF THE EARTH.

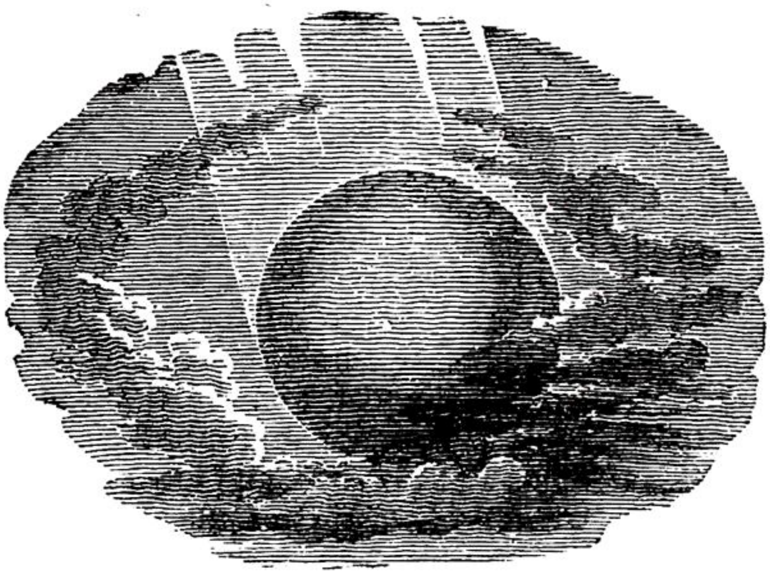
CHAPTER IX.

LAND AND WATER.

CHAPTER X.

SUPERFICIAL TEMPERATURE OF THE EARTH.

This Page Blank



INTRODUCTORY CHAPTER.

No branch of knowledge is more interesting or useful than that which teaches the physical constitution of the world in which we live, the appearances by which we are surrounded, and the laws which govern them. It cannot, however, be denied, that this subject has been greatly neglected, and that many educated men are as ignorant of the cause and influence of natural phenomena as though they had no interest in the provisions established for the support of animated being. This ignorance may be in part traced to erroneous systems of education; but it is also in some degree owing to a false estimate of the difficulties to be overcome in acquiring scientific knowledge, and an inadequate conception of its importance. It may not, therefore, be inconsistent with the character of this work, that we should present the reader with a few personal and relative motives to an acquaintance with the appearances of the material world, and the causes from which they flow; or, in other words, with the physical sciences.

Physical science, in its widest acceptation, embraces the investigation of matter in all its conditions and combinations. The entire material world comes under its cognizance. It not only considers the phenomena by which we are assured of existence, but determines the properties of matter under all its forms, and the mutual influence which different species of matter, having various subordinate properties, exert upon each other. It embraces a knowledge of the laws of combination and form, the peculiarities of each element in itself, and in its union with others; and attempts to reveal the secret processes by which the universe itself is regulated.

Such a subject, however, would be far too extensive for the mightiest human intellect, and we are compelled to form certain artificial divisions, that, by the united efforts of many individuals, we may advance to some knowledge of the universe itself. The consideration of material existence has in consequence been assigned to three classes of philosophers, the natural historian, the chymist, and the experimental philosopher. To the first of these is appropriated the study of animals and vegetables, and the form and localities of mineral substances. The chymist investigates all those phenomena which alter the composition of bodies, and endeavours to determine the nature of the elementary substances which enter into their formation. To the experimental philosopher is assigned the investigation of the laws of matter, and the nature and cause of all those phenomena in which it suffers change without altering any of the essential properties of its composition. But, as these boundaries are artificial, they are often broken down, for the gradation from one branch of knowledge to another is in nature so perfect, that it would be difficult to form such definitions as might prevent the student of one department from encroaching on the territories of others.

But although we have thus divided physical science, and have appropriated only so small a part to the experimental philosopher, it is still necessary to arrange the objects of his pursuit, and hence we have the sciences of hydrodynamics, electricity, and others. One great advantage has resulted from this subdivision. Men of investigation have been able to give their exclusive attention to particular subjects, and have thus been encouraged to pursue their inquiries at a time when knowledge was obtained with much difficulty. We would not, however, insinuate, that those who devote themselves to one science, are better fitted for discovery than those who have taken a wider view of nature. But, in the infantine state of philosophical knowledge, it was necessary, much more than at present, that there should be those who could give their undivided attention to the accumulation of facts, leaving their combination and the deduction of general laws to others, who had either more of the inspiration of nature, or had taken a more extensive view of physical causes. It is not the collector of flowers, or of minerals, who can give the character of a country, and theorize on the problematic causes from which it originated, but the man who has traced the connexions of its parts, and from an eminence surveyed its outline, and marked its features. And he who in the general pursuit of knowledge has cultivated that spirit of generalization which can alone enable him to perceive the relations of different phenomena, will be best able to determine the character and influence of the immutable laws of nature.

It may be here necessary to remark, that in the study of nature, all preconceived opinions must be renounced; and the mind must ever be in a waiting attitude, ready to receive the evidence of phenomena, whether they contradict or support the theories which have been adopted.

We can conceive it possible that an individual should have so entirely devoted himself to other studies, as to be ignorant of every discovery of modern chymistry. Such an individual would consider water as an elementary substance, and, were we to speak of its decomposition, a feeling of incredulity would certainly rise in his mind. But, let him proceed to the investigation, and with a few plates of copper and zinc, this apparently elementary body will be decomposed, and the two gases of which it is constituted may be collected in separate tubes. One of these, he is informed, is oxygen, which is a component part of air, and the supporter of combustion; the other, hydrogen. When combined in the gaseous state, they form a most explosive compound; and, in proof of this fact, they are placed in the same tube, and ignited. But this last experiment resolves them again into the liquid state, and drops of water are observed around the tube. What must be the result of such experiments upon the mind of the man who is thus suddenly driven from an opinion that he had received upon the sanction of all the ancient philosophers! This, however, is but a solitary instance of what has continually occurred, and we are thus admonished to renounce the influence of all preconceived opinions in philosophical inquiries, and to give every phenomenon its true estimate in the determination of a cause.

But while the student carefully avoids the interference of his opinions with the evidence deduced from phenomena, he must at the same time carefully guard his mind against those deceptions which may be practised on him by his senses. The senses are not always to be trusted, for they frequently deceive us when we most depend on their evidence; and this statement does not in any degree reflect upon the wisdom which was exerted in the formation of man, for his Creator has supplied him with that condition of mind which is amply sufficient to compensate for the inaccuracy with which those organs may convey an impression of external appearances.

But it may be still asked, what advantages are to be derived from the study of the physical sciences? and are they proportional to the labour which must be expended, and the mental discipline that must be suffered? These questions will be best answered by the mention of those results which ought to follow the investigation. We do not profess to teach the physical sciences, systematically, in this volume, but to explain the nature and cause of some of the most remarkable terrestrial and celestial phenomena, hoping to excite in the mind of the student an anxiety for a more extensive acquaintance with the sciences in general. It will not, therefore, be inappropriate to direct his attention to a consideration of those advantages which he may derive and confer upon society, by the study of this important branch of knowledge.

The personal advantages to be derived from the cultivation of natural philosophy, are chiefly mental. There are men who esteem themselves philosophers, and act as if this sentiment were highly enthusiastic and absurd. To what serviceable result can this or that study be applied? is the question which they are incessantly asking: by which they mean to inquire, how much money can be made of it. They are governed by the "auri sacra fames," and it for ever forbids their acquisition of the advantages in question. The best pleasures of life are but the flowers which beguile a laborious journey; and whatever may be the character of those we choose, they are usually obtained with difficulty. Those who select them from the paths of philosophy may receive titles of distinction, which, however, will not be conferred to encourage the pursuit, but to honour the title. The man who devotes himself to the advancement of science, must seek his remuneration in the influence which it will exert on his own mind; and although he may be unrewarded by his contemporaries, he will possess many resources suited to sustain his independent energy under circumstances that ordinarily produce an injurious effect on the character.

Almost the first impression produced by the study of nature, is a conviction of the existence of a universal Governor. And although we do not assert, or believe, that the Divine character is so evidently portrayed in material creation as in the inspired revelation, yet many principles of universal government may be deduced from the existence and action of those laws which regulate external phenomena. In every feature of nature, the philosopher may trace the evidence of mind, and his estimate of the wisdom displayed will be in proportion to the minuteness of his examination; and should he be deeply impressed with the universal and minute superintendence of a regulating Being, he will feel but little difficulty in committing himself to his government.

It has been asserted by some writers, that a close investigation of nature tends to cultivate or produce atheism. The habit which is acquired of tracing effects to their origin, leads, it is imagined, to a satisfaction with secondary causes, and induces the philosopher to close his investigations when on the verge of the noblest results; and investing physical operations with the attributes of Deity, to resolve all phenomena into the uncertain operations of chance, or to give the attribute of immortality to all things. We might fairly deny this assertion, by adducing numerous instances in which the capability of most profound philosophical investigations has been united with the most exalted veneration of the Deity; and it may be questioned whether those who have denied the existence of a Superintending Power, derived their opinions from the examination of nature. But, judging of the statement by the reason given to support it, we need not hesitate to deny both the one and the other, for what can be more absurd than to believe, that a habit of tracing effects to their causes, prevents the mind from distinguishing between a primary and secondary agent?

A thousand individuals may pass over a beautifully varied country, and feel no other emotion than that arising from the influence of the scenery on the feelings. If they should be informed that it owes its present appearance to the violent convulsions which have upheaved the crust of the earth, and that it offers a proof of wise and benevolent design, they will either express their wonder or incredulity. But the geologist estimates the importance of the cause that led to the result he sees. He knows that if the strata which compose the exterior or crust of our earth had remained in the horizontal position in which they were formed, no bed or channel would have been provided for the superficial waters, except those uncertain excavations which its own feeble motion could produce; and that, under these circumstances, the earth would have been an unfit residence for man. And if these causes had been less violent than they were, the repositories of the metals and coals, which are now in some places exposed on the surface, would have been buried beyond the most curious research of man. The geologist, therefore, can hardly fail to esteem this appearance, which excites no devotional feeling in the mind of the multitude, as one of a series of facts proving an intelligent design, and the choice of appropriate agents. This phenomenon, however, is an instance of provision for the welfare of man, prior to his wants; and was produced by an arrangement of causes calculated to secure a future state of things best suited to sustain the permanence and happiness of animated existence.

From the study of nature, then, we can hardly fail to gather ennobling views of the Universal Governor, or to deduce that a knowledge of his character is essentially important, as our happiness and safety are immediately under his control. It is difficult for those who have derived their opinions from revelation, to determine how far the attributes of Deity and his relation to man might be gathered from nature; but there can be no doubt that the sources of knowledge illustrate each other, and that we are surrounded by sensible proofs of his superintending care.

The cultivation of an acquaintance with the nature and effects of physical causes has some influence in raising our standard of happiness, by impressing us with the true dignity of the human mind. One design in the creation of the human mind was, probably, to secure the appreciation of the wisdom evinced in the action of natural causes, and the praise of the Creator as the necessary result; while, at the same time, the investigation of nature is a noble pursuit to man, increasing his nobility and power with his advance in knowledge. And hence it is, that the man who has even a slight acquaintance with the phenomena by which he is surrounded, and the causes from which they flow, feels himself raised above the great mass of mankind. He is conscious that the attributes of mind form the true and characteristic dignity of our species, and that their health and energy are the highest distinction of individuals. The laurels of the warrior are but the ensigns of our mortality; the achievements of the philosopher are, in some degree, evidences of our divine origin and immortal destiny.

But if there were no other personal advantage to be derived from acquainting ourselves with the physical constitution of the world in which we live, and if philosophy had no ulterior benefits to confer, the pleasures resulting from the pursuit would be sufficient of themselves to allure to the study. To satisfy the love of knowledge, a principle deeply implanted in the human mind, is in all cases a reward for toil, though the pleasure we derive from our pursuits is intimately associated with the kind of knowledge to be obtained. In the study of nature we seek to know that which engaged the attention of the Supreme Mind, and this thought makes us peculiarly conscious of the dignity of the pursuit.

When we have grasped a few of the general laws of nature, an additional satisfaction is derived from a contemplation of their harmony. The scenes by which we are surrounded are no longer inadequate to our gratification, but in every change we are able to trace the combination of causes from which it proceeds. The mind, intent upon its purest gratification, is ever waiting for instruction, and seizes upon every phenomenon as an illustration of causes with which it is already acquainted, or deduces from it one with which it was before unacquainted. Thus, in the very pursuit of his inquiries, the philosopher finds his reward.

But the physical sciences confer benefits on society as well as on the individual who is devoted to the investigation of them, and to the enlargement of their boundaries; and this they do, not only by providing rational amusements and methods of well employing time, but by enhancing the comforts and diminishing the number and amount of the evils of life. There is so intimate a connexion between the physical sciences and the arts of life, that it is almost impossible that the one should not derive some benefit from the advances made by the other. Science, however, is the pioneer, while art successfully applies the properties and powers of matter for the accomplishment of its purposes, often placing in the hands of science the means of extending its investigations. To elucidate these statements, two or three instances may be mentioned in which the study of physics has been most advantageous to the progress of the mechanical arts.

As a maritime people, our prosperity greatly depends upon our facilities of water communication with other nations; and consequently the improvement of naval architecture is, to us, of the greatest importance. The business of a naval architect is to construct a vessel, whether for war or burden, of such a shape that it may be conducted with safety over the ocean, and at the same time offer the greatest possible convenience for cargo and men. Could we pass in review the history of this art, we should not fail to observe that it has been entirely dependant on the progress of natural philosophy. There are two questions which immediately present themselves to the mind when we consider what is required in the construction of a vessel; what constitutes the stability of floating bodies? and what is the solid of the smallest resistance? The science of hydronamics answers both these questions, and thus provides data on which calculation may in all cases be established.

The stability of a floating body depends upon the situation of the centre of gravity in relation to a point called the meta-centre; that is, the point where the axis of the centre of gravity of the body, and of the fluid which it displaces, intersect each other. When this centre of gravity of the body is below the meta-centre, it is stable, when above, unstable, that is, it will upset; and when the two points coincide it is indifferent to motion. These facts are evidently calculated to assist the naval architect at all times to provide a vessel which, with her cargo, may float with stability upon the water.

But every floating vessel would not be suited for the purposes of navigation; for although all bodies experience resistance in moving through fluids, that resistance will differ according to their shape. A line-of-battle ship would require a much greater power to move her with a given velocity broadside first, than is required to move her in the usual manner. A broad surface, then, moving in a fluid, experiences a greater resistance than a narrow one; but from this it might be imagined that a swift sailing vessel ought to be built as narrow as possible, that she may cut her way through the waters. There is, however, a limit to the narrowness of a floating body, that it may be the solid of smallest resistance, and to determine this limit is in itself a difficult problem, though science lends its aid and solves the question.

If civil architecture might be taken as another example, it would be easy to show that the science of construction is entirely dependant on results determined by the philosopher. Unhappily, however, the undue attention that is, in the present day, paid to the decoration of buildings, has dismembered the profession; and all those works which require a knowledge of scientific facts, are now referred, by many architects, to a class of professional men called civil engineers. But whether the construction of harbours, bridges, canals, and railways, be under the direction of the architect or of the engineer, they cannot be properly constructed without the aid of philosophical principles.

The design of fortifications, the theory of gunnery, the art of guiding a vessel through the water, are all dependant on natural philosophy; and to understand the construction of the human body, or the practice of surgery, some acquaintance with it is essentially required. In every civilized country except England, it is a requisite branch of medical education; and we do not fear to state, that without an acquaintance with it, the philosophy of the animal frame cannot be understood. What are the limbs of animals but a combination of machines? what the heart and bloodvessels but hydraulic apparatus? and who would be acquainted with the construction of the lungs, the eye, and the ear, and yet remain ignorant of the sciences of pneumatics, optics, and acoustics? The study of natural philosophy may, in fact, be considered as an essential branch of medical education, and the student has a peculiar motive to the pursuit, for all the mental advantages are his, with the prospect of employing his knowledge to alleviate the misfortunes and suffering to which the human frame is exposed; while the accessions made to the efficiency of medical science by the study of physics ought to be sufficient to demand the attention of that profession, no less from philanthropic than from personal motives.

To enumerate the public and more general advantages which have resulted from a study of those phenomena that govern the appearances presented by material existence, would be an almost endless task. It has destroyed the monsters, superstition and priestcraft; it has aided the progress of civilization; has increased the comforts of the poor, and the wealth of the rich; has given to man the control of the ocean and of the air; established the kindred of humanity, and united the ends of the earth.

It is quite impossible, in the present day, to estimate the amount of mischievous influence exercised by systems of philosophical imposture on the ignorance of the early and middle ages. It is, doubtless, to be accounted for by the disproportion existing between the degree of their philosophical knowledge, and their ingenuity and taste in the elegant arts, and the luxuries of life. With all the susceptibility which refinement engenders, and yet with a total ignorance of religion and sound philosophy, the early nations were so deeply immersed in superstition and idolatry, as to be of necessity the helpless dupes of imposture. To what extent they were misled and bewildered is difficult to ascertain, for the secret recesses of the temple and of the cave have not been thrown open to our view. But this we do assuredly know, philosophy has detected the cheat, and silenced the impostors.

Scientific knowledge, associated with the more powerful energies of Christianity, has raised the human mind from a depth of degradation, the records of which cast a gloom upon our nature; and we now anticipate the arrival of the day when the intellectual and moral power of mankind will be completed by their united influence.

But science has accomplished more than this: it has not only assisted in breaking the chains of superstition, but has provided for that communication between man and man in all parts of the world, which, by allowing an interchange and communication of opinion, cannot fail to destroy prejudice and establish truth. We are not now the servants of the winds and the tides, but their masters; we have learned to combat nature with her own weapons, and in many instances have employed with advantage the very impediments that long opposed our efforts.

To the invention of the steam-engine we might refer as one of the most surprising effects of the application of the human intellect to the study of physics. A vapour is the moving power; and though it would appear, to the man who was ignorant of its properties, the least probable of all the attempts that have been made to obtain a power sufficient to counteract the impediments to motion resulting from natural causes, yet it is infinitely the most efficacious and controllable.

When rain falls upon the surface of the earth, it remains a short time, and disappears. It may have been thought by some unnecessary to investigate the cause, but the observer has satisfied himself with the supposition that it passes through the soil into the interior of the earth. There are, however, some strata through which the water cannot be filtered, strata which are impervious to its passage, and over their surface it passes as it would over a basin of oil. The rapid disappearance of the rain that falls on the earth cannot, therefore, in all cases, be attributed to the process of filtration, but is the result of that calorific influence of the solar rays, which, heating the surface of the earth, quietly carries away the redundant moisture as an invisible vapour.

The same process is in operation from the surface of all oceans, seas, and other masses of water; were it not for this, the amazing body of water which the Mediterranean Sea, for example, receives of the many rivers and tributary streams that flow into it, would necessarily raise its level. But no such effect is produced; there appears, on the other hand, to be a larger quantity evaporated from its surface than is carried into it by these rivers and streams, for there is a constant current of water rushing from the Atlantic, through the Straits of Gibraltar.

This is one of those wise provisions of the Creator, by which the continuance of vegetable and animal life is effected. But who, in the consideration of this phenomenon, or the almost analogous one of vapour rising from a boiling fluid, could ever imagine, from the knowledge of it, the application of steam as a moving power?—yet the philosopher, by continued investigation, ascertains the laws of action and of change, and at last invents the steam-engine

The application of the steam-engine is scarcely less remarkable than its invention. It has relieved man of part of that curse which rests upon him; "by the sweat of thy brow shalt thou eat bread." It saws his timber, and forges his iron; constructs the materials for his clothing, and grinds his corn, leaving him little more than a spectator of its marvellous operations. But its most remarkable application is that by which it becomes the source of locomotion. It ploughs the mighty waters in its own strength, and virtually connects remote cities and nations, in spite of distance and the obstacles which nature herself has interposed. The railway and the steamboat give an importance to this and succeeding ages which cannot be too highly estimated. In order that despotism should be destroyed, and Christianity be established, a freedom of access between the several sections of the human family is almost essential. The means have been already provided, and the time, we trust, is not far distant, when, by their combined influence, all nations will be united in the bonds of a catholic philanthropy, if not of a common faith.

If the accuracy of these remarks and deductions be admitted, the importance of physics will not be denied. The works of God are in all things our model; and when we attempt to apply natural agents to accomplish our purposes, we only imitate that which is constantly going on in the material world. Men are accustomed to boast of the profundity of their knowledge, and the extent of their influence over natural agents, but their efforts are like those of the child, who blows a soap bubble to mimic the upward flight of the aeronaut. The philosopher is but nature's schoolboy, and his efforts are but attempts to understand and apply the agents by which God governs his material creation. All true science is written on the page of nature; and the man who can explain the phenomena by which he is surrounded, and the character and habits of the causes which give them birth, is in every respect a philosopher. In this nature God has in some degree developed his own character, but he has thrown a shade over it, as though to preserve it from the incurious gaze and profane violation of the indifferent and contemptuous. Mind is not less under the guidance of law than matter; and if there be one principle more distinctly developed than any other, it is the necessity of a means to a result. A casual or careless attention to one or two series of phenomena is not sufficient to determine their origin, and much less to ascertain the nature and activity of those causes by which matter is universally governed. The human mind has never arrived at any important discovery, but by slow and progressive means. We have not a single instance of the discovery of a valuable philosophical fact by conjecture; and had this statement been known and appreciated by the schoolmen of Greece, Rome, and the middle ages, the modern philosopher would be more engaged in teaching than in learning. Experiment is the foundation of philosophy; and for the want of it men have established dogmas for causes, trusting opinions as data, and building hypotheses on unsound foundations. Every science within the boundary of natural philosophy offers proofs of this statement, and illustrates the value of experiment.

But let it not be supposed that in insisting on the high importance of experiment we depreciate the value of mathematical studies. They are important, and necessary to him who desires to investigate with minuteness any branch of physics; but they are not indispensable to an accurate knowledge of principles, and we have acquaintance with many successful experimenters who are utterly ignorant of the mathematics. In one case we entirely trust to intellectual energy and the infallible power of numbers; in the other to reason and to our senses, which, though they offer a readier, and generally a more appreciable species of evidence, involve at the same time greater liabilities to error. The mixed method of investigation is, therefore, always to be preferred.

The reading public, though not so opposed as it once was to scientific research, is not to be attracted by mathematical erudition, or the statement of prolix propositions, but must have plain reasons, or experiments, before it is willing to admit the statements of those who pretend to teach philosophy. The greater number of readers are unable to appreciate mathematical demonstrations; and there can be no doubt that their general use in elementary works, and the unpopular manner in which scientific truths were explained, have tended to prevent the progress of scientific knowledge. We must interrogate nature by experiment, availing ourselves of the assistance of the sciences of quantity and number, as useful auxiliaries in the study of the more complex principles of motion as exhibited by various agents; but, in the explanation of phenomena, the simplest methods of demonstration ought to be used, and the most familiar illustrations should be chosen to allure and encourage him who is in search of information.

These hinderances to the progress of scientific knowledge have been in our day removed; and though the process of education has derived little advantage from it, the fault is with the teacher rather than the public. The faculties, capabilities, and condition of the mind are never studied, but ten years of vivacious and energetic being are occupied in the acquisition of words. A new inhabitant of earth, surrounded by strange and novel appearances, governed by a curiosity to know something of that which affects his senses, and produces the sensation of pleasure or of pain, is checked in every inquiry that he may make, and is compelled to cultivate a single faculty, and to attain a knowledge of words and criticisms · is in fact doomed to pass his existence in a world which, for aught he knows, has not a single attribute of perpetuity. We may be permitted, from experience, to pity the mind that is doomed to a lengthened slavery in the acquisition of words, and the improvement of memory, when observation and curiosity are the predominating principles of mental activity. To deny the value of an acquaintance with foreign languages, and even of those which are so improperly called the dead languages, since they, in a great measure, form the literary taste of our own and other nations, would be to deny the value of accuracy of style and expression, energy of thought, bursts of eloquence, sentiments of morality, and knowledge itself. There are minds that break the trammels of system, and, possessing a knowledge of languages and literary elegance, add to it a knowledge of men and of things which gives lustre to learning; but minds of less strength are too often buried under lexicons and grammars, or acquire a distaste for all species of knowledge. The error is not in the acquisition of languages, but in studying them exclusively at a wrong time. It is not our intention to advocate the importance of scientific knowledge, by misrepresenting the claims of literature, but rather to urge the necessity of their union, and the combination of their efforts; for though "the mind is the standard of the man," it is ever desirable to remember that it dwells in a material tabernacle, and is acted upon by material causes.

Although much has been done calculated to diffuse knowledge, education is still in a great measure confined in its objects, and frequently injurious in its effects. The establishment of philosophical institutions has certainly a tendency to correct the evils which flow from the system of education adopted in our schools, and it is now little less than culpable negligence in a teacher if he does not avail himself of the aids which these societies offer. But we can expect little improvement in the system, until both the teacher and the public feel the necessity of blending literature and science and of regarding the peculiarities of mind which may distinguish individuals. It is seldom that the faculties of mind are uniformly developed; and although it may be necessary to correct the inordinate passion which is sometimes indulged for a particular pursuit, yet it is evident that to repress it altogether would be to destroy the energy of a mind, and to create a disgust for learning itself. Scientific knowledge is at least as important as ancient literature, but we should as much regret an exclusive attention to it in our schools, as we do the system now adopted of only teaching the classical languages. All minds are not equally suited for the same pursuit; and unless some circumstance in after life should rouse to activity in that department of knowledge for which the individual is by nature adapted, the energies of his mind must be irretrievably lost to society.

CHAPTER I.

THE EARTH IN RELATION TO THE UNIVERSE.

No science can be perfectly understood by a person who has confined his attention to the facts it teaches, for philosophy may be compared to a golden chain, which men are compelled to examine link by link, unable at once to perceive the connexion which exists between its parts. So, if we attempt to explain the phenomena we witness upon the earth's surface, without previously acquainting ourselves with the conditions of the body, and the relation it bears to those bodies by which it is surrounded, we shall always be sensible of the incompleteness of our knowledge, and may, in many instances, be led into error. All the causes acting upon the surface of the earth may be in themselves suited to sustain and nourish the creatures by which it is inhabited; but the relation it bears to other bodies may, for aught the mass of mankind know be calculated to derange their action, or to destroy the planet itself. Our first object, therefore, must be to ascertain the celestial relations of the earth as a member of the universe.

THE FORM AND DIMENSIONS OF THE EARTH.

From a casual examination of external phenomena, an observer would probably be led to the conclusion, that the earth is an extended plane. This opinion was long entertained by the illiterate, and in different periods of the history of science was believed and taught by the learned. Fabricius, in his "Bibliotheca Græca," gives an account from Photius and others, of the theory proposed by Cosmas Indopleustes, which greatly resembles the systems once taught in the Hindus and Egypt. This theorist maintained that the earth was an immense plane, surrounded by an impassable ocean. A conical mountain was supposed to be situated towards the north, and the sun and stars to perform their diurnal revolutions round it, the sun itself having an oblique motion. By this wild conjecture, he explained the unequal length of day and night, and the variation of the seasons; and accounted for the motion of the heavenly bodies by the assertion, that they are carried round in their courses by celestial spirits.

It is almost impossible to determine the influence of an erroneous theory in retarding the progress of scientific knowledge, and in delaying those benefits which that knowledge confers upon society. When error is cherished as truth, the mind has no incitement to investigation; but, being satisfied with the false opinion, exerts its ingenuity and intelligence to sustain it in the esteem of others. It is a proverbial remark, that first impressions are the strongest; and it must be admitted, that it is more difficult to destroy a belief in a false principle than to discover truth. But this difficulty becomes still greater when the public has adopted the erroneous opinion, and to correct it requires a mind that has sufficient daring to disregard the sentiments of others, and to appeal to posterity rather than its contemporaries. But it must not be forgotten, that erroneous theoretical principles prevent the practical results which may always be expected to follow the establishment of scientific truth. Had the hypothesis of Cosmas Indopleustes maintained its influence over the public mind, it would have prevented men from attempting the investigation of the surface of the earth; for the conviction that it was surrounded by an impassable ocean could not have acted as an inducement to attempt its navigation, but fear would have prevailed over curiosity, and the hopes of every man must have been centred in the society of which he happened to be a member. All the benefits that have resulted from the distribution of the human race over the surface of the earth would have been retarded, commerce would everywhere have been restricted, and civilization have been unknown, if this hypothesis had not been disproved. It will therefore appear, that the reception of error in philosophical inquiries, while it retards the advancement of knowledge, must entirely prevent all the beneficial practical results which are the consequents of ascertained philosophical truth.

A casual or imperfect observation of phenomena might in the present day lead an ignorant observer to imagine the earth an extended plane, but a careful investigation could scarcely fail to convince him that his first impressions were erroneous. We can conceive an individual determined to judge for himself, and, having no attachment to any opinion that does not commend itself to his mind, to trace the phenomena he observed to their cause, and approach to a demonstration of the true form of the earth. "Wherever I stand," he might say, "there is a vast extent of space above me, and beneath my feet an impassable mass of matter; and hence I know that the earth is limited, at least on one side. But the sun rises in the east, and sets in the west, and this it does day after day; and when it disappears, I observe the moon and the stars to take the same revolution from one extremity of the hemisphere to the other; and I may deduce from this appearance, that the earth is not indefinite in extent, but is an entirely independent body, and, having limits, it must have figure. But I have often observed that when I stand upon a flat and extensive country, or in a vessel at sea, I appear to be placed in the centre of a distinct circular line, which is not, however, the limit of my vision; for lofty objects, such as the steeples of churches, and the topmasts of vessels, are distinctly seen beyond it; and when I ascended an eminence, the lower parts of the same objects came into view. Such a phenomenon as this," the inquirer might say, "can only be accounted for by supposing that those portions of the earth on which I have made these observations are curvilineal, and as other persons have observed the same appearances in distant places, there is some evidence that the earth has a convex surface." Thus far an inquisitive mind might proceed, without being able to determine whether the earth was a globular body, or an irregular mass with a convex surface. But let him be informed that a navigator, leaving some shore in one direction, has, by keeping the head of his vessel towards the same point of the compass, returned to it in an opposite direction, and he will no longer doubt that the earth is a spherical body.

To determine the precise form of the earth requires observations of a more accurate character, and more artificial means of inquiry are necessary. If the earth be a spherical body, we may draw a line round it in any direction, and by measuring it we might not only determine the precise form of the earth, but also its dimensions. How difficult soever this may appear, it has been done, and we have thus become acquainted with the form and dimensions of the earth. Those lines which are imagined to be drawn round the earth, passing through the poles, are called meridians; and if the earth were round, all these lines would be circles, and we might divide them into any number of parts, which would be equal to one another; but if the meridians be not exact circles, then the parts would differ in measurement the one from the other. Let us then divide a meridian into three hundred and sixty parts, that is, into degrees, and measure one of those at different places, and we find that the length of a degree is greatest near the pole, and least at the equator. The following table, given by Professor Airy in his paper on the Figure of the Earth, and by Sir John Herschel in his Treatise on Astronomy, will show the length of a meridional degree at different places, as calculated from the results of the most accurate experiments.

1845 G. B. AIRY FIGURE OF THE EARTH, ENCYCLO. METROPOLITANIA Vol 5, pp 165-240

Country.	Latitude of the middle of the arc. D. M. S.	Arc measured. D. M. S.	Length of the degree concluded.	Observer.
Sweden . . .	66 20 10	1 37 19	365782	Svanberg
Russia . . .	58 17 37	3 35 5	365368	Sturve
England . . .	52 35 45	3 57 13	364971	Roy, Kater
France . . .	46 52 2	8 20 0	364872	Lacaille, Cassini
France . . .	44 51 2	12 22 13	364535	Delambre, Mechain
Rome	42 59 0	2 9 47	364262	Boscovitch
America, U. S.	39 12 0	1 28 45	363786	Mason, Dixon
Cape of G. Hope	33 18 30	1 13 17½	364713	Lacaille
India	16 8 22	15 57 40	363044	Lambton, Everest
India	12 32 21	1 34 56	363013	Lambton
Peru	1 31 0	3 7 3	362808	Condamine.

From these and other observations we deduce that the earth is not a perfectly round body, but that its real figure is that of an oblate spheroid. A spheroid may be either oblate or prolate, the former being flattened, and the latter drawn out, at the poles.

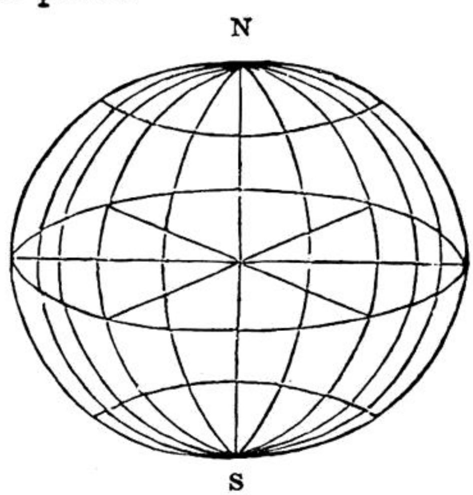


Figure of the Earth.

The following are the dimensions of the earth, as calculated from the best series of meridional arcs.

	Miles.
Greater or equatorial diameter . .	7925.648
Lesser or polar diameter . . .	7899.170
Difference of diameters, or polar compression	26.478

THE REVOLUTION OF THE EARTH ON ITS AXIS.

Having ascertained the form of the earth, there will be little difficulty in determining the relation it bears to the celestial bodies. It has been already stated that an observer, by carefully examining the position of the stars for a few hours, would discover that they have a regular unaccelerated motion. All the celestial bodies are moving, but their motion is uniform, and each one is in relative rest to the others, pursuing, from the moment it rises, an undeviating path towards that opposite point where it is to set.

This apparent motion of the stars may either arise from some proper motion in the heavenly bodies, or from a revolution of the earth on its own axis: either of these suppositions will account for the phenomenon to which we have alluded. If the appearance be supposed to result from the proper motion of the stars, it must be acknowledged that they are fixed in an enormous concave sphere, which has a perpetual uniform revolution; for it is hardly possible to imagine that each individual body has a motion of its own, so adapted to the motion of all the others as not to change its relative position. The immeasurable distance of the stars, however, forbids the supposition that they are all fixed in a revolving sphere, for such mechanism would be in itself most cumbersome, and unlike the simple arrangements commonly employed by the Creator for the accomplishment of his purposes.

It is far more probable that the earth has a revolution on its axis, and this supposition will enable us to account for all the appearances that are presented by the celestial bodies. If the earth has a diurnal revolution on its axis, an observer, situated on its surface, will participate in its motion; but as his horizon remains fixed, and as the objects around him have the same motion as himself, he will imagine that he is at rest. But as the horizon of the individual revolves from west to east, so the heavenly bodies have an apparent motion from east to west: and for the same reason, a person in a sailing vessel may imagine the shore to be receding from him, instead of attributing its apparent motion to the real motion of the ship in an opposite direction. The whole hemisphere, then, upon the principles of this explanation, makes an apparent revolution; and in that period required by the earth to perform its diurnal revolution, the stars will return to the relative places they before occupied; and as the velocity of the earth's rotation is uniform, this will occur in equal times.

But let us suppose our observer to pursue his investigations a little more closely. He has already discovered that the stars apparently move in the arc of a circle, rising in the east and setting in the west. Towards the south there are some that just rise above the horizon, take a short arc, and disappear; while towards the north there are some that never set, but revolve in very small circles around a point, which is called the north pole; but this point is not marked by any star, although there is one so near to it, that the unassisted eye cannot discover its motion. As soon as the observer has ascertained these facts, he becomes conscious that there is one section of the celestial sphere that is hidden from his view; for as there is a segment containing stars which never set, so there must be one in which stars revolve without rising, and these are called the south polar stars. To obtain a view of these, he must travel southward. As he proceeds on his journey, the north polar stars will approach the horizon, and the stars of the southern hemisphere will be proportionally raised. When he has reached that line on the surface of the earth called the equator, that is, an imaginary line dividing it into hemispheres, the poles will be in his horizon, and every star will appear to perform half its revolution above and half below his horizon, and no part of the heavens will be hidden from his view. And here we may suppose the inquiring traveller to be struck with the fact, that although the paths of the stars are so different in extent, those which rise exactly in the east having much the longest arcs, and those at the poles the shortest, yet every star is above the horizon for the same period of time. But if the observer still travel southward, the south pole of the heavens will be raised above his horizon, and the north pole will be depressed below it; and when he is as near to the south pole of the earth as he was to the north pole at the commencement of his journey, the phenomena will be entirely reversed; the south polar stars will never set, the north polar will never rise; and if he could still travel southward and reach the pole itself, the stars would appear to revolve in circles parallel to the plane of his horizon, and to one another.

These results cannot fail to confirm the conviction, that the motion of the stars is only apparent, and that it is produced by the revolution of the earth on its axis.

THEORY OF THE FORMATION OF THE EARTH FOUNDED ON ITS DIURNAL REVOLUTION.

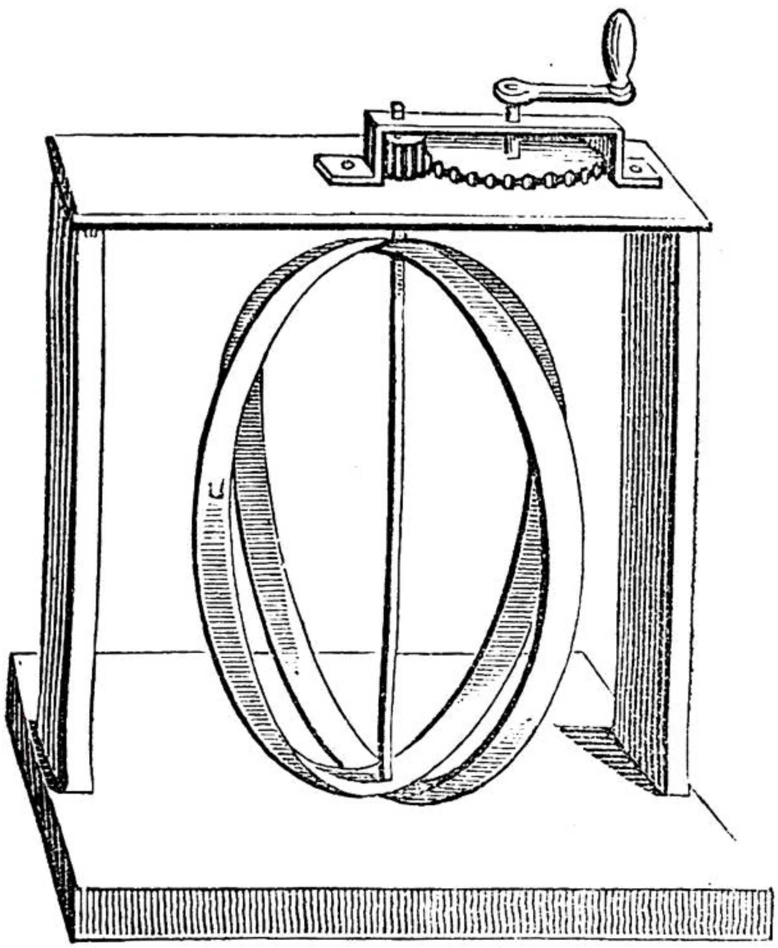
Now it is a singular fact, that these results perfectly accord with the combined theoretical deductions of astronomers and geologists. The covering or crust of the earth is known to consist of a series of strata of different substances and of various thicknesses. Beds of clay and marl, limestone and sandstone, gravel and sand, are promiscuously mingled together, many of them containing the remains of marine and fresh-water animals, and all of them bearing evidence of their formation as resulting from the deposition of water. Some have been formed at the bottom of rivers and lakes, and some in seas and oceans, while others have been produced by casual catastrophes, which have caused the waters to leave their channels, and sweeping over localities, or the entire surface of the earth, to destroy rocks, and round the fragments they have broken from the parent bed. The same process of destruction and reproduction is going on in the present day, though not perhaps to so great an extent as at the time when the crust of the earth was formed. If the beds of rivers, or of lands that are frequently flooded, be examined, strata of sand, mud, or gravel will be found, as produced by sediment from the water that has flowed over them; and many contain the remains of the animals that once lived in the water, or were destroyed by its means. Wherever strata, having the same characters, and containing organic remains, are found, it is fair to deduce, how deep soever they may be below the surface, that they are attributable to causes similar to those which are now active in the production of rocks. But such strata have been seen in all those parts of our globe which have been visited by man, and hence it would appear, that the dry land has actually been produced by water; and that the particles which, united together, now form the superficial covering of the earth, must at a former period have floated in loose unconnected particles in pre-existing rivers and oceans.

Taking these statements as the legitimate deductions of geological inquiry, they may be so applied as to account for the present form of the earth. If the earth had been formed a perfectly spherical body without a motion on its axis, all the water, however distributed on its surface, would have left the places it occupied, and have rushed towards the poles, leaving a ridge of barren mountains round the equator. But if it had been possessed of the same form, and had received an impetus giving it a revolution on its axis, the centrifugal force being greatest at the equator, the water would have been accumulated there, and a mountainous ridge of rocks would have been exposed at the poles.

It may not be perfectly understood by the reader what is meant by the centrifugal force. When a body is made to revolve on its axis, there will always be an attempt in the particles composing that body to fly off from the centre of motion. If a bucket of water be suspended by a string, and a rapid rotary motion be communicated to it, the water will accumulate, and form a sort of wave round the side of the vessel: and if we could give the same motion to a substance which consisted of very loosely connected parts, they would fly one from the other, and leave the string by which they were suspended. Now these are the results of the centrifugal or centre-flying force.

But it is well known that the force with which a particle is urged to fly away from the centre of motion increases with its distance from the centre, and consequently, in every globular body, that line of superficial particles intermediate between the points which terminate the axis of revolution, will have the greatest centrifugal force. From this statement it follows, that the equator of the earth must suffer a greater centrifugal force than any other part of its superficies. A very pretty instrument is used by lecturers to illustrate this fact. Two elastic iron hoops are united together, and placed upon an axis, having a capability of compression, so that a pressure upon the top would cause a swelling out of the centre or equator. These hoops are put into motion by a multiplying wheel, or by a band and wheel, which, in consequence of the centrifugal force, causes an expansion of the equator, with an attendant depression of the poles.—(*See p.* 32.)

Now let it be supposed that the earth, when created, was a perfectly spherical body, and that it had a revolution on its axis, then an immense body of water must have been accumulated round the equatorial regions. But water is everywhere charged with the *débris* of rocks, which it forms or collects in its passage from one place to another; and as i has always had the same force under the same circumstances



it must have done this from the beginning. But rocks are formed by the sediments deposited by water, and the detritus it accumulates; therefore rocks must have been formed in greater amount round the equator than upon any other part of the earth's surface, and hence the greater equatorial diameter.

We do not assert that the earth must necessarily have derived its present form in this way, but that these theoretical considerations will account for the form which we know it to possess; and we are thus led to observe the influence that one branch of science exerts upon another. The sciences are arbitrary classifications of the laws under which various causes act upon different kinds of matter, or matter under different forms, and of the phenomena produced. To suppose that the various physical sciences are distinct one from the other, would be to invade the unity of design and harmony of effect constantly observed, and necessarily existing in material creation. The limitation of our capacities may render this division or classification necessary, but we must be careful to remember that it is still artificial, and that the sciences are not independent branches of knowledge. This view of the physical sciences will prove the propriety of the effort we are now making, to avail ourselves of their united assistance in explaining the conditions of the earth; and sufficient has already been said to convince the reader that an extensive series of phenomena, such as we behold wherever we may be placed, can only be understood by an acquaintance with many branches of knowledge.

The first doubt as to the perfect sphericity of the earth, is said to have arisen from observations on the pendulum. M. Ritcher, while observing the transits of the fixed stars in the Island of Cayenne, noticed that the pendulum of his clock moved at a rate of 2′ 28″ a day less than it ought, as regulated by the motion of the sun, and found it necessary to shorten the length of his pendulum nearly one fourth of an inch, in order that it should make vibrations equal to those it made at Paris. This singular phenomenon excited the attention of the astronomer, and, when inquiring into the cause, he was induced to suspect that the earth was not perfectly round.

It may not, however, be quite clear to the reader, what connexion there is between the vibration of a pendulum and the form of the earth, and we may be permitted to illustrate the statement by a few remarks. The instrument we call a pendulum consists of a heavy body suspended by a slight cord or thread, and is frequently used in combinations that are intended for the measurement of time. It must not, however, be supposed, that the pendulum is in any case the moving power; it acts as a regulator in clocks, and the motion originates in the fall of a weight, or in the recoil of a spring attached to the machine. Weights are invariably used in clocks, springs in watches; and the latter are generally regulated by a balance-wheel, and not by a pendulum. The contrivance by which the pendulum of a clock is connected with the train of wheels, and regulates their motion, is called the escapement, and of this there are several varieties, as the lever, and the dead beat, the latter being so named on account of the peculiar sound it produces.

The theory and laws of the pendulum will be easily understood. When the ball of a pendulum that has been freely suspended from a point is raised from the perpendicular, and is allowed to fall by its own weight, it begins a series of vibrations, which would be infinite, if the motion were not retarded by the friction upon the point of suspension, and the resistance of the air. It falls to the perpendicular position from which it was drawn, by virtue of the same power that causes a body to fall to the earth; the force of gravitation. But when it comes to this position, it has acquired a certain velocity, sufficient to urge it upward on the opposite side, and to cause it to describe as large an arc as in falling. The pendulum, therefore, is in theory capable of a perpetual motion.

Galileo discovered that the oscillations of a pendulum are isochronous, or performed in equal times, whether the arc be large or small, within a certain limit. He was led to this discovery by observing in the church of Pisa the vibrations of the large chandelier which had been left swinging when the candles were lighted for the evening service. But the law that is most important for us to notice is, that the times required to perform an oscillation are as the square root of the length of the pendulum.—If, for instance, there be three pendulums, whose lengths are as one, four, and nine respectively, the oscillations of the second will require twice the time of the first, and the third three times, because one, two, and three, are the square roots of one, four, and nine. As the oscillations of the pendulum vary with its length, a certain length will be required that it may beat seconds, or, in other words, vibrate sixty times in a minute. For the latitude of London it must be thirty-nine one fifth inches long; but a pendulum that will beat seconds in one latitude will not do so in another.

The attraction of gravitation is a force with which all matter is endowed, and belongs to particles as well as to masses, all bodies universally attracting each other, directly as their masses, and inversely as the squares of the distance. But when a body is made to revolve on its axis, a new force is called into action, which in some measure resists the attraction of gravitation. In the case of our earth, for instance, gravitation would cause it to fall towards, or into the body of the sun, but the centrifugal force solicits it to fly away from the sun; and these two forces being adjusted, the earth retains its place. If the force of gravity were to cease, the earth would fly off in a tangent to that part of its orbit in which it happened to be situated at the moment; and if the earth were to cease its revolutions, it would fall towards the centre of gravitation. Connect with this statement the fact, that the centrifugal force is in proportion to the distance of the body from its centre of attraction, and there will be no difficulty in understanding the application of the pendulum to the measurement of the earth.

If the attraction of the earth were not sufficient to neutralize the effect of its centrifugal force, the detached bodies on its surface would be thrown off; but even under present circumstances it diminishes their weight at the equator. If the earth did not revolve on its axis, a substance would have the same weight at all places equally distant from the centre. But as the centrifugal force, which attempts to throw all bodies from the axis of rotation, increases with the distance, so the force of gravity must decrease from the poles to the equator.

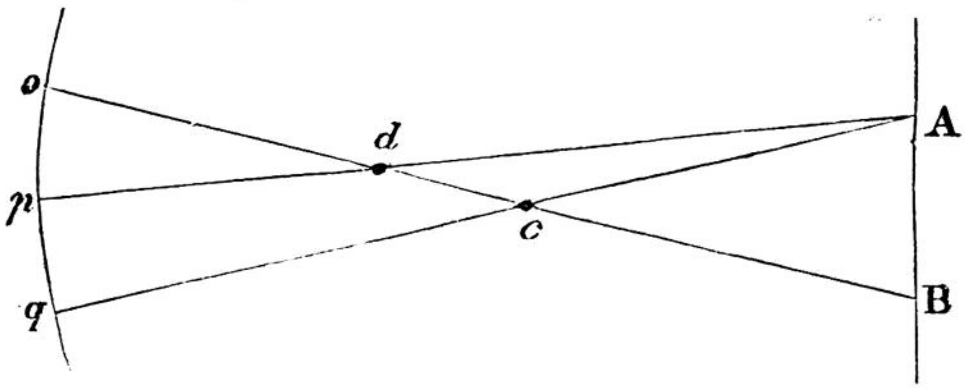
From this explanation it follows, that the fall of bodies is accelerated from the equator to the poles; and as the pendulum is a falling body, its oscillations must be accelerated in the same proportion; and hence it is that the length of a pendulum must be altered to make it perform the same number of vibrations in all latitudes. Now it is well known, that in the instance of a spheroid of rotation, the centrifugal force varies from the equator to the poles, as the square of the sine of latitude.

From these principles we may deduce the real form and dimensions of the earth; and although the method may appear to the general reader to be somewhat involved, yet it is capable of as great accuracy as any plan of measurement that has hitherto been adopted. While the result of the experiments that have been made to determine the form of the earth by actual measurement and by the oscillations of the pendulum, prove it to be an oblate spheroid.

THE RELATIVE REST OF THE FIXED STARS.

The thoughtful reader may still have some difficulties connected with this subject, and be unable to account for the unvarying position of the stars in relation to one another

He must know, that when he is looking upon objects that are near him, they present different relative positions according to the situation of the point from which he views them. If he alter his position only a few feet, the relative places of the nearer objects will be greatly changed, but in those which are more distant the change will be less distinct. Acquaintance with this fact may have already induced him to imagine that the stars do not change their relative places, from whatever point he may view them, because they are so far distant that there can be no comparison between the distance of the stars and the distance from each other of the two places from which he views them. We are, in fact, accustomed to refer all objects to an imaginary sphere of indefinite radius, the eye being its centre; and in proportion to their nearness, their relations will change with an alteration of the place from which they are viewed.



Let A and B be two positions from which we view the two objects *c* and *d*. At B we should refer both the objects to the point *o*; but, as we advance towards A, the objects apparently change their place; and at A we should refer the object *c* to the point *q*, and the object *d* to the point *p*, the nearer object subtending a greater angle, A *c* B, than the more distant, A *d* B.

This angular motion of an object on our sphere of vision, arising from our change of place, is called the parallax. But, as the amount of parallactic motion decreases as the distance of the object increases, it will cease altogether when the object is very far removed, and this is the case with the fixed stars. Were it not so, the stars would present different relative positions; on the horizon they would be crowded together, interfering the one with the other, and, as they approached the zenith, they would expand and come into view

From these remarks it follows, that the dimensions of the orbit of the earth are absolutely imperceptible when com-

Constellation Orion.

pared with the distance of the stars; but astronomy offers us no method by which to determine the distance of the nearest fixed star. To such a nicety have the means in our power been applied, that, had any of the stars yet examined possessed an angle amounting to one second, that is, if the earth's orbit subtended an angle amounting to one second, it must have been detected. But, although we cannot determine the distance of the nearest fixed star, we do know that it cannot so little as 19,200,000,000,000 miles

It may be worthy of notice, that astronomers in every age, for the convenience of reference and description, have thought it desirable to divide the fixed stars into groups or constellations, to which different names have been given. These divisions, though arbitrary, have been generally acknowledged and used by modern astronomers, and some new ones have been introduced. It has not, however, always happened, that the figures proposed by the ancients have been accurately retained, and in some instances they have been actually reversed. The position of the stars frequently bears little or no resemblance to the drawings which are supposed to represent them, but they are of much advantage to the student, and serve him as an artificial memory. Who, for instance, can have attentively examined the representations usually given of the constellations Orion and Ursa Major, and then have sought for them in the heavens without finding them? Some attempts have been made to change the names of the constellations, and to introduce a new division of the celestial sphere. The venerable Bede proposed to name the twelve signs of the zodiac after the twelve apostles, and Judas Ichillerius gave Scripture names to the other constellations. It is, however, quite evident, that any innovation upon the established order would introduce many practical inconveniences, and increase the difficulties and errors of a comparison of ancient and modern observation.

THE PLANETS.

We have hitherto considered all the stars to be fixed at relative distances from each other, without any individual motion; but an observer who has paid sufficient attention to determine the facts already mentioned, cannot have failed to discover, that some of the celestial bodies, and these the most conspicuous, are constantly changing their positions, and wander abroad among the multitude of less restless worlds. The moon has ever been among poets the emblem of fickleness, not only for the ceaseless variation in the size and form of her illuminated disk, but for her varying motions over the broad face of the heavens. These erratic bodies are called planets, and perform, in various times, their independent circuit of the heavens. The fixed stars also have a change of place, but it is so unimportant that no material alteration has been produced during the whole of that period in which the heavenly bodies have been astronomically considered.

We are accustomed to judge of distances and magnitudes by the organ of sight, but it entirely fails us when used in relation to the heavenly bodies. An ingenious and shrewd observer may, however, deduce from appearances, without instruments, many important facts concerning their motion and relations, and he may also gather some information concerning their magnitudes and distance, though it will be by no means satisfactory, nor approximate to a systematic knowledge. He may, for instance, discover that the clouds are nearer to the earth than the celestial bodies, for they often spread themselves like a veil over the entire surface of the heavens; and upon the principles already explained, he may prove that they are but a few miles high, as they are only seen under particular forms over a very limited district. But the moon is at a very great distance, for she is seen over one half of the earth at the same moment, yet she is not so distant as the sun, for she sometimes comes between the earth and that body, producing a solar eclipse. He may also happen, by the observation of a transit, to discover that Mercury is sometimes nearer to us than the sun; but all the information that can be thus attained will be disjointed and imperfect, and it is only by very accurate observations with the aid of instruments, that any valuable or correct information can be ascertained. To trace the methods by which our knowledge has been acquired, would be inappropriate in this place; such a general outline of results as may be sufficient to acquaint the reader with the relations of the earth to the wandering bodies and the sun, is all that will be attempted.

The earth is an individual and almost unimportant member, of a system of bodies of which the sun is the centre. The solar system, as it is called, consists of eleven planets, which revolve round the sun in orbits nearly circular, some of them being attended by satellites that have orbits of nearly the same form. These motions are produced by the attractions of the central bodies; that of the sun prevents the planets from flying off into space, and that of the planets supports the satellites. All these bodies have therefore an influence on one another at a distance, each one assisting in connecting the whole as securely as though they were absolutely united by a tangible substance; and that influence is the attraction of gravitation.

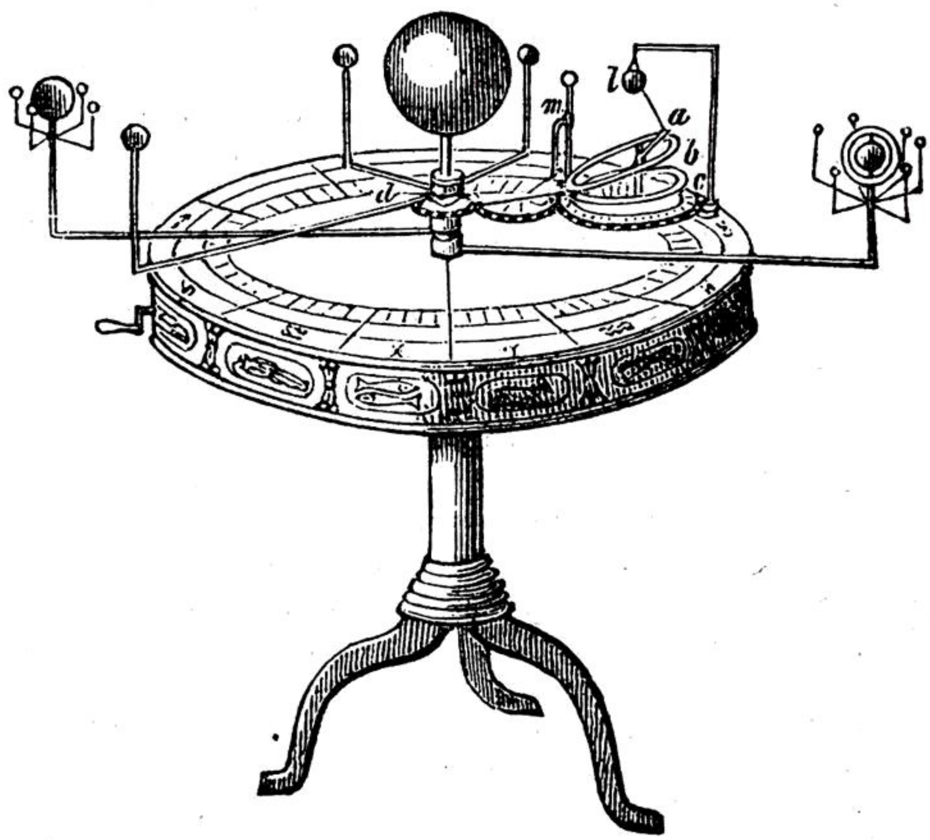
Four of the planets, Venus, Mars, Jupiter, and Saturn, are not only visible to the naked eye, but may almost be distinguished by their remarkable brilliancy. Uranus can scarcely be seen without a telescope, and Mercury, though visible as a large star, is only occasionally in view, on account of its nearness to the sun, in the splendour of whose beams it is lost. Its greatest angular distance from the source of light is about 29°, and it is either seen as a morning or an evening star. When it is to the east of the sun, and is sufficiently distant from it not to be lost in its retiring glory, Mercury may be seen in the western horizon; when to the west, in the eastern horizon, shining with peculiar brilliancy, as the harbinger of its lord. Ceres, Pallas, Vesta, and Juno, are never seen by the naked eye, to which circumstance we may perhaps trace their comparatively recent discovery.

It is not our business at the present time to examine the peculiarities and varied appearances of the planetary bodies, but the following table may be useful to the reader, as giving the most important particulars in relation to their orbits and dimensions: the planets are placed in the order of their proximity to the sun.

Planet's name	Mean distance from the sun, or semi-axis.	Mean Sidereal period in mean Solar days.	Equatorial diameter, the sun being 111.454.
Mercury .	0.3870981	87.9692580	0.398
Venus . . .	0.7233316	224.7007869	0.975
Earth . . .	1.0000000	365.2563612	1.000
Mars . . .	1.5236923	686.9796458	0.517
Vesta . . .	2.3678700	1325.7431000	
Juno . . .	2.6690090	1592.6608000	
Ceres . . .	2.7672450	1681.3931000	
Pallas . . .	2.7728860	1686.5388000	
Jupiter . . .	5.2027760	4332.5848212	10.860
Saturn . . .	9.5387861	10759.2198174	9.987
Uranus . . .	19.1823900	30686.8208296	4.332

Instruments called orreries are sometimes introduced in public lectures, to explain the order, size, and relative positions of the planetary bodies, or, as we might more properly state, to amuse the audience. These arrangements may possibly attract the attention of children, and assist them in remembering the order and names of the bodies composing the solar system, but they are utterly useless in any other respect, except in inducing the presence of those persons who seek to gratify the eye. Many of them, however, are constructed in a very ingenious manner, and are interesting as exhibitions of mechanical skill. The term by which they are known appears to have been derived from the circumstance, that the first instrument of the sort was constructed for the Earl of Orrery, to whom the manufacturer, Mr. Rowley, paid the undesirable compliment of affixing his name to a paltry philosophical toy.

The peculiar orbits in which the planets move can scarcely fail to attract the attention of the student. All the planets



Planetary Orbits.

revolve in orbits nearly circular, that is to say, in nearly con centric circles. The greatest and least distances of the earth from the sun are in the proportion of twelve to thirteen, those of Mars as five to six, and the other planets revolve in paths that differ more or less from an exact circle; but still in curves nearly circular. Now these bodies might have been made to revolve in ovals of larger or smaller degree, or in exact circles. They have, however, been placed in such positions, and compelled to take such paths, as must prevent them from interfering with each other's motions, either by positive contact, or by the powerful disturbing force they might have exerted upon each other. There are, therefore, proofs, in the very arrangement of the solar system, of design, and strong evidence of a foreknowing mind.

It may also be observed, that the present arrangement of the members of the solar system, as far as investigation has carried us, is the only one by which the stability of the whole can be secured. But, in contemplating the stability of the system, it must be borne in mind, that the planets exert an attractive power on each other, though they are all under the still more powerful influence of the sun. The earth, for instance, is retained in its orbit by the sun, but it is proportionably affected by Mercury, Venus, Jupiter, and the other planets, according to their masses and distances. But all these bodies are constantly changing their positions in relation to the earth and to each other, and upon the discovery of this fact we are naturally led to inquire what will be the ultimate result of these combined attractions. The question is not whether they will produce an immediate effect injurious to the stability of the system, but whether they will not do so in ages to come. In a single revolution their influence must be small, for the combined attraction of all the planets, by which the disturbances are produced, is insignificant when compared with the force of the sun. But if these slight influences continue to act upon the body, revolution after revolution, they may, in process of time, remove the planet from its present orbit.

To give an individuality to the inquiry, it may be asked, if it be not possible that the attractions of the planets may, in process of time, draw the earth from its orbit, and thus produce all the evils which would result from a change of season? or is it not possible that it may be brought so near to another body as to interfere with equable motion, or produce a second deluge? There are perturbations, and if they can be carried on without limit, there is no possibility of calculating, or even of imagining, the wretched condition to which the earth and her sister planets may be reduced by their long-continued and progressive action.

The eccentricity of the earth has been decreasing from the earliest times of astronomical observation, and her satellite, the moon, has been moving more and more rapidly from the time of the first recorded eclipse. It is not irrational, then, to inquire where will these changes end. What but destruction can result from these innovations on the beauty, harmony, and stability of the system? But the author of the incomparable mechanism of the universe has not left his work to disarrange and destroy itself. There is a limit to these changes in the very constitution of systems. They may proceed for a time, but the causes themselves must cease to act, and the bodies that are for a while disarranged will be brought again to their first condition. It may be readily imagined that it is not easy to estimate the amount of these perturbations, or the time when they will be corrected; for it must be remembered that every fresh position that is taken by the disturbing bodies, will cause an alteration in the motion of the body acted upon. But Lagrange and Laplace have proved that these perturbations cannot exceed a certain limit, which will never affect the stability of the system. The effect produced upon a planet by the attraction of minor bodies, is only periodical; the causes produce a maximum result, and then cease to act; so that the disturbed body is brought again into the orbit from which it had wandered, without deranging the order of the system.

Nothing can give us a more elevated notion of the wise arrangements of the Supreme, than such considerations as these. If these bodies had been projected with either greater or less velocity than was originally given to them, they would have moved in orbits of greater or less eccentricities, and then the stability of the entire system would have been destroyed, and an element of destruction have been introduced. No other arrangement, as far as we can judge, would have produced the desired effect, or ensured the combination from destruction.

THE FORCE OF GRAVITY.

We have made some allusion to a force which we have called the force of gravity, and we should not give even a sketch of the relations of the earth, and the condition under which they are supported, if some allusion were not made to its influence upon matter in general, and upon the celestial bodies in particular. It is by virtue of this force that unsupported bodies near the earth fall downward; that they exert a pressure on the surface on which they rest; that the planets revolve round the sun; and the satellites round their primaries; it is, in fact, the cause of nearly all the phenomena of motion which we observe around us. The origin of this force we cannot determine; but the circumstances under which it acts, and the laws by which it is governed, are perfectly understood.

It is a law of gravitation that bodies attract each other according to their masses. Thus, if two bodies exist in space beyond the influence of all other matter, one having a mass twice as great as the other, they will exert a mutual attraction; but while the larger approaches through a space equal to one, the less will move through a space equal to two. If the greater be doubled, then the less will feel the force of its increased attraction, and advance through a space equal to four, while the larger advances one. There is no difficulty in understanding this law; for as all bodies attract each other according to their masses, then every particle in the universe attracts every other particle. This law accounts for the fall of bodies to the surface of the earth, and it is only the existence of this force of gravity that causes them to do so. Matter is in itself perfectly passive and inert; and when we perceive it to be in a condition of rest or motion, we may be certain that it is produced by some external force. It will therefore follow that, independently of the force of gravity, there is no reason why a body should fall downward, but it should rather take the direction in which it is thrown. But as different bodies fall to the earth in different times, it may perhaps be difficult to identify the law to which we have alluded. The entire attractive force of the earth is exerted upon the individual atom of every body, and consequently they ought, whether large or small, to fall in equal times. This difficulty, however, is removed by the consideration that the air acts upon the surface of bodies; and in bodies of equal weight, but of different volumes, that will fall first which presents the least resistance to the air. A stone and a feather would fall from a height in equal times in a vacuum; but when exposed to the retarding influence of the air, the stone falls first; not because it is more powerfully attracted by the earth, for the same force is exerted upon its particles as upon those of a feather, but because it is less resisted in its progress by the action of air.

This attractive force between two bodies varies inversely as the square of their distance, or, in other words, the attraction decreases as the square of the distance increases. Suppose a body to be attracted by another with a force equal to one, at a distance represented by one; at the distance of two the force will only be one fourth; at three, one ninth; and at four, one sixteenth.

With a knowledge of these two laws there will be no difficulty in accounting for the fall of bodies, whether they are raised into the air, and abandoned without force, or whether they are dropped into a mine or well from the surface of the earth. To determine the direction of gravity, it is only necessary to ascertain the line in which bodies fall. The direction of a thread suspended by one end, and having a heavy ball attached to the other, will give the direction of gravity; for into whatever line it is drawn, it can only result from the action of the force of gravitation; and hence we determine that the tendency of the power we call terrestrial gravity is to draw all bodies towards the centre of the earth, or, in other words, its direction is in a perpendicular to the surface of still water.

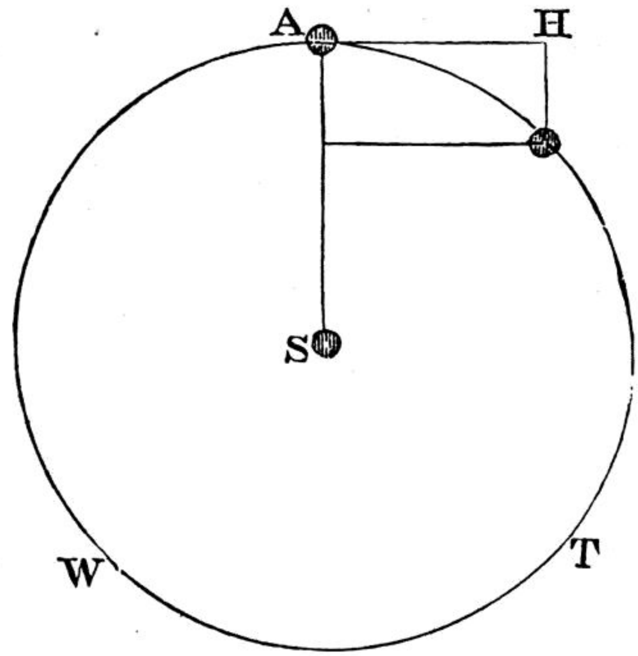
CURVILINEAR MOTION.

But if a body be cast obliquely into the air, this tendency is greatly modified; and although it will be brought to the earth, yet it is deflected from its rectilinear path, and moves in a curve, and is not directed towards the centre of the earth, and consequently it would not even reach the centre, but continue to revolve around it. But why did the stone move in a curve? why did it not take a rectilinear path to the point towards which it was thrown; and when that force was destroyed, why did it not fall in a perpendicular line to the earth? Bodies are made to move in curves when one of the forces by which they are influenced is an accelerating force; that is, when it causes a body to move faster and faster by its continued action. A certain projecting force is impressed upon a stone when it leaves the hand or the sling; and it moves with a velocity proportional to the force until the power is expended, and then it begins to fall. But gravity is a force that acts continually upon a body, not only at the moment it begins to fall, but every instant during its fall, so that, in calculating the time required to bring a body from any height to the surface of the earth, an estimate must be made of its constantly increasing velocity. The force of gravity is therefore an accelerating force; and when it acts upon bodies moving obliquely to its line of direction, a curvilinear motion is produced.

Sir Isaac Newton chose the sling as an illustration of his doctrine of the curvilinear motion of the planets. Now in this instrument, or toy, we observe that the stone placed in the bag of the sling makes an incessant effort to escape, but is restrained as long as the string is held in the hand. The string may represent the attraction of a central body, or, as it is technically expressed, the centripetal or centre-seeking force; the stone is the revolving body, and the effort it makes to leave the string is called the centrifugal or centre-flying force. But it is evident that some power is necessary before these forces can be developed, for the string may be attached to the sling without producing motion; some impulse must be impressed before the body will begin to revolve; this is done by a sudden effort of the hand, and that is called the projectile force.

It is easy to apply these remarks on the sling to the motion of the heavenly bodies, which is entirely dependant on the continued action of a centripetal and centrifugal force.

Let the body A, representing the earth, be projected along the line AH, into space, and if it be acted on by no other force, it will move in that line for ever. But let S, the sun, begin to attract it with an adjusted force, at the same moment that the projectile force is impressed, and it will revolve in a curvilinear line, as ATW, instead of flying off in the line AH. Now, according to the power of the projectile force will be the curve in which the planet will move; and hence it is that we perceive an evidence of design in the forms and arrangements of the orbits of these bodies. If either the centripetal or centrifugal force were to cease, the connexion between the members of the solar system would be immediately dissolved; in one case they would be thrown abroad in space, and in the other they would rush towards the body of the sun, which they would reach in longer or shorter times, according to their distances. The following table will show the times in which the planets would fall to



the sun, provided that the centrifugal force generated by their revolution were destroyed.

	Days.	Hours.
Mercury would fall to the Sun in .	15	13
Venus	39	17
The Earth	64	10
Mars	121	0
Jupiter	290	0
Saturn	798	0
Georgium Sidus	5406	0
The Moon would fall to the Earth in	4	21

THE RELATIVE MAGNITUDES AND DISTANCES OF THE PLANETS.

We have now ascertained that the earth is an oblate spheroid, having one revolution on its axis, and another round the sun as the centre of the system to which it belongs; and we have traced the origin of that wonderful combination of worlds, and have explained the action of the forces by which their motions are produced and their stability ensured. To give an idea of the relative magnitudes and distances of the planets, we cannot do better than quote a passage from Sir John Herschel's very elegant and masterly Treatise on Astronomy. "Choose any well-levelled field or bowling-green, on it place a globe two feet in diameter; this will represent the sun; Mercury will be represented by a grain of mustard-seed, on the circumference of a circle of 164 feet in diameter for its orbit; Venus a pea, on a circle 284 feet in diameter; the Earth also a pea on, a circle of 430 feet; Mars a rather large pin's head, on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas, grains of sand, in orbits of from 1,000 to 1,200 feet; Jupiter a moderately-sized orange, in a circle nearly half a mile across; Saturn a small orange, on a circle of four fifths of a mile; and Uranus a full sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter. As to getting correct notions on this subject by drawing circles on paper, or, still worse, from those very childish toys called orreries, it is out of the question. To imitate the motions of the planets in the above-mentioned orbits, Mercury must describe his own diameter in forty-one seconds; Venus in four minutes and fourteen seconds; the Earth in seven minutes; Mars in four minutes forty-eight seconds; Jupiter in two hours fifty-six minutes; Saturn in three hours thirteen minutes; and Uranus in two hours sixteen minutes."

How little does the world, which is our habitation, appear when compared with the system to which it belongs; but how much more so when contrasted with the immensity of the universe. What a sublime sight is presented to view when the bright hemisphere with its million worlds is unveiled before us; worlds that, for aught we know, may be as thickly inhabited as our own. But all these are at a distance too great to be measured, and yet possessing an independent light sufficiently intense to cast a glimmering ray upon the earth. The astronomer says they are suns, and in all probability the centres of systems as large and important as that of which the earth is a member. No appearance in material existence can, perhaps, raise our conception of the wisdom and power of the Supreme Mind so high, as a view of the celestial sphere when presented to the sight by the aid of art; and the adoration that is excited can only be increased by a combined estimate of the mighty energy that supports all these systems, with the solicitude that is evinced in the provisions for animal existence, and the endless happiness of man.

Such considerations as these are adapted to every mind that possesses a power of raising itself in any degree above the influence of animal gratifications but they can be fully enjoyed only by those who are alive to all the impressions of beauty and sublimity that external appearances are calculated to produce. The man of intellect, too often harassed with the feverish excitement of prolonged thought, or raised to a state of high sensibility by the cold indifference or unmerited taunts of the world and of friends, requires some such considerations as these to subdue his overwrought and sensitive mind. With a consciousness of his superiority to the crowd who affect to despise his pursuits and to pity him, he is sometimes ready to persuade himself that he is a being of higher order than they. But when he feels in necessity the result of that peculiar character of mind which he knows to distinguish him from his fellow-men, he is ready to imprecate a curse on the predominant principle that raises him in his own estimation. At such a moment the proud and discontented thought of the man is subdued by a remembrance of the condition in which he is placed; the benevolent wisdom that has set in order the laws of material existence; the immensity of the universe; the littleness of the earth; and the provisions that have been made in it for the support and happiness of animated being, according to their wants and capabilities of enjoyment.

But although the earth appears so trifling a thing when compared with the system of the universe, it will not be uninteresting to attempt an explanation of the many curious phenomena by which it is distinguished. Things are great or small by comparison, for all our conceptions are relative. It is important that we should know something of the system with which the earth is connected, and something of the universe of which it is a member. In the review of these, we are struck by their magnitude and sublimity; and when we compare the earth with them, we are startled with the idea of its minuteness. But the mind which feels these impressions will not fail to be struck with the grandeur of a mountain scene, and the violence of the causes that produced it; the volcano will not appear the less terrible, or the lightning the less grand. Our investigation of the relation that the earth bears to the universe may therefore, it is hoped, rather stimulate than repress our anxiety to know something more of the globe on which we dwell, and the appearances by which we are surrounded.

DAY AND NIGHT.

The man who has acquainted himself with the statements which have been made in relation to the earth, as a member of the universe, and has been convinced of their truth, will have no difficulty in accounting for the phenomenon of day and night. We have seen that the earth, instead of being, as we might from appearances imagine, the centre of a combination of bodies, is an almost insignificant member of a small system; and so far from being the world around which the whole universe revolves, it is a little planet, having a rotation on its axis, as well as a revolution round the sun, the source of its light and heat. From these facts it follows, that at all times one half of the earth's surface must be illuminated by solar rays, and the other must be in a state of entire or partial darkness. When the sun is above the horizon of any place, it is illuminated by the light which is roused into action by its presence. But the mere presence of the sun above the horizon would not be sufficient to spread over the exposed hemisphere the cheering influence of its beams. Were there no atmosphere, or did that which envelops our planet possess no reflective and scattering powers, then an object placed at ever so small a distance from the direct beams of the sun would be shrouded in a midnight obscurity. But the dispersive influence of the atmosphere scatters the light in every direction, and the entire of one hemisphere is at once lighted by the sun. The origin of the inequality in the length of day and night will be evident when we speak of the seasons, which, although they essentially depend upon the celestial relations of the earth, will be more properly discussed when we speak of the phenomena resulting from the distribution of heat.

CHAPTER II.

CELESTIAL APPEARANCES.

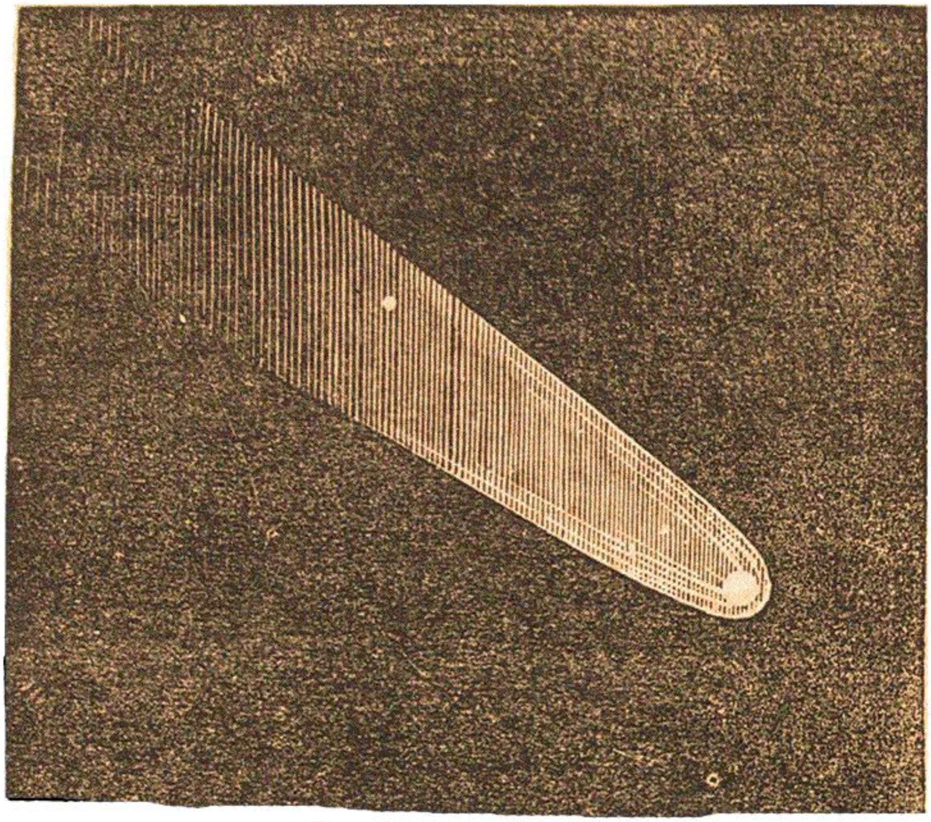
Astronomy has greatly aided the progress of civilization, and has proportionally benefited society, by explaining celestial appearances. Without this information the human race might still behold with terror many occasional phenomena, or doubt the continuance of those motions and conditions with which we are familiar, and by experience know to be productive of benefit. The security of past ages against injury from celestial appearances would not be sufficient, in all instances, to quiet our fears; but, ignorant of the mysterious motions we observe, thought might suggest new causes of terror, while the illiterate and superstitious would be constantly exposed to the imposition of the crafty.

By the knowledge that has been acquired, we are made confident that we are in a state of being where natural phenomena are curbed and regulated by the very causes of motion; and if we had not the confidence of security arising from this knowledge, we could not be certain that the appearances we now behold with delight, might not hereafter exert an influence to our detriment or destruction; and there could be no reason why we should not believe that the seasons might be changed into a perpetual arctic winter, or a worse than tropical summer; or that some wandering comet might not in its eccentric course destroy this fair world of ours. It would not be sufficient to say that such evils have not as yet occurred, for that is not a pledge that they will not hereafter happen. We might therefore be justified in indulging the most gloomy apprehensions of the future fate of the earth, if we were ignorant of the causes that regulate the celestial phenomena we occasionally or daily see, and be perplexed with the visionary theories of those who seem to have no other employ than seeking a temporary fame in the deception of others.

By the expression "celestial appearances" we do not intend to include all those phenomena we behold in the heavens, but those only which are connected with the conditions and motions of the celestial bodies. There are many phenomena which have their origin in the region of the clouds, such as lightning, and the aurora borealis; to these we shall make no reference in this chapter, but introduce an explanation of them when considering the causes from which they derive their origin. The most striking celestial appearances, and those to which allusion will be made in this place, are Comets, Nebulæ, Eclipses, and the Phases of the Moon.

COMETS.

Comets were long beheld with a feeling of superstitious awe as the harbingers of evil. Reasoning from assumed principles, men were accustomed to regard them not only as the forerunners, but as the causes of political convulsions. All human affairs were supposed to be under the control of celestial influences, and it is not strange that comets were



The Comet of 1819.

invested with an uncommon degree of malevolent power There is strong historical evidence to prove that the art of astrology was practised among the earliest nations, and that it had been widely distributed among successive generations. Not only was it used in the temples and oracles of the Greeks and Romans, but also in Assyria, Babylonia, the Hindus, and in Egypt. In all these countries it was practised, and by universal consent acknowledged to be the most noble of all sciences. It was this that gave the priesthood so entire and enslaving an influence over the public mind, led to the establishment of sanguinary superstitions, and was the origin of idolatry itself.

It is not, perhaps, singular that the early nations, who are known to have paid great attention to celestial phenomena, and especially to the relative motions of the heavenly bodies, should have chosen them as the subjects of their art. The influence which the apparent solar motion exerted upon the seasons, and the rising of particular stars as the forerunner of periods, might induce them to feel an especial interest in astronomical phenomena, and be a reason for the choice that was made of them as emblems. But whatever influence these thoughts may have had upon their minds, there can be no doubt that they were still more governed by a pervading and universal belief in astrology, or the influence of the stars upon the moral character, the intellectual powers, and the individual fortunes of mankind The cylinders found in the ruins of Babylon, Nineveh, and other ancient cities, might be mentioned as proofs of this statement; for they are generally acknowledged to be horoscopical devices employed by individuals as signets, and only differing from the seal now employed in being of a cylindrical form, and containing the engraved representation of the planets at birth, instead of the device assigned by the College of Heralds. But we have only occasion to look at the works of the most ancient poets to find the high value that was attributed to the engravings of celestial bodies, for almost the only device used on the armour and shields of warriors was a representation of celestial bodies or phenomena. We often read of the flaming star, by which is probably meant a comet, as having been employed; Achilles bore on his shield the full-orbed moon, Orion, and the Pleiades; and the shield of Tydeus was marked

> "With this proud argument; a sable sky
> Burning with stars, and in the midst full-orbed
> A silver moon."

It may also be mentioned, that the designation of warriors and legislators as the sons of the gods was not received in its literal application, as if their descent could be traced from them; but is another proof of the universal belief of astrology among the Greeks and Romans, and means nothing more than that they were born under the influence of a certain star, for stars were invested with the attributes of divinity. Lucan is explicit on this point where he says, "How can we suppose that Æneas was the son of Venus, Minos of Jupiter, Ascalaphus of Mars, and Autolychus of Mercury? All of them were beloved by the gods; but Venus beheld one, Jupiter another, and Mars another at their respective nativities; for which soever presided at the time of birth was supposed to adopt the children, and form them after his own similitude in *body and mind*. Thus Minos was a king, under Jupiter; Æneas was beautiful, as born under Venus; and Autolychus a thief, from his father Mercury."

Without extending our remarks upon the universal belief in the influence of the stars, which obtained in the darker ages, it will be evident that the opinion must have been exceedingly injurious to all ignorant people, conforming itself, as it does, to the indolent habits of man, by assuring him that all the circumstances of his life are fixed, independent of the exertions he may make. With such a belief the public mind was prepared to expect some personal result to attend every celestial appearance, and both comets and eclipses were viewed with terror, increased by the ignorance of the nature of the one, and the cause of the other. These feelings, however, are now removed, and we are in possession of information by which we can calculate the paths of the comet, and foretel the appearance of eclipses.

The physical constitution of comets is little better known in the present day than in former times, though the ancients appear to have differed in opinion as to their character. The Peripatetics described them as meteors, while Aristotle, Plutarch, and others, class them among the planetary bodies. "I cannot believe," says Seneca, "that a comet is a fire suddenly kindled, but that it ought to be ranked among the eternal works of nature. A comet has its proper place, and is not easily removed from it; it goes its course and is not extinguished, but moves from our view. But, you will say, if it were a wandering star, it would keep in the zodiac. Yet who can set one boundary to all the stars? Who can confine the works of divinity to a narrow space? For each of those bodies which you imagine to be the only ones that have motion, have very different circles; why, therefore, may there not be some that have peculiar motions of their own, by which they are caused to recede far from the rest?"

Newton discovered that comets are bodies moving in fixed orbits round the sun. As soon as this philosopher had discovered the laws of universal gravitation, he applied them to the determination of the motion of comets; for having proved that, according to the conditions of that force, a body might describe any conic section about the sun, he conceived that comets, in their apparently irregular motions, might be governed by that principle. The comet of 1680, which approached the sun to within one sixth of its diameter, enabled him to test the truth of his conjecture; and he proved that it moved in an elliptical orbit of so great eccentricity that it could not be distinguished from a parabola, having the sun as one of its foci; and that, as in the case of the planets, the areas described about the sun were proportional to the times; a law discovered by the illustrious Kepler. From this calculation it became evident that the comets were governed by the same laws as the planetary bodies, and that the orbits of the former differed from those of the latter in the great elongation of their elliptical paths.

Halley applied the principle discovered by Newton, and by calculating the elements of the comet which appeared in 1682, from its perihelion passage, identified it as the comet that appeared in 1531 and 1607, and predicted that it would again appear in the year 1759. After this, Clairaut, a French astronomer, computed the influence that would be exerted upon it by the planets, and calculated that if it retained its period it would be delayed about 618 days, and that it would pass the perihelion about the middle of April, 1759; but it made its perihelion passage on the 12th of March, a time sufficiently near to prove the accuracy of the principle. This comet, called after the celebrated astronomer Halley, who first calculated its elements, will be visible in the year 1835, and its return to its perihelion has been calculated by Lubbock, Damoiseau, and Pontecoulant. Lubbock supposes that it will be there on the thirteenth of October; Damoiseau, on the fourth of November; and Pontecoulant makes its time to be on the seventh of that month. Its first recorded appearance was in 1305, and from this time it has been decreasing in brilliancy and in the length of its tail, which, however, was 30° in 1682, and consequently may be expected to present a very splendid appearance when it next becomes visible, as it approaches comparatively near to the earth.

The nature of comets, and the purposes they serve in the system to which they belong, are almost entirely unknown. No probable explanation has yet been given of the characte of that train of luminous matter frequently appended to them, and very inappropriately termed the tail, since it frequentlv precedes the body itself. The tail is sometimes of very considerable length. Aristotle states that the tail of the comet that appeared in 371 A. C., occupied a third of the hemisphere, or 60° ; that of 1580 is said to have covered an extent of more than 70° ; and that of 1618, 104°. But a tail is not a necessary appendage to a comet, for some have been quite destitute, as were those of 1585 and 1763 ; but there are also some that have several tails ; that of 1744 had no less than six, which, spreading out in the form of a fan, extended over a space of nearly 30°. A very small condensed spot has been observed in the heads of some comets, but the fixed stars may be seen through the densest parts of many ; and from the circumstance that none of them have exhibited phases, though they undoubtedly shine by reflected light, we may gather that they have no claim to be considered as solid bodies, but have in all probability the condition of the lightest vapour.

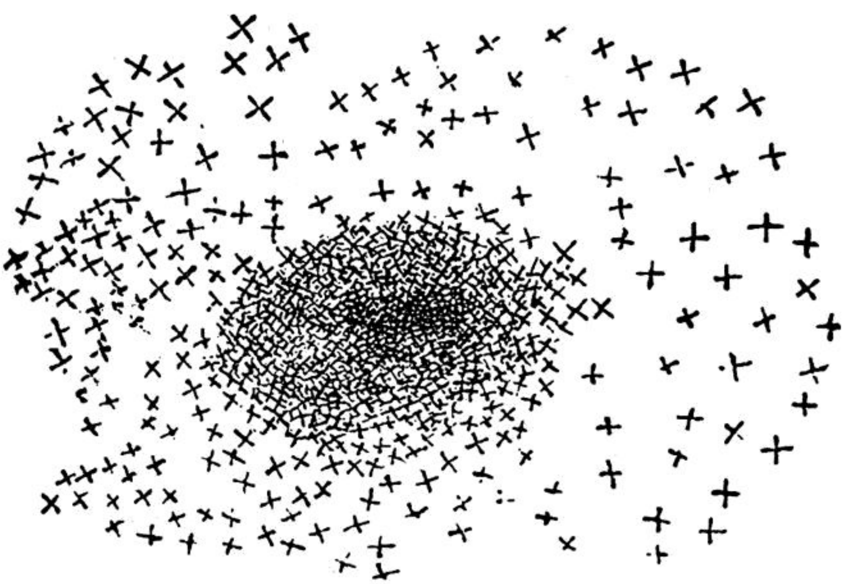
The appearances of several hundred comets have been recorded, but in estimating their probable number it should be remembered that only the largest among them could have been observed previous to the discovery of the telescope ; and that many are not seen on account of their traversing that part of the heavens which is above the horizon in the daytime, although it has sometimes happened that they have been sufficiently bright to be seen in spite of the solar beams, as were those which preceded the death of Cesar, and those which were observed in 1402 and in 1532. Yet scarcely a year passes without an appearance of one or two comets, and it occasionally happens that two or three are visible at the same time. According to a calculation on the theory of probabilities, by Mrs. Somerville, there may be no less than fourteen hundred comets that range within the earth's orbit ; and Herschel being twenty times more distant, there may be no less than eleven millions two hundred thousand comets that come within the known extent of our system. This calculation was founded upon the circumstance that a hundred and forty comets appeared within the earth's orbit last century.

The calculations that have been made to determine the dimensions of comets prove that they are by far the largest bodies in our system. The greatest length of that which appeared in 1759 was sixteen million leagues ; that of 1811, thirty-six million ; while that of 1680 was not less than forty-one million leagues.

The path of a comet is frequently deranged, and sometimes entirely changed, by its proximity to the planets. That which appeared in 1770, revolving in a moderate ellipse, in a period of about five years, passed among the satellites of Jupiter; and was so affected by the planet itself, that it was thrown out of its path, and afterward revolved in a much larger orbit. To the same cause we may often attribute the gradual dissipation of the tail of a comet, and its retardation in its orbit, though, at other times, the latter effect may be attributed to the resistance it suffers in passing through a rare ethereal medium in the regions in which it moves. This cause has been acting upon Encke's comet, the velocity of which has been continually decreasing, and with it consequently the centrifugal force; so that the centripetal force increasing in power, the comet must ultimately fall into the body of the sun if it be not previously dissipated, a circumstance by no means improbable, as it decreases in size at every revolution.

NEBULÆ.

There are appearances in the heavens called nebulæ, concerning which we may make a few remarks, although they come less within our objects of inquiry, as they are chiefly telescopic. These nebulæ exhibit a variety of appearances, sometimes presenting themselves as globular clusters of stars,



Nebulæ.

and sometimes as diffused nebulosity. Many are, no doubt, stars at so enormous a distance from us that they can only be distinguished by the doubtful light they throw around them. Others have been supposed to consist of phosphorescent matter, which either extends itself over the heavens, or is condensed around some star or dense matter. Sir William Herschel has delineated a very beautiful nebulous appearance in Orion, which he observed with his large telescope. Huygens, speaking of the same nebulosity, says, "*that its appearance had the same effect upon an observer* as that which might be supposed to proceed from raising a curtain that hid from the observer an ocean of light, the waves of which were irregularly illuminated."

To the question, what is the ultimate designation of these nebulæ, we can only answer by conjectures. Sir William Herschel thought he could trace a regular series of changes from a simple distribution of nebulous matter to that of a nebulous star, and some astronomers believe that a condensation of this matter is constantly going on, and that new worlds are daily in the process of formation. This is a splendid idea, and if the mind could at all adequately grasp it, would give an overwhelming conception of omnipotent skill; but there are some who have no higher ambition than to exclude God from his works, and to invest with his dignity and sovereignty that indefinable thing they are pleased to designate chance. It is not to be doubted that the great mind of Laplace was tainted with this unaccountable and unphilosophical desire; but, however this might be, he has availed himself of the discoveries that were made by Sir William Herschel for the invention of an hypothesis by which to account for the formation of the planets, and the sun itself, from a nebulous luminosity, which he is pleased to designate the primitive cause. Laplace imagines a time when the sun, having a revolution on its axis, was surrounded by an atmosphere, which, on account of the excessive heat of the luminary itself, was so dilated that it extended beyond the orbits of the planets, the planets themselves having no existence. But in proportion as the temperature of the sun decreased, or, in other words, the solar atmosphere was condensed, the rotation increased, and the centrifugal force of the most distant portion of the atmosphere overcoming the centripetal force, that is, the attraction of the sun, a ring of vaporous matter was separated, which, breaking into pieces, united together, and, forming an independent mass, began to revolve around the source of light. As the cooling went on, other zones would be thrown from the mass, and thus a series of vaporous planets be formed; and he supposes that, as the detached masses of vapour were cooled and condensed, they, like the sun itself, threw off a portion of their matter for the formation of rings or satellites. By this singular hypothesis, which is built on no other foundation than a conjecture as to the ultimate destination of the now existing nebulous matter, the French philosopher accounts for the formation of the solar system. We cannot, however, conceive how the reception of such a theory can at all advance his object, or prove that the primitive cause of material existence was a fortuitous combination of atoms; for, admitting the truth of his hypothesis, it may still be asked whence the atoms, and the properties by which they were distinguished.

PHASES OF THE MOON.

The phases of the moon may also be mentioned as celestial appearances worthy of attention, and come more immediately under our consideration than those just mentioned as being constantly visible to the naked eye. The moon is not inherently luminous like the sun, but becomes visible by reflecting the solar beams. If the moon's surface were smooth and polished, an appearance very different from that now exhibited would be observed; for it would not then reflect light in every direction, but at certain periods an intensely brilliant image of the sun would be seen. The moon is a rough and opaque body, and, like the primary planets, reflects a portion of the rays that are thrown upon its illuminated surface, that is, the hemisphere nearest to the sun.

The surface of the moon, as a telescopic object, presents a most interesting appearance, being diversified with mountains, valleys, and plains, having apparently all the varieties of distribution that are known to exist on the surface of the earth. Some of the mountains form elevated continuous ridges; others are insulated and conical, having the precise form of the terrestrial volcano. It may appear a bold statement that there are lunar volcanoes in different stages, but those who have an opportunity of observing the moon's disk, with a tolerably good telescope, for a few months, may easily convince themselves of the truth of the assertion.

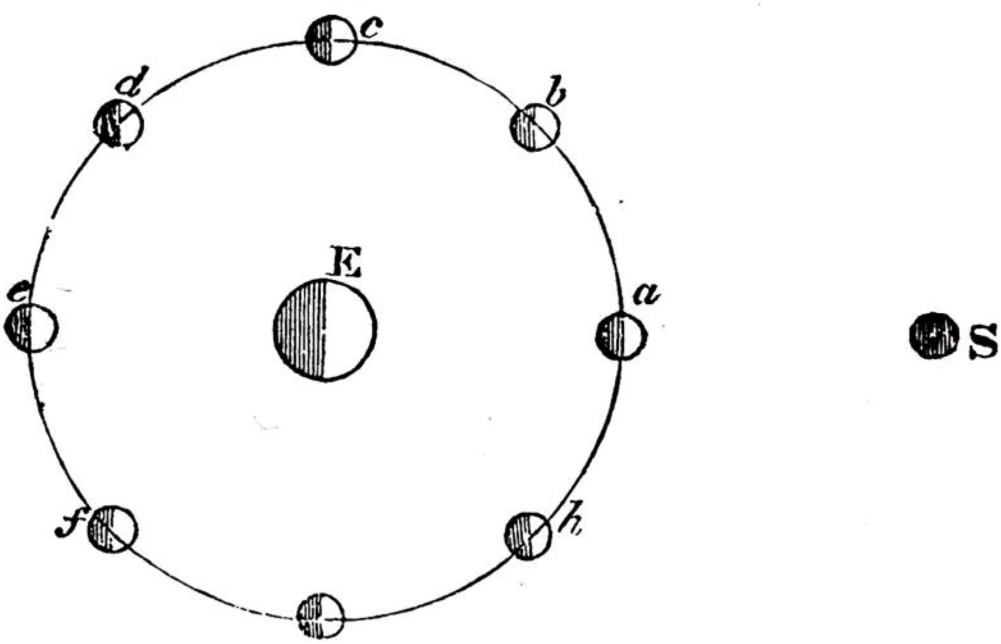
But the inhabitants of the earth can only see that part of the moon's body which is turned towards the earth, and consequently she presents different appearances according to the

Telescopic Appearance of the Moon.

position of the illuminated disk in relation to the earth. It will be readily perceived, that when the moon is between the earth and the sun, she must be invisible to us, since her dark surface is the nearer; but when, by her revolution, the earth comes between the sun and herself, then her illuminated disk is presented to us, and she is said to be at her full. Between these two positions, different portions of the illuminated surface are seen upon the earth, and these are her phases.

A complete revolution, that is, from new moon to new moon, is called a lunar month; but this period is not equable, as it would be if the sun itself had no apparent motion; but as it has an apparent, though slower motion, in the same direction as the moon herself, a longer time will be required in order that she may again be brought into conjunction with the sun.

Let us take E as representing the earth, and *abcd*, &c., as the moon in different parts of her orbit, and S as the sun at its real distance, the sun's rays falling in parallel lines upon every part of the moon's orbit. Now, in whatever part of the orbit the moon may be situated, there is always one enlightened and one dark hemisphere. When in the position *a*, that is, when in conjunction with the sun, the dark part is turned towards the earth; when she comes to *g*, half the dark



and half the bright hemisphere are presented, and the same happens when she is situated at *c*; but when she is situated at *e*, the whole of the bright surface is presented to the earth, and there is a full moon. When the moon is situated at *b* and *h*, less than half the bright surface will be presented; when at *d* and *f*, more.

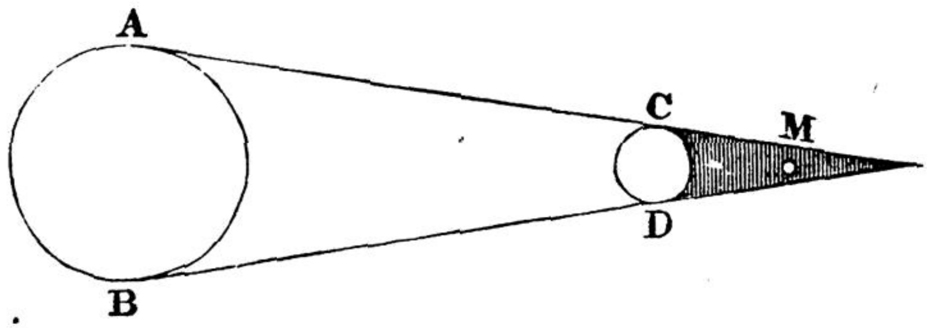
The orbit of the moon, like that of the planets, is an ellipse, but considerably more eccentric, and its plane does not coincide with that of the ecliptic, but is inclined to it at an angle of 5° 8′ 48″, which is called the inclination of the lunar orbit, and the two points where the moon's orbit intersects the ecliptic are called the moon's nodes; that in which the moon passes from the southern side of the ecliptic to the northern is called the ascending node; and the other, the descending. This fact will assist us in explaining the circumstances under which solar and lunar eclipses are produced.

ECLIPSES.

An eclipse is the interception of the light of one of the lu minaries by the interposition of an opaque body; and, in re spect to their objects, they are characterized as the eclipse of the sun, and the eclipse of the moon. In regard to the circumstance, it may be total, partial, or annular, the last epithet being given to that in which the whole of the body is darkened except a narrow rim of the exterior or edge; or, in other words, when an annular eclipse occurs, a fringe of light is exposed round the edge of the shadowed luminary.

An eclipse of the moon is occasioned by the intervention of the body of the earth directly between herself and the sun, thus intercepting the sun's rays; or it may be otherwise described as resulting from the passage of the moon through the shadow of the earth. But at the same moment that we observe an eclipse of the moon, the lunarians, if indeed the moon be inhabited, must behold a solar eclipse.

Let A B represent the sun, and C D the earth; that hemi-

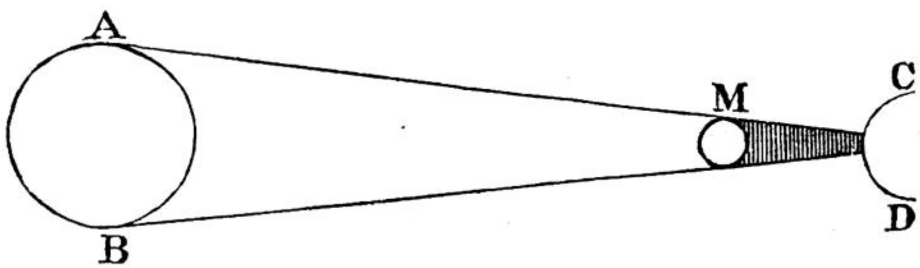


sphere opposed to the sun's body will be illuminated by it, and the other will be dark; so that if we prolong the lines A C and B D until they meet, it will be the space within which the shadow of the earth extends, and any body, as the moon, M, entering it, will see no part of the sun's disk; this shadow is called the umbra. There is a space beyond the umbra, in which a spectator being placed would see only a portion of the sun's disk, the other part being intercepted by the body of the earth, and this is called the penumbra.

In a lunar eclipse, the body of the moon is seen to enter the penumbra first, for she is less and less distinctly seen until she at last enters the real shadow of the earth, one part after another disappearing; and when she has passed through the shadow, she comes progressively into view; at first as though surrounded by a haze, until, having passed the limits of the penumbra, she regains her accustomed brightness. The cone of the earth's umbra extends beyond the orbit of the moon, so that, if she be in her node at the time when she comes into conjunction with the earth and the sun, she must pass through the umbra of the earth, and a total eclipse will be observed; but the eclipse may also be total if she be only a short distance from her node, or, to express the fact more definitely, if the moon's latitude be equal to the apparent semi-diameter of the earth's shadow, minus the semi-diameter of the moon's disk. All lunar eclipses are universal, that is to say, they are visible at all those parts of the earth where the moon is above the horizon, and present the same appearance as to magnitude and duration. It may also be observed that the eastern side of the moon first immerges into, and emerges from, the shadow, for the motion of the moon being swifter than that of the earth's shadow, she approaches it, and, having passed through, leaves the shadow to the westward.

An eclipse of the sun is occasioned by the interposition of the body of the moon between the earth and the sun, and consequently can only occur at the time of the new moon.

Let A B represent the sun, M the moon, and C D the earth. Now if the shadow or umbra of the moon extend so



far as to cover a portion of the earth's surface, an individual situated thereon would observe a solar eclipse. An eclipse of the sun differs in many particulars from an eclipse of the moon; it does not present the same appearance on all parts of the earth where it is seen, for in one it may be total, in another partial, and in a third annular; nor can an eclipse of the sun happen at all the places where the sun is visible, as the penumbra cannot, under any circumstances, cover a hemisphere; it is not seen in all places at the same time, and it always commences on the western side.

The object of this sketch prevents us from entering into any farther particulars relating to eclipses, and especially into any details of a practical character. The reader will not, however, it is hoped, be satisfied with this outline, as he may easily acquaint himself with the method by which these phenomena are predicted; and will find more satisfaction in determining the time when an appearance of this kind will be seen, and will acquire more information by doing so, than he could obtain from such details as are suited to the character and objects of this volume.

This phenomenon is one of great importance to us, and must also be so to the inhabitants of the moon, if that planet be inhabited by beings of similar capabilities and wants as ourselves. By a lunar eclipse, the opinion that the earth is a spherical body is confirmed, for the shadow of the earth upon the lunar disk is always bounded by an arc of a nearly circular curve. Now this could not be the case if the shadow were not conical, and the shadow could not be conical if the earth were not spherical. It may also be deduced from the same phenomenon, that the sun is larger than the earth, and that the earth is larger than the moon; for if the sun were not larger than the earth, the shadow could not converge, or end in a point; and if the earth were not larger than the moon, the latter could never be totally eclipsed; but the earth's shadow envelops it at the distance of the lunar orbit. By eclipses, and especially those of the moon, the longitude of places may be determined, the latter being peculiarly adapted for the solution of this problem, because the appearance is the same in all places where it is visible.

It must not, however, be forgotten, that the calculation of the periods when eclipses have occurred has sometimes assisted in determining the time of historical events; and thus astronomy has lent its aid to literature. It is stated by Thucydides, that a solar eclipse was observed at Athens in the afternoon of a summer's day, in the first year of the Peloponnesian war; and it was so nearly total that the stars made their appearance. By calculation, it is found that this happened at about six o'clock in the evening, on the third of August, in the year 431 before Christ. When it is remembered that all our divisions of time are founded upon the motions of the heavenly bodies, and the phenomena which are thus produced, it will not appear singular that the record of eclipses should often assist the chronologist in the determication of dates. The paths, periods, and irregularities of the moon and the earth being known, it is not a very difficult task to determine the times when eclipses have occurred. An industrious and persevering man might easily compute the times when the sun or the moon has been eclipsed, as well as the time when they will be; and he may thus frequently ascertain the dates of remarkable, political, or national events. The attention of men has ever been directed to a consideration of the appearances exhibited in the heavens, and they seem to have been always conscious that no terrestrial phenomenon could be employed to measure the lapse of time. These two circumstances may probably account for the frequent allusion to astronomical occurrences in the works of the ancient historians and poets.

There are other celestial appearances, besides those which have been described, that are occasionally seen from the earth; but those that have been mentioned are the most remarkable. It is seldom that men take an enlarged view of the influence of scientific knowledge upon the minds of individuals. They speak of it as calculated to raise the intellectual standard, to free the individual from the dominant control of superstition or fear, and to give him great capacities of generalization. But the advantages of knowledg can be appreciated only when we can perfectly realize the condition of a society in which it had never been acquired, and upon which it had exerted no influence by the medium of others; if, indeed, a society could exist under such conditions. Compare the feelings which an individual of that community would experience during a solar eclipse with those which would be indulged by one who, though he could not account for it, had made himself acquainted with laws which govern some of the most remarkable celestial phenomena. The one would suffer an uncontrolled fear by an appearance that he must have heard of by tradition, or perhaps may have himself beheld; the other, under full conviction of the propriety of the causes with which he is acquainted, would be induced to seek some information concerning the origin of this newly-exhibited effect, and would be ashamed to entertain, and much more to express, a fear, until he knew it to be justified by the cause. Our object, however, in describing the celestial relations of the earth, and the astronomical phenomena seen upon the surface, has been to give the reader as comprehensive a view as possible of the position of the earth in the universe, and the means by which it is retained in its position, feeling certain that the personal advantages, to which we have occasionally alluded, will be enjoyed by every successful inquirer.

CHAPTER III.

THE ATMOSPHERE AND ITS PHENOMENA.

THE earth is surrounded by an immense aerial ocean, which is an important agent in supporting animal and vegetable life, and in sustaining the present condition of the phenomena around us. An atmosphere is not the necessary appendage of a world; but we have evidence, both within and without us, to prove that the earth is enveloped by a gaseous medium, and that it is of no small importance in the economy of terrestrial conditions. Were we to select from the phenomena we occasionally behold a few that might prove the existence of an atmosphere round our planet, we might mention the resistance it offers to bodies in motion, the force with which at other times it propels them, and the colour it gives to the ethereal vault.

PROOFS OF THE EXISTENCE OF ATMOSPHERE.

Every body in rapid motion is retarded by the atmosphere through which it moves. A ball, or any other substance, when once put into motion, would continue in that state for ever if there were no disturbing force. Matter has no predisposition to rest, and the ancient philosophers described its habitude very incorrectly, when they compared it to an idle man capable of motion, but much attached to rest. Motion and rest are relative conditions; and when a body is in one or the other, it is because of the forces that are acting upon it. Matter is in fact perfectly passive, and therefore matter once in motion would continue in motion for ever if there were no force tending to bring it to a state of rest. The resistance of the air is one of these. The pendulum, for instance, when put into motion, vibrates in obedience to the force of gravity.

and would never come to rest if its motion were not destroyed by friction and the resistance of the air.

The atmosphere itself is capable of motion; and when its equilibrium is disturbed, either locally or generally, it produces by impact an effect upon all bodies that are in its path. It not only carries away in its progress the lighter substances with which it comes into contact, but, when greatly agitated, uproots trees, crumbles rocks, and overturns buildings. Man, who subdues and regulates all natural agents by the exercise of those noble properties of mind with which God has blessed him, has applied air in motion as a mechanical force, and compels it to accomplish his wishes, not only in the alleviation of his daily toil, but in facilitating the intercourse between the several sections of the human family; and as though these adaptations were not sufficient to prove the superiority of mind over matter, it is often made to minister to his pleasures, both of mind and of appetite.

If it were necessary to mention any other phenomenon as proving the existence of an atmosphere, allusion might be made to its colour. The vault of heaven, when uncovered by the clouds which sometimes hang as draperies beneath it, has a beautiful azure or blue tinge. This colour cannot of course belong to space, nor is it the result of the influence of those bodies which revolve in it, but is occasioned by the passage of light through the atmosphere. When a small quantity is examined, the colour cannot be detected, because the portion of coloured light transmitted to the eye is too faint to give the sensation of colour; and, for the same reason, a bottle of sea water has a clear transparent appearance, though the deep sea from which it was taken may have a rich green colour. By such facts as these we are made acquainted with the existence of an atmosphere surrounding the earth, and extending to a considerable height above its surface.

The atmosphere is highly important as being the cause of many phenomena we behold, in modifying the influence of others, and in its essential character as the supporter of animal and vegetable life. It has been ascertained by chymists that no other combination of the gases with which we are acquainted would serve the same purpose as that which has been employed, but would be either instantaneously or progressively destructive of life. The atmosphere is also the conductor of sound, gives buoyancy to the clouds, and capabilities of flight to winged animals. If man were able to exist without an atmosphere, he would exist without a knowledge of pleasure, and the expenditure of muscular strength would be so much increased as greatly to augment the burden of the curse under which he labours.

COMPOSITION OF AIR.

The body of gaseous matter by which the earth is surrounded is composed of two elastic fluids, called oxygen and nitrogen, in the proportions of one part of the former to four of the latter. But the atmosphere contains other substances, which must be rather considered as impurities than as absolutely necessary for its composition, and these are consequently in variable proportions. Carbonic acid gas is a principle commonly found in atmospheric air; Saussure found it in that which he brought from the top of Mont Blanc; and Humboldt, in that from near the summit of the Andes. It is however now certain that the proportion of carbonic acid in air not only varies in different places, but also at different seasons of the year; and it is possible that it may be sometimes absent, as the companions of La Perouse failed to detect its presence on the top of the peak of Teneriffe.

A most interesting series of experiments has been made by M. Saussure the younger, at Chambeisy, near Geneva, from which it appears that meteorological changes and seasons have a tendency to alter the proportions of carbonic acid in the air. A long-continued frost increases, and a thaw decreases, the proportion; heavy rains were also found to diminish its quantity, probably by dissolving it; and on the same principle we may account for the circumstance, that there was less of this gas in the air over the Lake of Geneva than at Chambeisy. The philosopher ascertained that there is more in the three winter than in the three summer months, and at night than in the day; and he estimates the average proportion of carbonic acid at 4.15 volumes in 10,000 of atmospheric air.

Aqueous vapour is also present in the atmosphere in variable quantities between one and one and a half per cent.; and many gaseous bodies may be detected; for all the substances that can become aerial fluids at common temperatures must be occasionally found. But these are locally distributed, as well as variable in amount.

The two essential component principles of atmospheric air are extremely different in their properties, and yet both are necessary in the economy of nature. The oxygen gas is the supporter of combustion, and is required for the sustenance of animal life, while on the other hand nitrogen is destructive to both. If a lighted taper be placed in a receiver inverted over water, it will be in a short time extinguished; and if the remaining gas be examined, it will be found that the whole of the oxygen has been expended in the combustion. In the same manner an animal confined in such a situation that it can only breathe a certain amount of air, will soon abstract all the oxygen, and will then die, being unable to breathe the nitrogen. This was the cause of the death of the miserable prisoners in the Black-hole of Calcutta; and of the two men who, some years since, went down in a diving-bell, and by an accident were unprovided with a fresh supply of air. And yet oxygen alone would be very unfit for respiration, for Dr. Higgins has stated that the pulse of a young man that beat 64 times in a minute was raised to 120, after he had inhaled oxygen gas for a short time. It would be equally unfit as the supporter of combustion, for all combustible bodies are burnt in it with so great a rapidity, and with such an intensity of light, that it would be exceedingly unsuited as an atmosphere. The nitrogen seems to neutralize in part, or rather to modify its effects, adapting combustion to our power of beholding it, and preventing a too violent circulation of the blood.

The atmosphere supports life by giving out oxygen and caloric to the blood. When the blood is brought into the lungs it is of a dark purple colour, but it then throws off the hydrogen and carbon, and receives oxygen, which gives it a bright red colour. By every inspiration a man of average size inhales from sixteen to twenty cubic inches of air. It was estimated by Allen and Pepys that 26.6 cubic inches of carbonic acid are given off every minute by a healthy man, but this is perhaps somewhat more than the truth. A portion of the nitrogen that is received by the lungs appears to be absorbed, while the other and larger part is rejected and thrown back again into the atmosphere, in which it immediately rises, being lighter than air. But this uncombined nitrogen gas would very soon accumulate, and prove detrimental to animal life, if there were not some provision for its recombination. This provision has been made in the constitutional arrangements of the vegetable kingdom. The upper sides of the leaves of vegetables give out a large portion of oxygen during the day, while they absorb the nitrogen. By this reciprocal action between animals and vegetables, the purity of the atmosphere is maintained, the oxygen given off by plants combining with the nitrogen expired by animals. When we consider the large amount of carbonic acid that is thrown into the atmosphere by animals, we cannot but feel delighted with the provision for its decomposition by vegetables; and this fact, connected with that already mentioned, gives as strong an evidence of the exquisite skill with which material agents have been arranged to subserve the wants of life in its various gradations, as any in the whole range of philosophy.

There has been some difference of opinion as to the manner in which the gaseous principles of air are united together. Some philosophers have maintained that they are merely in a state of mixture, while others considered them to be chymically united. It is a law in chymistry that bodies combine in definite proportions. Now it has been determined that the oxygen and nitrogen of atmospheric air are in the proportion of one volume of the former to four of the latter, and it was therefore very natural to suppose that they must be chymically combined. But although the oxygen and nitrogen of atmospheric air are united together in proportions adapted to form a chymical compound, yet, from the experiments made by Mr. Dalton, it is probable that they are only mixed, or, in other words, that the particles of the one are diffused among those of the other. It is known that gases possess a principle that may be called a self-repulsive power, that is to say, particles repel those of the same kind, though they have neither an attractive nor a repulsive influence over those of a distinct character. For this reason gases, when mixed together, do not arrange themselves like liquids, according to their specific gravities, but the particles of each kind are diffused throughout the whole space that is occupied by the fluid. This theory is supported by the results of M. Dulong's experiments, by which he has proved that the refractive power of the atmospheric air is precisely equal to the sum of the refractive powers of its elements.

This constitution of the atmosphere is of the greatest importance, as adapting it to purposes it was intended to fulfil. From the principle of gaseous diffusion it necessarily follows, that at all habitable heights above the level of the sea, the air must have a nearly uniform composition; for though the oxygen and carbonic acid must have a decreasing ratio in ascending, yet, at the height of the highest mountains, the alteration of the proportions would be little more than perceptible. If a portion of either gas be consumed in any place, the loss is now immediately made up; but if the principle of diffusion did not exist, then the deficiency could not be compensated, but the whole atmosphere might be described as consisting of patches of different gases; here we should have a patch of oxygen, and there one of nitrogen, while the intermediate space might be divided into parts, each of which would be occupied by the two in some new proportion, or in the order of their specific gravities, according to the force which might be brought into activity in place of the self-repellent power. An atmosphere thus constituted would be evidently unfit to support either animal or vegetable life

PROPERTIES OF THE ATMOSPHERE.—TRANSPARENCY.

The general properties of the atmosphere are transparency, fluidity, elasticity, and expansibility.

The surface of the earth is so richly adorned with things calculated to delight the eye, that we can hardly avoid the conclusion, that its Maker had an intention of pleasing as well as of supporting his creatures. But all the display of beauty, so well adapted to cheer the spirits, to enliven the sensibilities, and to excite the adoration of man, would have been devised and formed in vain, if the atmosphere had not been a transparent fluid; and yet we must admit that the Creator might have provided an atmosphere which would support us, though of such a nature that we might wander about in gloom and despondency, or have viewed all objects through a medium calculated to present them to the eye in the most disgusting forms. And if there were no atmosphere, then the entire vault of heaven would be unilluminated, except that part in which the sun itself was situated, while the dim reflection from the illuminated portion of the earth could only increase the horror of the scene.

FLUIDITY OF THE ATMOSPHERE.

Air is possessed of all the physical characters of fluids, and differs in no respect from them, either in its motion, or the pressure it exerts upon bodies. Fluids press in all directions, and so does atmospheric air, upward as well as downward, and it is capable of supporting light bodies, as well as liquids. We shall best illustrate the fluidity of atmospheric air by an allusion to the theory of floating and sinking bodies.

There are many substances which, under particular circumstances, do not apparently obey the attraction of gravitation, but act in a manner contrary to that which the laws of gravity would lead us to expect. Wood and cork float upon water, and iron upon mercury; smoke rises into the air instead of falling to the ground; and the clouds float over our heads, without exhibiting any tendency to fall. The same phenomena are therefore observed in the atmosphere as on liquids, and they are sufficient to prove it a fluid.

A body immersed in a fluid displaces a certain amount of that fluid. If we plunge a cube of metal in a vessel of water, the level of the water will be raised, and the difference between the two levels will give the amount of fluid displaced. If a cube of marble of equal size, which is not so heavy as the metal, be plunged in the same vessel, the fluid will rise to the same height as in the former instance. From this simple experiment we learn that when a body is dropped into water and sinks, it displaces a certain amount of water equal to its bulk, and that entirely independent of its weight.

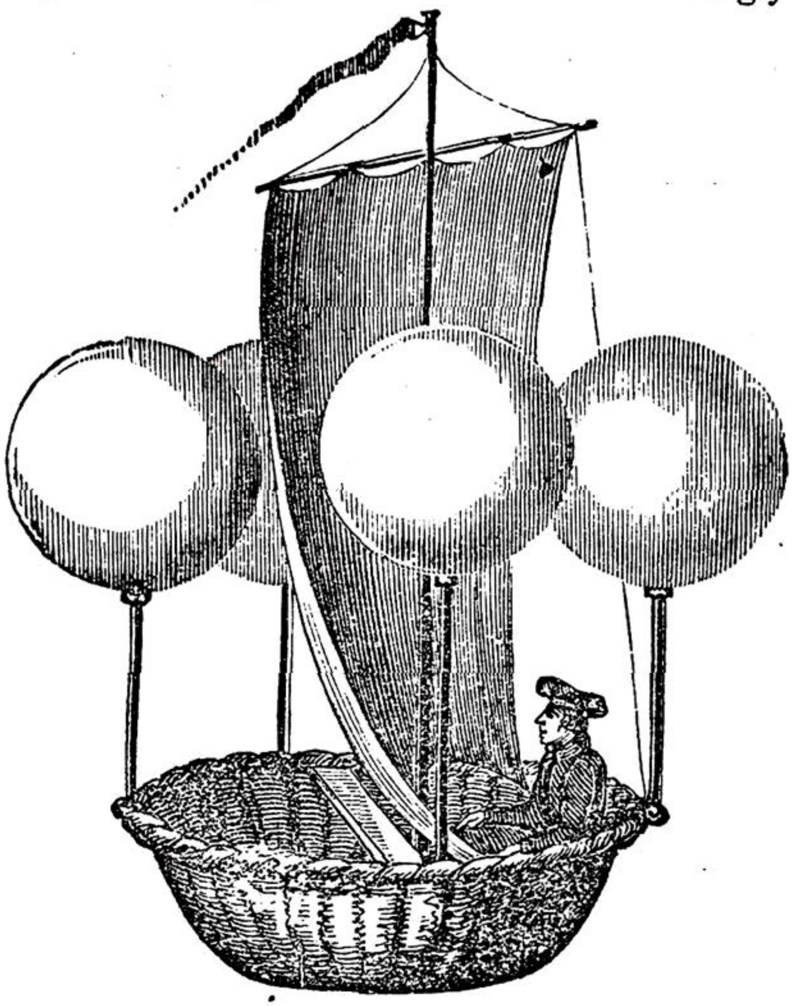
But a body immersed in a fluid loses part of its weight equal to the weight of the fluid displaced. It is well known, that the weight of a bucket in a well is much less when in the water than when in the air. And it is so, because it loses a much greater part of its weight in water than in air; for though they are both fluids, yet the weight of an equal magnitude of the former is much greater than that of the latter. For the same reason, men in a diving-bell may lift with ease bodies at the bottom of rivers, which on the surface of the earth they could scarcely move. A pleasing anecdote is connected with this subject. Hiero, king of Syracuse, applied to Archimedes to know whether his crown was really composed of pure gold, or whether the workman to whom he had delivered a certain weight of that metal had debased it with copper. The crown was found to be of the same weight as the gold that was delivered, but the king's suspicions were not silenced. It happened that Archimedes observed, as he descended the steps of a bath, that the level of the water rose in proportion as his body was immersed. The facts we have stated, and their application to the royal question, immediately suggested themselves to his mind, and in the moment of joy he ran into the streets of the city, crying, I have found it! I have found it! There is, perhaps, no period in the life of a philosopher so precious and ecstatic as that in which he makes a grand discovery; the variety of applications to which the principle may be applied, and the consciousness of the preservation of his name and exertions, rush through his mind, awakening every hope that he had indulged in the hours of retirement and complacency. Many had observed the fact which so excited Archimedes, but none had perceived the principles dependant upon it, or the manner in which it could be applied.

The theory of sinking and floating bodies is the immediate consequence of the two facts we have mentioned. If the weight of the fluid that is displaced be greater than the weight of the body, it will float; if less, it will sink; and if they be equal, the body will remain in equilibrio. A piece of metal sinks in water, because its weight is always greater than that of the fluid it displaces; and a cork floats, because it is less. So also bodies in the atmosphere, and in all other gases, lose part of their weight, equal to the weight of the volume of fluid they displace. It will be readily understood that these principles imbody the theory of balloons.

BALLOONS.

The wish to navigate the atmosphere, and its practicability, seem to have been indulged by philosophers from a very early period in the history of science; but no rational plan for the construction of a vessel was proposed until the year 1670, when Francis Lana, a Jesuit, revived the inquiry by the invention of an ingenious balloon. The great difficulty was to form a sailing vessel sufficiently light to float in the air, and at the same time to support its pressure. Lana proposed to attach to a car four large exhausted globes, which would render the apparatus so light, that the aeronaut might be able with a sail to navigate the lower strata of the atmosphere.

In the year 1676, Cavendish investigated the properties of hydrogen gas, the levity of which made it exceedingly proba-



Lana's Balloon.

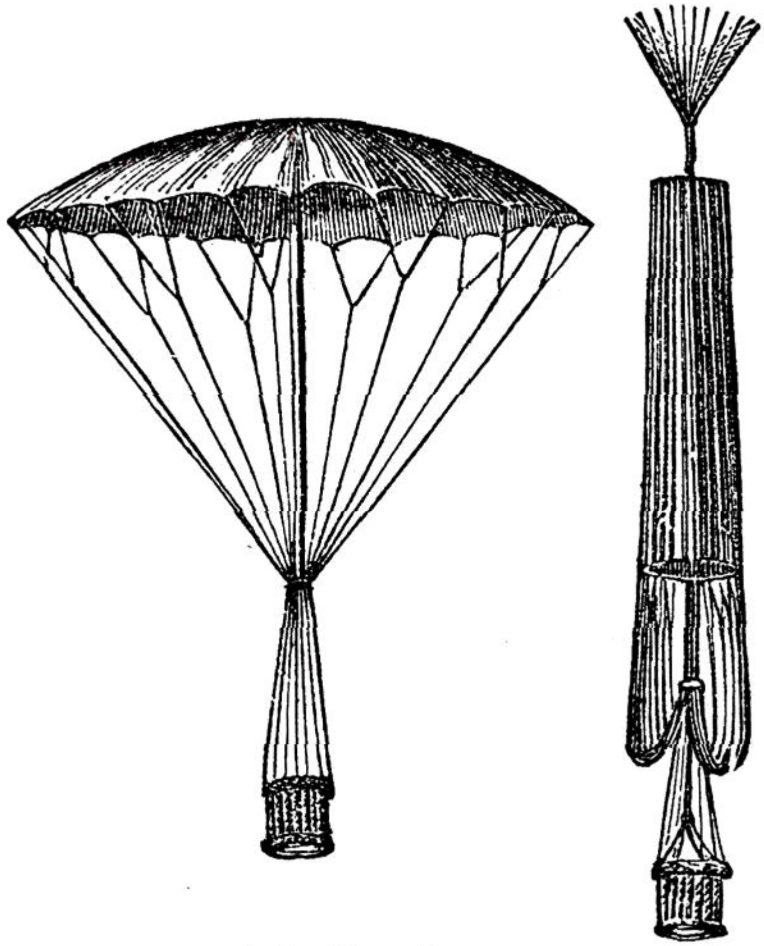
ble that a thin substance filled with it would float in the air. Cavallo made some experiments in 1782, but apparently gave up the subject in despair. In the same year Stephen and Joseph Montgolfier succeeded in constructing an apparatus which was lighter than the same bulk of atmospheric air, and consequently floated in it. After having made a number of experiments upon a small scale, they made public their discovery, and sent up a large balloon at Annonay on the 5th of June, 1783. It consisted of a large linen bag, lined with paper, 117 feet in circumference, and weighing 430 pounds. To the open end was attached a light wire basket, in which combustible substances were placed and inflamed, the heat so rarefying the enclosed air as to render it lighter than an equal bulk of the atmosphere. The machine ascended, and at this time carried more than 400 pounds of ballast, rising in ten minutes to the height of 6,000 feet.

Interesting as these experiments were, but little was yet done that could be made serviceable for the purpose of aerial navigation, as future experiments proved. The fire balloon, or Montgolfier, as it is sometimes called, is very unfit to support the aerial voyager, however the car itself may be fixed. Pilatre de Rozier and the Marquis d'Arlandes did however make the perilous attempt, and ascending from the castle La Muette, rose to the height of 9,000 yards, and descended in safety. Several persons at different times repeated the experiment, but many have lost their lives in the indulgence of their curiosity or pride.

M. Charles, professor of natural philosophy in Paris, at last succeeded in making an air balloon. He provided himself with a bag of lustring, twelve feet in diameter, and coating it with a varnish of gum elastic, filled it with hydrogen gas. The apparatus weighed about twenty-five pounds, and, when set at liberty, rose to the height of 3,123 feet in two minutes.

The next improvement in the construction of balloons was Blanchard's inventon of an apparatus called the parachute, by which the aeronaut can, when required, regulate the velocity of his fall. M. Garnerin improved this apparatus, and thus greatly diminished the amount of danger arising from aerial excursions.

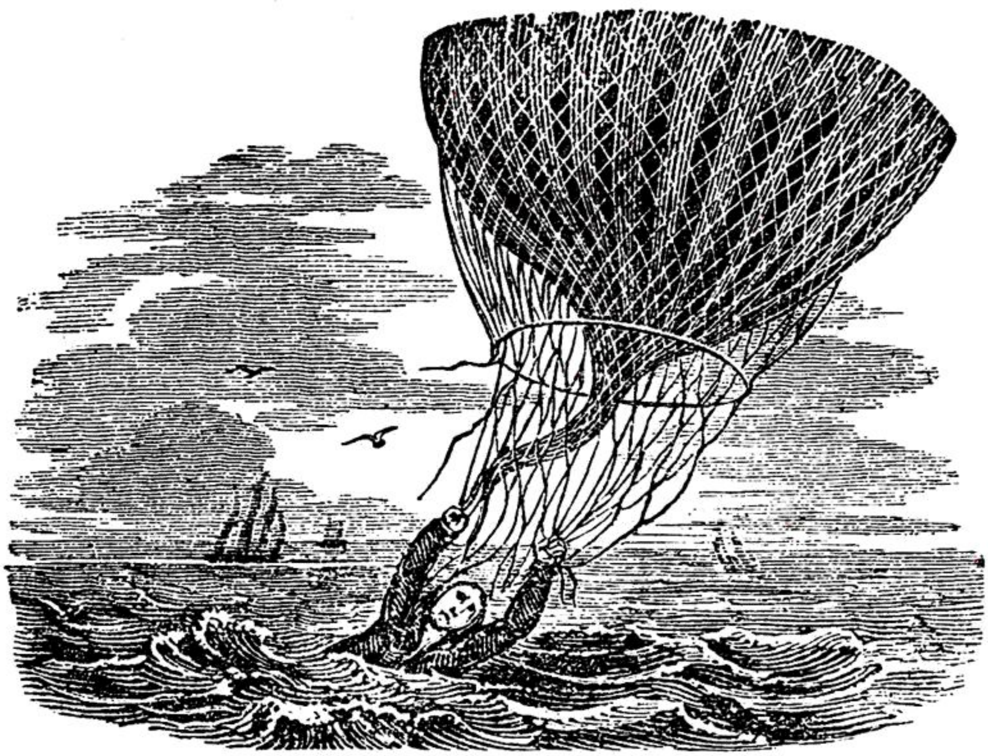
Among the aeronauts of our own country and time, Mr. Green is the most celebrated; but it may be doubted whether our capability of navigating the atmosphere will ever be found of any extensive service to man. The want of a method by which to control the direction of a balloon renders it at present worthless as a conveyance. The swiftness of its flight is a useless property to man, because it is the servant of the winds, and we have no power to stem the currents by which it is driven. Instances may occur in which it may be applied when the direction of the wind is favourable, but the opposing atmospheric currents, and their liability to change, give a doubtful character to every attempt. The result of Major Money's ascent proves the uncertainty of aerial advantages. This gentleman ascended from Norwich, the wind blowing at the time in such a direction as led him to suppose that he might fall in the neighbourhood of Ipswich. But he had scarcely attained the altitude of one mile before he encountered a violent current, blowing in a new direction, which carried him towards Yarmouth. The balloon fell in



The Parachute.

the sea about nine miles from land; the major supported himself for some time on the surface of the water by holding firmly upon the balloon, and he was at last relieved from his dangerous situation by a cutter that was cruising on the coast. This is not the only instance in which the aeronaut has been deceived by a change in the direction of the wind, and the existence of a superior current having a different course from that passing over the surface of the earth.

These general remarks on the causes of floating and sinking, as illustrated by the history of aeronautics, prove the fluidity of the air. But if a balloon had never been constructed, and man had never been poised between the earth and the ethereal vault, there would be no difficulty in proving the fact. Light bodies are conveyed from place to place upon the aerial waves, the clouds float over them at all altitudes, and the feathered tribe rise and descend in the vast ocean,



as fishes do in the water, having physical arrangements of anatomy and constitution as beautifully adapted to the fluid in which their movements are to be performed, as those which characterize the finny tribes.

ELASTICITY OF AIR.

Elasticity is another property of atmospheric air, and in this statement it is assumed that it has compressibility, a property which it is well known to possess. Previous to Mr. Perkins's experiments, air had not been made to occupy a space less than the one hundred and twenty-eighth part of its ordinary volume on the surface of the earth; but this gentleman, by means of an apparatus invented for the purpose, succeeded in reducing it to a much less bulk, and states that he at last compelled it to assume a liquid state. The latter assertion, however, has generally been objected to, as his experiments are by no means satisfactory. It does not necessarily follow that a body possessed of compressibility should likewise be elastic, for some bodies, when compelled by pressure to occupy a less space than they do under ordinary circumstances, retain that volume. But air is one of those bodies that have both these properties. If we take a syringe, closed at the end which is usually open, the piston may be driven down to a considerable distance by the exertion of a little force. The air, therefore, in the tube or syringe suffers compression; but as soon as the pressure on the piston is removed, the air recovers its former volume, and the piston is forced back into its first position, from which fact we learn that air is possessed of the property of elasticity.

EXPANSIBILITY OF AIR.

Expansibility, or the capacity of occupying, under particular circumstances, a much larger space than it does under ordinary pressure, is another property of atmospheric air. Dr. Ure has calculated that the gases disengaged by firing gunpowder are so rarefied by heat that they occupy more than two thousand times the space of the powder itself; and Mr. Boyle caused atmospheric air to dilate until it had attained nearly fourteen thousand times its ordinary bulk.

There are two agencies which are especially active in expanding air,—heat and a diminution of pressure. If a bladder containing only a small portion of air be exposed for a short time to the heat of a fire, or if boiling water be poured upon it, the air will expand, and the bladder appear as though it were fully distended by air in the ordinary state of density. So also, if it be placed under the receiver of an airpump, and a part of the air that presses upon it be abstracted, the remainder will expand and entirely fill the bladder.

From these statements it follows that air may have various densities, according to the circumstances under which it is placed. In the instance of condensation that has been mentioned, its density was great; in that of rarefaction, its density was small: and the same is true of the atmosphere; for its density at any height is just in proportion to the pressure that is exerted by the superincumbent mass of air. As the air is very elastic, it suffers, in the lower regions, where it bears a great pressure, considerable condensation, and extends itself as much in the higher regions, where there is no force to neutralize its elasticity. It therefore follows that the stratum of air immediately in contact with the surface of the earth is more dense than any above it, because it sustains a greater pressure, and its particles are consequently brought into closer contact; but at every step as we ascend from the surface of the earth the air becomes less dense, because it sustains a less pressure.

The elasticity of air increases proportionally with the density. The lower stratum of the atmosphere is confined to its present bulk, or has its present density, in consequence of the pressure it sustains. If that pressure were removed, then its elasticity would cause it to expand, and fill a much larger space; but if we would give it double its present density, that is, reduce its bulk to one half, then a double pressure must be employed; and if a triple density, a triple pressure must be applied; because its elasticity would increase in the same proportion. This is what may be understood by the expression, the elasticity of the air increases proportionally with the density.

The decreasing density of the air is not without a purpose, as applied to the habits and wants of particular animals and vegetables. The condor, which is generally met with at an elevation of from ten to sixteen thousand feet above the level of the ocean, inhabits a very rarefied medium. Whenever it visits the lower strata of the atmosphere, it is compelled to do so from an absolute want of food, and leaves it for the regions of perpetual snow, which are more congenial to its habits and constitution, as soon as its wants are supplied. Humboldt states that when he visited the Antisina, one of the Andes of Quito, he was accompanied by the condor to the height of sixteen thousand feet above the sea; but when he ascended Chimborazo, which is twenty thousand feet high, that kingly bird was seen hovering in the air beneath him. It would therefore appear that it is not suited to live in the warm temperature and great density of the atmospheric stratum that immediately surrounds the earth, nor in the intense cold and great rarefaction of that which rests upon the summit of Chimborazo. Every bird that floats in the aerial ocean has a certain habitation, governed or regulated by the power of its wing and its constitutional characters. The elevation from which Messrs. Robertson and Saccharoff threw from the car of their balloon the pigeons that fell like weights on the atmosphere, was that in which the condor would have stretched its broad pinions and defied the power of man.

PRESSURE OF THE ATMOSPHERE.

It is scarcely necessary to make the formal statement that the atmosphere exerts a pressure upon all the bodies on which it rests, for as it is a fluid, it must have weight. The weight of 100 cubic inches of atmospheric air at 60° Fahr., the barometer standing at 30 inches, is 30.92 grains, according to Mr. Kirwan's experiments. Sir George Shuckburgh obtained a different result, and fixes its weight at 30.5 grains; but from the experiments of Prout, Dalton, and Henry, it appears that Mr. Kirwan was nearer the truth, as these gentlemen agree in fixing the weight of air at above 31 grains. But whichever of these results we may adopt, it is quite evident that the atmosphere must exert an enormous pressure upon the surface of the earth, and, as it is a fluid, that pressure must be in every direction. It was proved by Galileo and Torricelli, that at the level of the sea the air presses with a force equal to about fifteen pounds upon the square inch. Now supposing the body of an average-sized man to present a surface equal to about two thousand square inches, he will support a weight of nearly thirty thousand pounds. This statement, however, is often misunderstood, and people imagine that we carry the enormous burden upon our shoulders, not remembering that the pressure is distributed over the body, and, being resisted by internal forces, tends rather to support than to oppress.

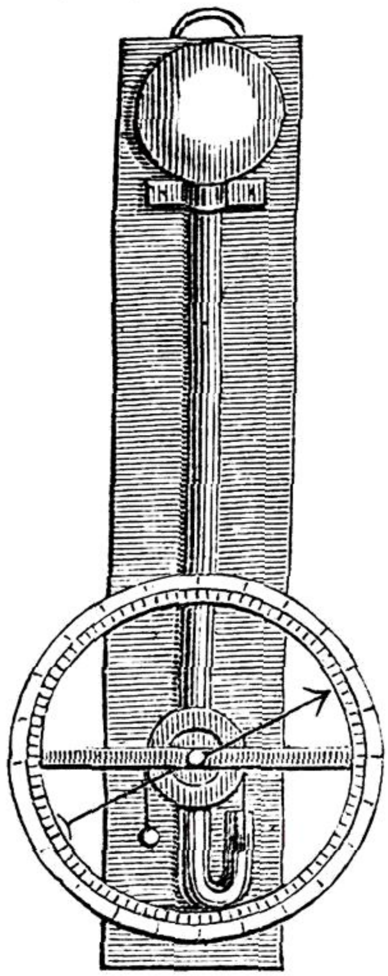
The Magdeburgh hemisphere is an instrument that very

Magdeburgh Hemispheres.

beautifully illustrates and proves the pressure of the air in every direction. It consists of two hollow brass hemispheres, so constructed that, when placed together, they fit, and are air-tight. These are furnished with handles, one of which may be unscrewed and the cup attached to the air-pump. This being done, let the two cups be placed together, and the air contained by them be abstracted. If the stop-cock be then closed, and the apparatus removed from the pump, the handle may be replaced, and two strong persons will scarcely be able to separate the hemispheres. This experiment, invented by Otto Guericke, demonstrates the existence of atmospheric pressure in every direction; for as soon as air is admitted into the interior, the external pressure is neutralized, and the hemispheres may be separated by a child.

The ancients were quite ignorant of the facts to which we have just alluded, and attributed all the phenomena now known to be the results of atmospheric pressure, to nature's abhorrence of a vacuum, or empty space. This dogma was universally received as the reason why water rose in a pump, till it was accidentally discovered, in the early part of the seventeenth century, that water could not be raised in a pump, when the sucker, falsely so called, was more than thirty-two feet from the surface of the water. Unable to look beyond the dogma they had received from the ancient masters, the philosophers of the day decided, after a consideration of this fact, that nature did not abhor a vacuum to a height greater than thirty-two feet. Torricelli, however, was not satisfied with the explanation, and a single experiment assured him that the air had weight, and that water could not rise to a greater height than thirty-two feet, because it then exactly balanced a column of atmospheric air with a base of the same dimensions. As soon as he had formed this opinion, he conceived the happy idea of testing its truth by using mercury instead of water; and the practical results of the experiment have been as important as the theoretical. Mercury being about thirteen and a half times heavier than water, a column of about thirty inches long ought to counterpoise a column of atmospheric air, if water be really sustained at a height of thirty-two feet above its level by atmospheric pressure. Torricelli made the experiment, and the result proved the truth of the supposition.

This discovery soon excited the attention of all the philosophers in Europe, and a variety of opinions were formed, and unhesitatingly expressed, by those who preferred prejudice to truth. To Pascal, whose active mind was immediately roused by the report of this important, we might say brilliant, discovery, we are indebted for an extremely original experiment. This philosopher at once perceived that, if the suspension of the mercury in the tube was due to the pressure of the atmosphere, the column ought to become shorter when carried to a place at some considerable elevation above the level of the sea, for it would then have a less column of air to support. Perier, the brother-in-law to Pascal, was engaged to try the experiment upon the top of the Puy de Dome, a lofty volcanic mountain in Auvergne, and he found that the mercury continued to descend as the height to which it was carried increased. In this way the Torricellian principle was confirmed, the barometer discovered, and the action of the pump ascertained.



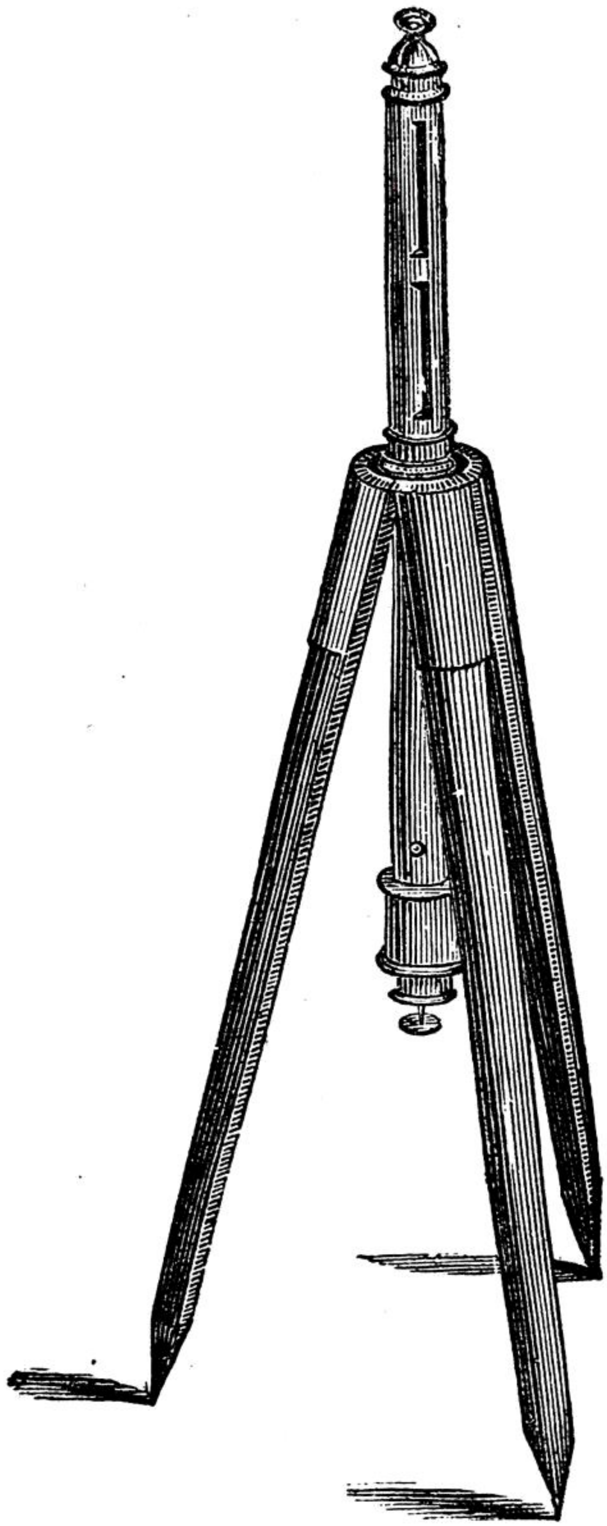
Hook's Barometer.

It was afterward discovered that the mercury rose and fell, within a small space, even when its elevation was unchanged, and that it was affected by the varying conditions of the atmosphere. It then came into use as an atmospheric prognosticator, and is still employed as a measurer of atmo spheric pressure, and as the foreteller of meteoric changes, though not always upon the most scientific principles.

The barometer in common use is that invented by Dr. Hook; and as its construction is not perhaps so generally known as its external appearance, it may be desirable to give a description of it. It consists of a glass tube containing mercury, the upper end being expanded into a small globule, the lower turned upward to the height of two or three inches. The column of mercury in the tube is supported by the pressure of the column of air resting upon the open end of the tube, and upon the surface of the mercury is placed a glass float, to which is attached a string passing over a pulley, and balanced by a weight. As the weight moves up and down, it turns the pulley, to which is attached a hand or index, that points out upon a graduated circle the exact amount of change in the altitude of the mercurial column, which it does with extreme accuracy.

Pascal's experiment can scarcely fail to suggest the use of the barometer to measure heights, and it has consequently been employed by philosophers for that purpose. At first considerable difficulties stood in the way, and many errors, for which the observers could not account, were observed in the results of the experiments. De Luc afterward discovered that the greater number of these might be traced to the circumstance of not considering the comparative expansions of mercury and of air; for a temperature which would greatly expand the latter would have no influence whatever on the former.

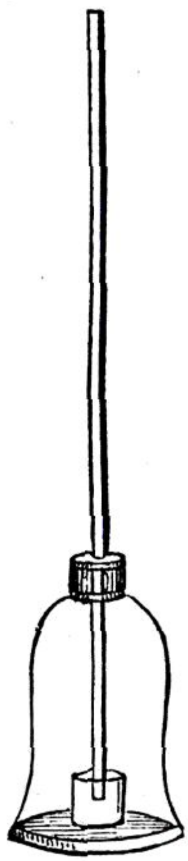
If the density of the atmosphere were uniform, nothing could be more simple than the measurement of heights by the barometer. It has been found by experiment that when the thermometer is 32° Fahrenheit, and the mercury of the barometer stands at thirty inches, it falls about one tenth of an inch if carried to the height of eighty-seven feet. Now, if the density were equal throughout, it would only be necessary to multiply eighty-seven by the number of tenths of an inch that the mercury fell, and we should have the height in feet. But the density of the atmosphere is not uniform, and conse quently the difficulty of the problem is increased. So neces sary, however, was it that this method of measurement should be rendered available, that it received the attention of many



Portable Barometer.

eminent philosophers; and the traveller, with the assistance of the tables that have been prepared, can now determine the height of a place above the level of the sea by the barometer as accurately as its horizontal distance from any fixed point, by the ordinary rules of trigonometry.

The experiment performed upon the Puy de Dome, under the direction of Pascal, may be readily made by any person who possesses an airpump and the usual pneumatic apparatus. If a barometer tube, not less than thirty inches in length, be filled with mercury, and inverted in a cup containing the same metal, the fluid contained in the tube will immediately fall to



Experiment showing the influence of the atmosphere on the mercurial column.

such a height as to balance exactly the pressure of a column of atmospheric air. But let the cup in which the mercury tube is placed be put under the receiver of an airpump, and as the process of exhaustion goes on, the mercurial column will decrease in height; and, could a perfect vacuum be produced, the mercury contained in the tube would be entirely discharged into the cup.

The pressure of the atmosphere upon the surface of the earth, and on all bodies, is not an unimportant principle in its direct influence upon organic structures, and in the provisions which are necessary for the supply of the wants of man in particular. The earth is essentially, in its structure and natural condition, the intended abode of organized beings; and there is, perhaps, no law of matter, or provision for the return of particular phenomena, that has not a more or less direct influence upon the wants and happiness of animal being. An average sized man sustains a pressure from without of about fourteen tons, and, so far from oppressing him, it is absolutely necessary for his existence, for, by resisting the outward pressure of the fluids in the body, it prevents the vessels that contain them from distention or bursting. Count Zambeccari ascended, in 1783, to so great a height in a balloon, and came into so rarefied an atmosphere, that his hands and feet were much swollen. Some travellers have suffered under a violent bleeding of the nose when they have approached the summit of very high mountains, and all experience inconvenience from the feeling of distention. We are not conscious of the weight that we sustain, because it is acting on all parts of the body; and if it were not so, we should be crushed under the burden we now unconsciously sustain. A man holds out his hand, and does not know that it is, as it were, supporting some hundred pounds of gas; but let him place the palm of his hand upon an open receiver, and a part of the air that it contains be taken away, and he immediately becomes conscious of an oppressive force on the back of the hand; for that which before supported or resisted the downward pressure is removed.

It will not now appear strange that we are extremely sensible, and particularly those who have weak or nervous constitutions, of atmospheric changes. Some persons have asserted that the animal body is not under the influence of external causes; but, not to refer to the habits of many animals at the time of meteoric changes, and the diseases that are floated from region to region on the wings of the wind, observe the countenances of men, and are they not unfailing barometers? Or, let us examine our own feelings. We feel braced and strengthened by the cool and dry atmosphere of a fine morning in spring, and are enervated and depressed by the wet and murky air of a dull day in winter. These effects are no doubt to be traced in some degree to electrical changes, but also in part to the alteration of atmospheric pressure; and when we consider that in the course of a few hours it may vary, upon a human body, as much as half a ton, we shall not be surprised at the results which follow.

Vegetable structures are of course as much indebted to the external pressure of the air as animal bodies; for, if it were removed, their vessels would be unable to contain the fluids which circulate in them. If we place a withered apple under the receiver of an airpump, and abstract the air, it will first of all swell out to its natural bulk, as when newly gathered from the tree, and its exterior covering will then burst, and its juices escape. The same result would follow the withdrawing of that conservative principle of nature, atmospheric pressure.

The pressure of the air serves another important purpose, in preventing liquids from boiling at very low temperatures. It is a well known fact, that water boils on high mountains when its sensible heat is lower than that required to produce ebullition at the level of the sea; and it does so, because it sustains a less pressure. Water must be raised to a temperature of 212° before it will boil, if the experiment be made at ordinary elevations, but at the top of Mont Blanc it was found to boil at 189°. Dr. Franklin invented a very pretty instrument, called a pulse-glass, to show that liquids boil at very inferior temperatures when deprived of atmospheric pressure. It consists of an exhausted glass tube, with a bulb at each end, and contains a small quantity of spirits of wine. If one of the bulbs containing the fluid be held in the palm of the hand, the instrument having a rather sloping position, the heat of the hand will be sufficient to make the spirit boil, and the vapour thrown off will be condensed at the opposite end. Now if there were no atmospheric pressure, many fluids which are now liquids would be vaporized at common temperatures, and the boiling points of others would be so much reduced, that a very slight increase of sensible heat would cause them to assume the vaporous state.

EXTENT OF THE ATMOSPHERE.

Having explained the chymical constitution, and illustrated the physical properties of atmospheric air, as well as its influence in the mass upon the general constitution of matter, and organized bodies in particular, we may proceed to inquire into the probable height to which the atmosphere extends. It has been already stated, that the pressure of the atmosphere decreases according to the increased elevation above the level of the sea. This decrease of density for equal ascents is in geometrical progression, that is to say, at an elevation of three miles, the density would be only one half what it is at the seashore; at six miles one fourth; at nine miles one eighth: so that at the height of fifteen miles the pressure of the superincumbent air would not support a column of mercury of more than one inch. It is evident, therefore, that the greater portion of the atmosphere is within fifteen miles of the earth's surface; and yet it is supposed, and it may be considered as satisfactorily determined, that the atmosphere extends to a height of more than forty-five miles.

Some persons have imagined that the atmosphere has no limit, but is spread in a state of extreme rarefaction through all space. Now if space were filled with an atmosphere, however great its rarity, the planets would have atmospheres, for these bodies would accumulate, by their attractive power, a portion of the fluid medium around them, which would increase in density with its proximity to their surfaces. But it does appear that some planets have no atmosphere, and, therefore, that which surrounds the earth does not extend through space.

But this supposition may be objected to on another ground, as opposed to the known influence of the forces by which matter is governed. As the density of the atmosphere decreases with its height above the surface of the earth, on account of a diminution of pressure, there must be some point where the elasticity of the air and the force of gravity are equal, and there the atmosphere must terminate.

Another argument in proof of the limitation of the atmosphere might be adduced from a consideration of the elementary constitution of matter. Substances are combinations of ultimate particles, united in definite proportions. The atmosphere must therefore have a limit, and that is a stratum of ultimate particles, beyond which it cannot be supposed to extend without investing it with hypothetical properties.

As we know the pressure exerted by a column of atmospheric air, we have a datum by which to calculate its extent. If the density were the same throughout, this would be an extremely simple problem; for, by ascertaining the weight of a column of air of any dimensions, and the height of a column of water of the same dimensions, we might, by a simple equation, discover the height of the atmosphere. But as the rarefaction increases with the altitude, it is a somewhat complex and difficult problem to ascertain its height. This may, however, be approximately determined by another method. It is generally known that twilight is a phenomenon resulting from the refraction and reflection of solar light after the luminary has descended below the horizon. Now from calculations made by Dr. Wollaston, founded upon the known law of decreasing density, it is certain that at the height of about forty or forty-five miles, the atmosphere does exist, and in such a state that it influences the direction of light. If we calculate its extension by the length of our twilight, we shall be brought to nearly the same result. It is also found capable of conveying sound at the height of sixty-nine miles. Thus, although it is almost impossible to say in respect to the atmosphere, thus far it extends and no farther, yet there are methods by which it is possible to acquaint ourselves with its existence and conditions within certain limits.

ADAPTATION OF THE ATMOSPHERE TO ANIMALS.

In the consideration of the principles and phenomena to which we have referred, the mind is especially interested by their adaptation to the physical or intellectual wants of animals. The senses are as capable of becoming the media of painful as of pleasurable sensations, and nothing but an admirable application of external agencies preserves us from those violations of sensibility to which our constitution renders us liable. The very capabilities of enjoyment that are possessed by man and inferior creatures, would have acted as a curse, had not external nature been in concord with them. Instead of the elastic and enlivened feelings with which we now look upon the face of nature, it might have been the source of constant annoyance; and thus the very capabilities by which man is distinguished, might have become the increasing causes of pain and discomfiture. But by the arrangements which the Creator has adopted, man is not only ordained to live, but to live surrounded with available pleasures, and double blessings are woven with his heaviest toil—those of the intellect and those of the senses. He sows and he plants for the relief of his wants, but he has an intellectual pleasure in watching and in accounting for the results, while the foliage and the blossom accord with his sensations of beauty, and the fruit is pleasant to his taste. These are the results of a symmetry in design; and we can scarcely conceive how great a disorder and disproportion would be produced by an alteration in one great principle, such, for instance, as the constitution of the atmosphere.

Allusion has already been made to the fitness of the atmosphere for the conveyance of light to the eye, which is not only necessary for the production of those pleasurable sensations which external nature is capable of affording, but also that the animal may be able to obtain its food, and preserve itself from those foes or dangers to which it may be especially exposed. It is quite true that animals have been provided with peculiarities in the formation of the eye, so as to enable them to fulfil the especial object of their creation; but, whatever may be the nature of these peculiarities, there are external adaptations suited to them all, and they are but particular illustrations of the same general principle. We may be chargeable with digression in so doing, but it is almost impossible to deny ourselves the pleasure of selecting an example. Take the vulture as the type of the whole class of animals to which it belongs, and, from what we know of its habits, we may expect it to have a peculiarly constituted vision. From its habitual residence in regions very far above the surface of the earth, it is necessary that it should have the power of seeing objects at a great distance; and as the distance between the point of the beak and the eye is small, it should also have the capability of seeing objects that are near. Both these powers it possesses in a most remarkable degree, being not only able to choose the part of the carcass upon which it will feed, but also to descend upon it, from a height at which the bird itself is scarcely visible to the human eye. It has therefore been furnished with a peculiarly constructed eye, and such a capability of adjustment, that it can adapt it to any distance that may be required. But the eye, however admirably formed, would be perfectly useless, were there not some medium by which the light could be conducted to it with a proper intensity

AIR A CONDUCTOR OF SOUND.

There is yet another adaptation of the atmosphere to the wants of man that deserves notice. Air is a conductor of sound. The sense of hearing is not so excursive as that of sight, but it is highly important to animals as affording a lively gratification, a means of detecting approaching danger, and a capability of communicating thought and feeling. It is by habit that we obtain the power of distinguishing places and things by sound, a capability that is acquired by animals as well as by men. This is no mean acquisition to beings who, by reason of their power of locomotion, have many more chances of destruction or injury than those which are almost or entirely fixed to the same spot. It is not a mere speculative opinion, but the result of constant observation, that the quickness of sensation, whether of hearing, seeing, or otherwise, is proportioned to the wants and enemies of the animal; but of all the senses, seeing and hearing are the most important for the independent preservation of life; and if that of sight be the most universal, that of hearing is best able to supply its place.

Three things are necessary for the production of the sensation of sound: a sounding body, an organ of hearing, and a medium by which the sound may be transmitted from one to the other. It is to the latter that our attention is particularly directed. Air is the ordinary, but not the only, conductor of sound. Hauksbee discovered that in a vacuum no sound could be produced; for having suspended a bell in the receiver of an airpump, he found that the sound became less and less intense as the air was rarefied, and was at last altogether inappreciable. But, on the other hand, when air is condensed into a receiver, the intensity of the sound is greater than in air having that density usual upon the surface of the earth, a circumstance well known to those who have descended in a diving-bell.

These facts will explain a phenomenon familiar to those who have visited mountainous regions. In consequence of the increasing rarefaction of the atmosphere, in proportion to the elevation above the surface, sound must necessarily, if the statements just made be true, become less intense in proportion to the elevation above the level of the ocean. Saussure relates that a pistol fired upon the summit of Mont

Blanc produced a report that was not louder than that of a cracker exploded at the base of the mountain. The solitary silence of mountains is indeed so well known, that it has become proverbial, and almost an essential property of the poet's elysium. It is not, however, so generally known that there is a physical reason for this result, for it is usually imagined that it arises from the destitution of animal life, which is not in itself sufficient to account for the phenomenon.

But although the intensity of sound is diminished by the rarefaction of the air, yet the atmosphere is capable of conducting sound at heights which cannot be attained by man. The sound produced by the explosion of the meteor of 1719 was like that of a large cannon, although it was at an elevation of sixty-nine miles. The great meteor of 1783, which was said to be half a mile in diameter, and to move with a velocity of twenty miles in a second, produced a distinct rumbling sound, although it was at the height of fifty miles at the time of explosion. These facts prove that air is capable of conducting sound even when in a state of great tenuity, as it must be at these heights, and we may also learn from them that the atmosphere extends beyond that limit at which it has the power of refracting light.

The intensity of sound, and the distance at which it may be heard, are considerably influenced by the state of the atmosphere. Fogs, rain, and snow obstruct the passage of sound, a circumstance that must have been observed by every one. A clear, cold atmosphere is favourable to the ready and perfect conducting of sound, and especially when it is carried over the surface of water or ice. We remember to have frequently listened, in a cold winter's evening, to military music, the tones of which were softly borne over the quiet waters from a distance. It must also have been noticed by the reader that sounds are more audible by night than by day. It is true that the silence which universally prevails may render us more sensible of feeble sounds than during the bustle and animation of the day, but there is another reason for this phenomenon. At night there is a greater uniformity in the temperature and density of the atmosphere; for all the ascending heated currents of the air which result from the action of the sun's rays, cease with the activity of the agent that gave them birth. An irregular medium has a great effect in obstructing and stifling sound, and consequently sounds are conducted with more facility at night than when the sun is above the horizon.

The great distance at which sounds have been sometimes heard is very remarkable, and probably chiefly depends on the state of the atmosphere. Lieutenant Foster states that he has conversed with a man across the harbour of Port Bowen, in the North Sea, at the distance of a mile and a quarter. Guns fired at Carlscroon were, according to Derham, heard across the southern extremity of Sweden as far as Denmark. But the most remarkable instance with which we are acquainted is that recorded by Sir Stamford Raffles, who informs us that the noise which attended the great eruption of Tomboro, in 1815, was heard at Sumatra, a distance of 970 miles.

Many experiments have been made, at various times, and in different parts of the world, upon the velocity of sound in air. The early experimenters, however, are all more or less inaccurate, for want of instruments sufficiently correct to measure the time that elapsed between the flash being seen and the sound being heard. Another cause of error was inattention to the influence of the wind, for which they seldom allowed, although it is quite evident that sound must be transmitted with a diminished velocity when the wind is blowing in a contrary direction to that in which the sound was heard; and when the wind is blowing in the same direction its velocity must be increased.

The modern experimenters have avoided both these sources of error; for, possessing accurate instruments, they have either chosen a time when the air was at rest, or have caused the sound to be transmitted in a direction at right angles to that of the wind.

But the chief difficulty is to ascertain the exact measure of the interval of time between the flash and the report. The most accurate experiments that have been made are those of Moll and Vanbeck, in 1822, and those of the French academicians in the same year. In the experiments made by the Dutch, a clock was used, so constructed that its index could be at any time stopped without stopping the machinery. By this instrument time could be measured to the one hundredth part of a second. The French used a watch of a very ingenious construction. It was furnished with two hands like a common watch, but one of them performed a revolution every second, and might be made to touch the dial-plate at any time without stopping, and being supplied with a kind of dotting pen furnished with printer's ink, left an impression to be read off at leisure.

By these experiments it was discovered, that when air is dry, and at the freezing temperature, it will conduct sound at the rate of 1,090 feet in a second.

Other gases have the property of conducting sound, but they do so with different velocities, and, what is still more singular, the intensity also varies with the medium. In hydrogen gas the sound is scarcely louder than in a vacuum; in carbonic acid and oxygen it is louder than in air. When hydrogen is breathed, which it may be for a short time, though not without danger, the voice is enfeebled but shrill. When equal quantities of this gas and of common air are mixed together, the intensity of a sound is not greater than it would be in a receiver, the contained air having not more than half its common density. This circumstance arises from the great difference in the velocity of sound in the two gases. *One propagates it more rapidly than the other,* and as the particles of both are diffused throughout the whole space, they hinder and stifle the sound, in the same manner as aqueous vapour diffused through the atmosphere during a fog. But atmospheric air is itself a mixture of gases, yet the velocities with which sounds are conducted in them are so nearly alike that little or no obstruction is produced. This fact gives us a new and very interesting proof of the great adaptation of the atmospheric constitution to the wants of animated beings.

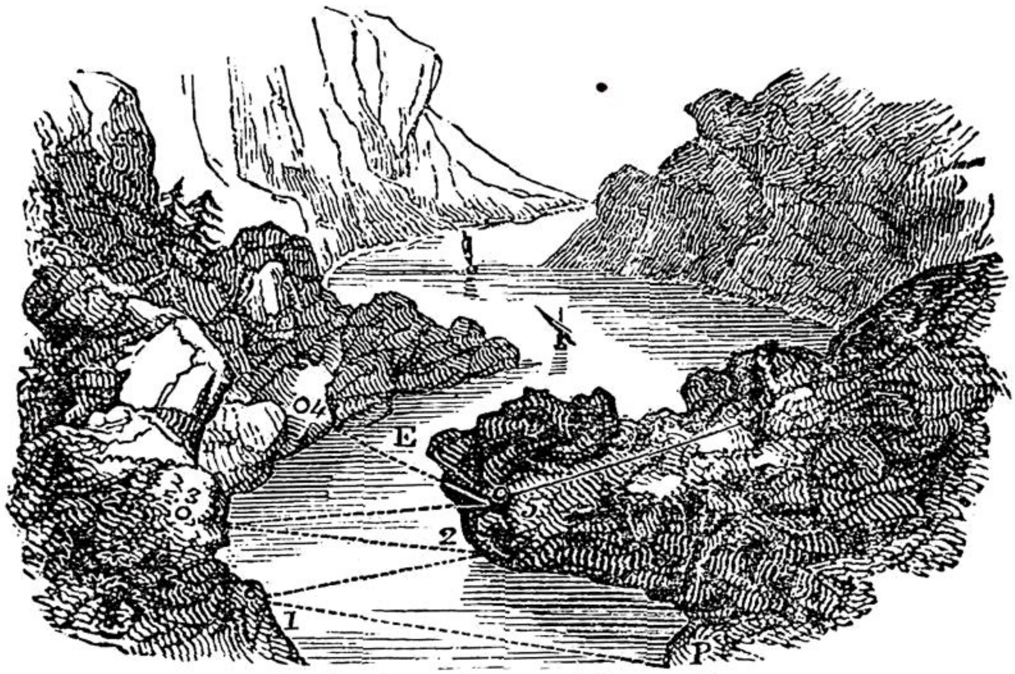
It must not be imagined, from the foregoing remarks, that an elastic fluidity is essentially necessary for the proper conduction of sound. Both liquids and solids possess this capability in a variable degree. It has been proved by many experiments, made in various manners, that sound is audibly conducted by water. Fishes certainly possess the sense of hearing, and divers have an accurate impression of sounds produced in water, although the sounds that are excited in the atmosphere are enfeebled by their passage into a new medium. From the experiments made by M. Colladon, on the velocity of sound in water, it appears to travel at the rate of 4,708 feet in a second. All elastic solid bodies also, such as glass, steel, and the metallic alloys, are good conductors. It is, however, always necessary that the conducting body should be homogeneous, or the sound is interrupted; and the same result is obtained if the parts be imperfectly joined.

The manner in which sound is conducted from the sonorous body to the ear cannot be perfectly understood without reference to a mathematical reasoning, which would be obviously unfit for these pages. We may, however, convey some idea of the means by a brief verbal description. When a body is in the act of sounding, it is observed to be in a state of vibration. A string may be seen to vibrate from one side to the other, and the vibration of bodies, when not seen, may be frequently felt. These vibrations are communicated to the air, and by it conveyed to the ear. But every vibratory motion produced in the air is not the source of sound; it must be occasioned by an elastic substance. Newton was the first who investigated the process by which these vibrations are produced, that is to say, by an alternate condensation and rarefaction of the air in contact with the vibrating body. We may conceive the effect produced on the air as resembling that which is occasioned by throwing a pebble into still water.

Whenever a sound is conveyed to the ear, it is occasioned by a vibration produced in the atmosphere. But a sound may be either a noise, or a musical note, the latter being the result of a regularly and uniformly repeated succession of vibrations.

ECHOES.

There is one other subject of inquiry connected with the atmosphere as a conductor of sound that seems worthy of notice in this place; and that is, the circumstance under which echoes are produced. An echo is produced whenever sound meets with an obstacle of sufficient regularity to reflect it. The laws by which the reflection of sound is governed are the same as those that influence light under the same circumstances; if it be obstructed by a plane surface, the direction will be changed, but the paths will be parallel; if by a concave, it will converge; if by a convex, it will diverge. A wall, or the sides and ceiling of a room or public building, may occasion echoes; but as sound travels with a great velocity, and as it takes no perceptible time in moving from one part of a room to another, the echo is so blended with the original sound that the two appear as one. In large buildings, however, this may not be the case, and then the echo frequently becomes a serious inconvenience. We may notice one or two of the most remarkable instances in nature and in art.



Reflection of sound by rocks.

On the banks of the Rhine, near Lurley, there is an echo that repeats the sound several times, and has been frequently described by travellers.

In the whispering-gallery of St. Paul's Church, London, the faintest whisper is conveyed from one side of the dome to the other. The tick of a watch may be heard from one end to the other of the Abbey of St. Albans; and in Woodstock Park, there is an echo that repeats seventeen syllables by day, and twenty by night. In the Cathedral of Girgenti, in Sicily, there is an echo by which a sound is conveyed from the great western door to the cornice behind the altar. The confessional happened to be placed at the former, and some over-curious persons resorted to the latter for news, till by some mishap a listener once heard more than was convenient, by which the secret became known, and the confessional was consequently removed. At the sepulchre of Metella, the wife of Crassus, there was an echo that repeated five times. We are informed by Barthius, in his notes on Statius's "Thebais," that on the banks of the Naha, between Coblentz and Bingen, an echo repeated the words of a man seventeen times; and although the repetition is, in most echoes, heard after the word or note of the person who speaks or sings, in this instance the repetitions follow the original sound so rapidly and clearly, with such varieties, that the voice seems to be lost in the multitude of mimicry.

In times when men were less interested in the investigation of the causes of the phenomena they heard or saw, the echo must have exceedingly perplexed them. Were we permitted to indulge imagination, it would not be difficult to picture to ourselves the amazement and consternation with which an inhabitant of the newly-peopled earth would be seized, when he first heard the rocks far and near reiterating the broken sentences that escaped from his lips, as he wandered alone by the banks of a river, or chased the deer in the mountains. There is much in external nature calculated to awaken that consciousness of invisible power which resides in every bosom that has not been entirely contaminated by vice. The Greeks, whose luxuriant imaginations were ever active in the personification of natural phenomena, have given to echo a place among the gods. The reader will recall to memory her history. She is described as the daughter of Air and Tellus, the attendant of Juno, and the confidant of Jupiter. Her loquacity, however, displeased the god, and she was so far deprived of speech as to only have the power of reply when spoken to. Pan was once her admirer, but never enjoyed her smiles. Narcissus was the object of her choice, but he despised her, and she pined to death, though her voice is still heard on the earth. It is unnecessary to point out the aptness and beauty of this personification.

We might here close our description of atmospheric phenomena, and introduce some remarks upon air in motion, under the head of "appearances dependant on the distribution of heat;" but we shall, perhaps, best maintain the order of our subjects by an allusion to the phenomena in this place.

WIND.

The equilibrium of the atmosphere may be destroyed, and streams or currents of air be produced, by a variety of causes, but change of temperature is by far the most important. Air, as well as other bodies, expands by heat, for its particles are thrown to a greater distance from each other. Heated air, therefore, must be bulk for bulk lighter than cold air, and will consequently rise and give place to that which is cold and heavier. If the air resting upon any spot be more heated than that which surrounds it, there will be a constant flowing in of cold streams from every direction, and those persons who are situated to the north of the spot will experience a north wind. while those to the south a south wind; but those who are on the spot where all these several currents meet will suffer violent and tempestuous weather. When this process is extensive and violent, hurricanes and whirlwinds are produced.

We may often learn principles that may be applied to the investigation of nature, from comparatively insignificant results. Artificial winds are constantly circulating through our houses. Smoke rises because it is mingled with hot air, and the deficiency of air which is thus produced in an apartment, is supplied by the cold air which rushes through the crevices of the doors and windows. But our fires communicate at the same time an increased temperature to a portion of the air in the room, which consequently rises; and it will always be found, in every building, that the hottest air is at the top. On this account there are always two currents in a room, one outward, and another inward, as may be easily proved; for, if a lighted candle be placed near the top of the door, the flame will be blown outward by the heated current which is making its escape; and if at the bottom, it will be blown inward by the cold current which is rushing in. The same process is going on in nature on a larger scale, and the principle which explains the one is applicable to the other. Take the land and sea breezes, which occur in all the islands of the torrid zone, as a proof of this statement. During the hottest part of the day the winds set in from every direction towards the centre of the island, for the sun's rays produce more heat by their reflection from land than from water. When the sun ceases to throw its rays upon the region, the land cools, and that portion of air which had been heated by them will begin to descend, and currents will be produced off the land, occasioned by the spreading or equalisation of the atmosphere.

But the principle to which we have referred is not sufficient in itself to account for all the phenomena we witness as the results of air in motion. The air resting upon the equatorial regions being more heated than that which surrounds the polar, there must be a constant current of cold air rushing from the poles to the equator, and a counter current of hot air from the equator to the poles. We might therefore anticipate, that all countries in the northern hemisphere would experience a constant north wind, and all in the southern hemisphere a constant south wind, except so far as local obstructions might interfere. No such results, however, are produced; but within thirty degrees of the equator in each hemisphere, constant winds are blowing, called the tradewinds; that in the northern hemisphere from the northeast, that in the southern from the southeast.

It is true that there is a never-ceasing under-current of air from the polar regions to the equator. But, in consequence of the revolution of the earth from west to east, the atmosphere is influenced by a force acting at right angles to that which results from the heating of the air at the equator. As an atmosphere must necessarily participate in the motion of the body it surrounds, and as the velocity of the earth's circumference must increase from the poles to the equator, so the velocity of the atmosphere from west to east must increase in proportion to its advance towards the equatorial regions. Let us, then, imagine a current of cold air rushing from the poles to the equator to occupy the place vacated by the heated air, and throughout its progress to be influenced by a constantly increasing rotary motion from west to east, and it will be evident that, as two forces are acting upon it, it cannot implicitly obey either, but must take an intermediate path, and in fact describe a curve line, the convexity of that line being turned towards the east. The cause of the tradewinds will now be easily deduced. In the northern hemisphere there is a current of air from the north to the equator; but, being impressed by a force tending to drive it eastward, that is to say, being under the influence of the earth's rotation, it takes an intermediate course, and a northeast wind is produced. In the southern hemisphere there is a current from the south to the equator, but this being also under the influence of a force tending to drive it eastward, a southeast wind is produced.

Some writers have referred to the influence of the solar and lunar attraction upon the atmosphere as a general cause of winds. There can be no doubt that the two luminaries, by their attractive force, have an influence upon the atmosphere somewhat similar to that which disturbs the ocean, but their effect upon it is of little or no importance in our present inquiry, and it is quite certain that the tradewinds, so far from being produced by, exist in spite of their attraction.

The tradewinds in some parts are subject to a change of direction every six months, and they are then called monsoons. This variation in the tradewinds is produced by the annual revolution of the earth round the sun, which causes the north pole to be directed towards that luminary one half of the year, and the south pole the other half; one being the summer of the northern hemisphere, the other the summer of the southern. When the northern hemisphere is especially exposed to the sun's rays, Arabia, Persia, India, and China, being greatly heated, raise the temperature of the atmosphere that covers them, and the colder air from the regions south of the equator rushes towards the parts. It will therefore follow that for one six months the tradewind is in this instance produced by a current of air rushing from the equatorial regions; but, when the summer of the southern hemisphere approaches, then the direction of the current changes, and the colder air rushes towards the ocean and countries near the southern tropic, which are then the most heated.

It is not always easy to determine with precision the causes which disturb the equilibrium of the aerial ocean. There are so many active agents exerting their influence, and in such an infinity of ways, that it is equally difficult to separate or to combine their effects. But although some objections may be made to the explanations we have given, yet there can be no doubt that the causes which have been supposed to operate in disturbing the equilibrium of the atmosphere are the most important, however their results may be obstructed by not less active though minor local agencies.

From the parallel of 30° to the pole in both hemispheres, the winds are irregular both in direction and violence. But in all countries there is a tendency to periodical winds more or less marked. Even in the Island of Great Britain, which, from its situation, having a continent on one side and an ocean on the other, must necessarily have a variable climate, there is a certain prevalence of periodical winds; easterly winds usually prevail during the spring, and during the remainder of the year westerly winds are most common.

The irregular winds are most feared by voyagers and travellers, and the most violent of these are the whirlwind, the harmatan, and the sirocco.

The whirlwind appears to be produced by the contact of two or more currents blowing from different parts, and is usually produced by a temporary and local, though violent agitation of the atmosphere. The harmatan is not uncommon on the western coast of Africa, and is probably produced by an interruption of the direction of the tradewinds in the course of their progress over the sandy deserts of Africa. It is generally attended with an oppressive heat and heavy fog, and is said to be the forerunner of a hurricane. The sirocco is occasioned by the passage of a current of air over the heated sands of Africa, which render it so dry and rarefied as to unfit it for respiration; it is therefore chiefly characterized by its unhealthy qualities; but in passing over the Mediterranean Sea it absorbs so large a quantity of moisture, that a suffocating and oppressive fog is produced.

We often hear of the destructive effects of a violent wind, but we are happily, experimentally, unacquainted with them. The noblest works of man are not unfrequently destroyed by its energetic efforts, and countries are sometimes devastated by its fearful blast; but in no country are its effects more to be dreaded than in some parts of Africa. During the storms that often rage in the deserts, the loose and unstable sand is frequently carried into the air in such dense clouds as to intercept the rays of the there omnipotent sun, while at other times it is raised by the whirlwind into massive and gigantic pillars. The traveller who has to cross the extensive deserts of Africa, may consider himself fortunate if he passes them without beholding either of these terrific phenomena. It must be a magnificent but fearful sight to see a number of prodigious pillars of sand, stalking with greater or less velocity over the unmeasured waste, their tops reaching to the clouds, and sometimes based on the attenuated air. Should they, however, happen to cross the path of the traveller, there is little chance of escape. But if this phenomenon be sometimes destructive to a kafila, how much more so the sand-wind, or hurricane. Denham had the misfortune to encounter a sand-storm in crossing the desert and has briefly but graphically described its effects. The unlimited expanse seemed to be filled with particles of sand, and the eye of the traveller could only penetrate the space of a few yards around him; the sun and the clouds were obscured, and a suffocating and oppressive weight rested upon all; the horses refused to face the sandy clouds which threatened to overwhelm them, and both man and beast suffered under an oppressive thirst which could not be alleviated.

It is not necessary to compare the amount of evil produced by the atmosphere under certain conditions, with its beneficial influence upon the human species. Every phenomenon may be considered in two ways; there are a light and a shady side, and we may be perfectly satisfied that no agent is active for the mere purpose of destruction. The traveller may be sometimes overwhelmed by the vast masses of sand that the disturbed atmosphere bears on its wings as it hurries over the desert, and the pleasant country may be sometimes overturned in its fury, but the same agent still ministers to our wants and pleasures; it carries over the swelling bosom of oceans the riches and intellect of foreign climes, aids man in his heaviest toils, and bears life and health upon its balmy wings.

CHAPTER IV.

ATMOSPHERICAL PHENOMENA DEPENDANT ON THE DISTRIBUTION OF HEAT.

ALTHOUGH the chymist has appropriated to himself an individual right to the science of heat, it is intimately connected with all the inquiries of the natural philosopher. The composition and decomposition of bodies are, it is true, chiefly effected by the agency of that principle called caloric, but its effects are not less evident in those phenomena which do not result from chymical action. All substances possess it; the varieties of form and structure are its result; life and motion are its dependants; and all nature is animated and beautified by its influence.

Modern philosophers have thought it necessary to make a distinction in terms between the cause and effect of the sensation that is called heat, and have adopted the word caloric as expressive of the agent. So far as our own opinions are concerned, this refinement in phraseology is not a matter of little importance; although there will be equal difficulty in answering the apparently simple question "what is it?" whether one term be used or the other. It might be supposed that the distinction of terms is consequently unnecessary; but as their appropriate use may sometimes prevent a confusion or a circumlocution of expression, we shall use the word caloric as expressive of the agent in those instances where there might be a want of precision if the term heat were employed.

The various opinions that have been entertained concerning the nature of caloric may be considered under two general heads. Some persons imagine it to be a material agent of so great tenuity as to evade our observation, its existence being proved only by its effects; while others consider it as a property of that principle called motion. We are not among those who expect to ascertain with precision the elements of heat, light, electricity, and motion; for although we entertain an opinion that they are all united, and perhaps modifications of the same agent, yet it is, in all probability, one of those primary created agents which the most refined analysis, and the most careful inquiry, will ever fail to discover. To ascertain the variations and dependances of effects is within the reach of the human mind, but the cause is hidden from the most curious gaze, and must ever remain the secret of that self-intelligent Power by which it was brought into existence.

Among those who have maintained the immateriality of heat, and have considered it a property of matter producing a vibration among its particles, we may mention the names of Bacon, Boyle, Newton, Davy, and Leslie. The theory is well expressed by Bacon, "calor est motus expansivus, cohibitus, et nitens per partes minores."

In favour of this hypothesis, it has been argued, that as caloric does not possess weight, and is not under the guidance of those laws which govern bodies in relation to the conditions of motion and rest, so it cannot be a substance.

The opinions of Davy, the master mind that remodelled chymistry, we may give in his own words: "The immedi ate cause of the phenomenon of heat is motion: and the laws of its communication are precisely the same as the laws of the communication of motion. Since all matter may be made to fill a smaller volume by cooling, it is evident that the particles of matter must have space between them; and since every body can communicate the power of expansion to a body of a lower temperature, that is, can give an expansive motion to its particles, it is a probable inference that its own particles are possessed of motion; but as there is no change in the position of its parts, as long as its temperature is uniform, the motion, if it exist, must be a vibratory or an undulatory motion, or a motion of the particles round their axes, or a motion of particles round each other.

"It seems possible to account for the phenomena of heat, if it be supposed that in solids the particles are in a constant state of vibratory motion, the particles of the hottest bodies moving with the greatest velocity, and through the greatest space: that in liquids and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion round their own axes, with different velocities, the particles of elastic fluids moving with the greatest quickness; and that in ethereal substances the particles move round their own axes, and separate from each other, penetrating in right lines through space. Temperature may be conceived to depend upon the velocity of the vibrations; increase of capacity on the motion being performed in greater spaces; and the diminution of temperature, during the conversion of solids into fluids or gases, may be explained on the idea of the loss of vibratory motion in consequence of the revolution of particles round their axes, at the moment when the body becomes liquid or aeriform; or from the loss of rapidity of vibration, in consequence of the motion of the particles through greater space."

Those who maintain the materiality of caloric urge, in proof of their opinions, that substances always expand by an increase of temperature, and that their magnitude can only be increased by the actual addition of new matter, that is to say, by the particles of heat. Having no predisposition to either one or the other of the theories that have been mentioned, we may be permitted to remark that there is an immeasurable distance between the fact and the deduction; for it is equally easy to suppose the principle, caloric, to have an effect in increasing the expansive power of bodies, and thus augmenting their volume.

The transmission of heat through a vacuum has also been considered a proof of the materiality of caloric, in opposition to Davy's hypothesis. This conclusion we would admit if the statement had been proved; but a vacuum cannot be formed; for although the amount of elastic fluid contained in any given space may be decreased by artificial means, yet it is impossible to extract it entirely, and therefore this argument is of no value to the theorist. The same remark applies to electricity, and might be extended to light.

When governed by curiosity, we feel some anxiety to ascertain the nature of these agents which have been so improperly called the imponderable bodies. But we do not know how science would be benefited by the determination of the question, or what practical results would follow from the discovery, except that many given to speculation might be better employed, were one of the subjects, on which it has been so profusely dispensed, thrown out of the catalogue of queries. It is sufficient for us to ascertain the effects produced; and, however mortifying it may be to the man who prides himself on the variety of his learning and the extent of his investigations, to confess ignorance of all the great secondary causes which hold government over matter, yet it is desirable that we should be sensible of our relation to Him who gave all things birth. We shall not, therefore, dwell upon speculative principles, but proceed to make a few remarks upon those laws of action which have an influence in producing or modifying the phenomena which we observe upon, or believe to be produced beneath, the surface of the earth.

DILATATION BY HEAT.

The volume of bodies is generally increased with an increase of temperature. There are, however, a few exceptions. Some metals, for example, expand at the instant of congelation; and clay contracts with the addition of heat. This last result, however, can scarcely be considered as an exception to the law, for it is the liberation of the water which is combined with the clay that causes it to contract.

All substances do not suffer the same increase of volume with a certain increase of temperature. Gases and vapours expand more than either liquids or solids, and liquids more than solids. Of all solid bodies, the metals are most expanded with heat, and lead is more susceptible than any other metal. But the expansion is small under all circumstances, and it is consequently difficult to construct instruments by which to determine the amount. Lead, for instance, only expands one part in three hundred and fifty, when raised from the temperature of melting ice to that of boiling water. But this is not the only practical difficulty, for a solid expands equally in every direction, in its breadth and width as well as length. We have, however, no means of measuring an increase in volume, but must deduce the expansion of the whole from the increase in one direction. Another difficulty is, that an equal increase of temperature, at different temperatures, does not produce in solids the same expansive effects.

To prove that solid bodies do expand when their temperatures are raised, allusion might be made to the instances in which the principle is applied in the arts. The cooper surrounds his casks with iron hoops at a red heat, that they may, when cold, bind the tighter; and the smith must always bear in mind the same result. In some instances, it is necessary to guard very carefully against those errors which may arise from the dilatation of metals, and especially in the use of delicate philosophical instruments. The astronomer is peculiarly exposed to erroneous results from this cause; for a ray of light, a current of air, or the heat of the hand, may be sufficient to derange an observation, and to increase or decrease a distance or a diameter.

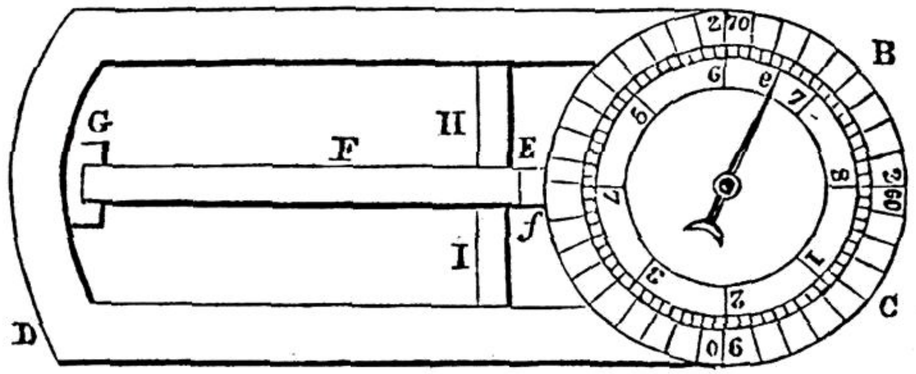
This effect must have some influence upon the solid mass of the earth itself, causing it to expand as its temperature is raised, and to contract as it cools. The variation of temperature on the surface is too small, in all probability, to produce any effect of importance; but the constant decrease of internal heat, a fact recently determined, must occasion contractions of no small amount; and it is probable that some of the phenomena observed on the surface of the earth may be attributed to this cause. We shall not attempt to defend the very ingenious theory of volcanic action proposed by M. Cordier, but the mention of it will prove the importance of considering the expansion of solids by heat, and their consequent contraction in cooling.

As the result of experiment, we know that the temperature of the interior of the earth increases towards the centre, and that it is cooling by the radiation of heat from the surface. Admitting these facts, it is easy to account for volcanoes, and many of the appearances which are presented by the several portions of the mineral crust. But there are many ways of applying these facts, and M. Cordier has one of his own; founding his explanation of volcanic activity upon the principle that solids contract in cooling; and if it be supposed that an enormous pressure be exerted upon a melted mass in the interior, by the external refrigerating mass, the intumescent rocks might be forced out. In this way M. Cordier explains the ejection of lava.

"At Teneriffe, in 1803, I calculated," he says, "as nearly as possible, the amount of matter ejected by the eruptions of 1795 and 1798. I performed the same calculation in respect to the products of two eruptions, yet more perfectly isolated, which exist in the extinct volcanoes of France; to wit, in 1806, those of the volcanoes of Murol in Auvergne; and in 1809, those of the volcano of Cherchemus, near Izarles, at Mezin. I found the volume of matter in each eruption to be much less than one cubic kilometre, or 1,308,044,971 cubic yards. From these data, and others of the same kind, which I have obtained at other places, I feel justified in taking the volume of a cubic kilometre as the extreme limits of the product of eruptions in general. But such a mass is very small in relation to the whole earth. Applied to its surface, it would form a bed which would not be 1-500th part of a millimetre in thickness. More definitely, if we suppose the mean thickness of the crust of the earth to be 62,1 miles, a contraction of this envelope, which would shorten the mean radius of the central mass 1-494th of a millimetre (1-12694th of an inch), would be sufficient to produce the matter of one eruption.

"Proceeding upon these data, that the contraction produces the phenomenon (of volcanoes), and that over all the earth five eruptions take place yearly, we shall come to the conclusion, that the difference between the contraction of the solid crust of the earth and that of the internal mass, would not shorten the radius of that mass more than a millimetre (-03937 of an inch) in a century."

Whether we admit the accuracy of M. Cordier's deductions or not, it is evident that the same force which causes a bar of iron to expand when heated, and contract when cooled, must influence all solid bodies more or less, and may possibly occasion terrestrial phenomena of the most violent character.



Ferguson's Pyrometer.

Many instruments called pyrometers have been invented for the measurement of the dilatation or contraction suffered by solid bodies, when their temperature is changed. Although many pyrometers have been invented, nearly all of which have some points of excellence, we shall only notice that invented by the celebrated Ferguson, whose mechanical genius has been rarely excelled, and scarcely, if ever, equalled. This instrument measures the expansion to 1-45,000th part of an inch. It consists of a mahogany frame B C D, attached to a disk divided into 360 equal parts, the central bar E being capable of motion, and of communicating that motion to the index. A dilatation of this bar, equal to one inch, will force the index round the circle, and it is easy to calculate the amount of expansion by the angular motion of the index.

The central bar is divided into two pieces, one long and one short. One end of the long bar F is fitted into an iron plate G, the other pressing upon the end of the short bar E, at the point F. When heat is applied to the bar F, its expansion acts upon the lever-formed bar E, which causes the revolution of the index.

It may be supposed, from what has been stated, that liquids also dilate when their temperature is raised. Liquidity is but the state of transition between solids and gases, and most substances may be made to assume either the one or the other. But all liquids do not suffer the same degree of expansion with the same increase of temperature, a statement which may be easily proved by filling three equal thermometer tubes to the same height with three different substances, mercury, water, and alcohol for instance, and plunging them into water heated to about 150° ; the degree of dilatation will not be the same in either two.

To determine the dilatation of a liquid is a very simple experiment, though the method to which we refer is subject to several minute errors. If a thermometer tube, that is, a tube having a bulb at one end, be partly filled with a liquid, it may be submitted to any degree of heat, and the difference of level between the commencement and close of the experiment will give the dilatation. But, in making this experiment, it is necessary that the air contained in the liquid and the tube should be first expelled, or its expansion will give a false result; and not only so, but as liquids become vapours at all temperatures when exposed to the atmosphere, and more abundantly as the temperature is raised, the quantity of the liquid will be diminished, and an erroneous opinion might be deduced. To prevent these two sources of error, the tube should be about half filled with water, and boiled for some time to expel the air; and when this has been done, the open end of the tube should be hermetically sealed.

Liquids, generally, have a uniform expansion or contraction, except when the temperatures approach those degrees at which they boil and freeze, and then their degree of dilatation is changed. Water is a most remarkable exception to this law. As its temperature is lowered, it continues to contract until it reaches about 39° of Fahrenheit's thermometer, and then the contraction ceases; but when its temperature is lowered to nearly the freezing point, it begins to expand, and continues to do so until it is frozen. This fact is one of considerable importance, for the expansion of water when in the act of freezing must in many cases be an active cause in the destruction of rocks, and will explain many results which are witnessed in regions subject to extreme cold. A lake, when frozen over, must, by its expansion, tend to destroy its banks, and form a considerable mass of detritus, and in this way extend by degrees the surface of its waters. But it is in elevated countries, which are for a large portion of the year covered by immense bodies of ice, that the effects are most frequently observed. Fissures are filled with water, which when congealed, expands so violently as to rend rocks asun der, projecting large fragments into the valleys beneath, and breaking away the lofty pinnacles from their parent beds.

There are several interesting experiments by which the expansibility of gases may be proved. If a flaccid bladder be held to a fire, or hot water be poured upon it, the air contained will dilate, and the bladder will be inflated. If a glass matrass be held over a spirit-lamp, the open end being immersed in some fluid, large bubbles of air will appear on the surface of the liquid, driven out by the expansion; but, as it cools, the elastic force decreases, and the liquid rushes into the bulb, showing the amount of expansion that was suffered by the enclosed air.

The expansion of gases by an increase of temperature is an effect productive of many of those phenomena which are observed in the atmosphere, for nearly all its changes are dependant on the action of heat. As all fluids become lighter when their temperature is raised, the heated particles will always rise to the top, and the coldest sink to the bottom, and a mass of liquid or vapour will consequently be arranged in strata. When a spirit-lamp is placed at the bottom of a vessel containing water or any other liquid, the particles in contact with the bottom will be heated, expand, and rise to the surface, while the colder particles descend; and a series of currents, some upwards, others downwards, will be established, until the whole mass is raised to the boiling temperature. It would be impossible to raise the temperature of a liquid by the application of heat to its surface. That which is true in these instances in regard to liquids is also true in relation to gases. The atmosphere, acted upon by solar heat, suffers innumerable changes as the result of the expansion it suffers. Currents of heated air rise from the surface in consequence of reflected or radiated heat, cold currents fall and occupy their places. In one region the surface of the earth is more heated than another, and a stream of cold air rushes from the colder regions to occupy its place, and by such processes as these, winds and hurricanes are produced.

From these statements it will be evident, that the expansion of bodies by an increased temperature is intimately connected with many phenomena which are witnessed on the surface of the earth; and that the facts to which we have briefly alluded are worthy the consideration of him who has no other object than to acquaint himself with the phenomena by which he is surrounded. But there is an instrument to which we shall have frequent occasion to refer, as the means by which many philosophical principles have been determined; and it would be impossible to describe its use, or the principles of its construction, to the individual who was not acquainted with the general laws of the expansion which substances suffer when their temperature is raised. It would, therefore, be possible to justify the propriety of introducing in this work some remarks upon the laws which govern the expansion of bodies, if there were no other object in view than the explanation of that instrument, the thermometer.

THE THERMOMETER.

Almost any substance might, under certain conditions, be employed as a thermometer. Solids and gases, however, would, from a casual consideration, appear to be best suited for this purpose, as they are more uniform in their expansions than liquids; but this deduction is not found to be practically true. The increase in magnitude of solids is so small, that they cannot be employed without mechanical contrivances; and the dilatation of gases is so great, that their use is attended with great practical inconvenience when adapted to the measurement of high temperatures. Liquids are best suited for thermometers. But liquids have, in general, an irregular expansion when they approach the boiling and freezing temperature; and, therefore, that one must be chosen whose freezing and boiling points are separated by the greatest interval, at the same time comprising those temperatures which it is commonly most necessary to determine. Alcohol freezes at a very low temperature, but it is readily vaporized; the oils are vaporized at a very high temperature, but they are easily solidified. Neither of these substances, therefore, can be used for common purposes, as thermometers, though they are useful under certain circumstances. Mercury has been very generally employed, and it may be necessary to give the reader such particulars as may enable him to construct the instrument, should he wish to test the accuracy of the information which is given in this volume, or to commence a series of experiments by which the boundaries of science may be extended.

The mercury to be used for thermometrical purposes must be pure, that is, must be free from admixture with any other substance, whether solid or liquid. The best way to secure this is, first to distil it, and it may then, if the subsequent processes be carefully attended to, be expected to give the same results, in how many instruments soever it may be employed.

To obtain a means of observing the contraction or expansion which the liquid may suffer is the next object. For this purpose the student may provide himself with a capillary tube that has a spherical bulb at one end, the bulb having a considerable proportion to the bulk of the whole tube. In selecting the tube, great care must be taken that its bore be uniform; for as the instrument is to be graduated, so it is necessary that any quantity of the liquid may stand at the same height in all places. To fill the tube requires a particular process; for, as the bore is capillary, the mercury cannot be poured into it. But if the bulb be held over a spirit-lamp, and the temperature of the contained air be raised, its expansion, and the consequent escape of a portion, will produce an exceedingly rarefied atmosphere. If the open end of the tube be then plunged into mercury, and the bulb be cooled, the enclosed air will lose a part of its elastic force, and the mercury will be driven into the tube by the pressure of the atmosphere. A small portion of the tube will be still occupied by air, and to expel it the instrument must be again submitted to a high temperature; and when the mercurial vapour occupies the space to the exclusion of the air, the open end of the tube must be hermetically sealed. The mercurial vapour condenses as it cools, and a tolerably perfect vacuum is formed.

The mercurial column being obtained, a scale must be attached to it. First plunge the bulb into a vessel containing melting snow or ice, and the mercury will contract, falling to a level at which it will remain until the liquefaction is complete; and as the result is the same in all places, the point of elevation may be marked on the tube, and is called the freezing point.

Then plunge the instrument in boiling water, and the mercury will expand until it reaches a certain height, and there it will remain stationary, however intense may be the fire applied to the water; and hence we discover that there is a temperature above which it cannot be raised, and the level of the mercury may be marked as the boiling point.

But the instrument is not complete, as no measure is yet provided for any temperature between the freezing and boiling points. The division of this space must be arbitrary, and indeed it is only necessary that such a graduation should be formed as shall enable different observers to understand each other's results. Unfortunately, the same division has not been universally adopted; and although it is easy to reduce the observations made by one graduation to the degrees of another, yet the want of unanimity is attended with inconvenience.

The scale employed in England was invented by Fahrenheit, and is called after his name. In his day, it was supposed that the mixture of snow and salt produced the most intense cold that could be obtained by any artificial means, and he consequently took that temperature as the commencement of his scale, and marked the level of the mercury in his tube, when placed in this mixture, as 0. The interval between this and the freezing point he divided into 32 parts, or degrees; and, continuing the division, the boiling point is 212°.

The centigrade scale is employed in France, and in this the interval between the boiling and freezing points is divided into 100°; the freezing point being 0. Reaumur's thermometer is generally used in other countries, and it differs from the centigrade in the division of the interval between the freezing and boiling points into 80 instead of 100°.

It must not be supposed that the thermometer is a measurer of the quantity of caloric contained in a body; degree of temperature and quantity of caloric are not synonymous expressions. The thermometer will be equally affected whether it be plunged into a river or a basin of water taken from it, and yet it cannot be supposed that there is as much caloric, if we may speak of the agent as though it were matter, in a small as in a large quantity. Caloric may be in a substance, and yet not affect the thermometer; and it has not been proved that when bodies have the same increase of temperature, they receive an equal quantity of the principle. There are, in fact, two states in which the agent may be placed: in one its presence is known by the effect which it has upon bodies, whether animate or inanimate, and in the other its influence is confined to an alteration of state: the one is called sensible, the other latent heat, or, more properly, constituent caloric.

LATENT HEAT.

Although the presence of latent heat cannot be proved by any sensible effect, yet there are proofs of its existence, and a knowledge of its action will illustrate many of the phenomena observed in nature. The mention of an experiment will perhaps better illustrate the kind of influence which it exerts upon matter than any description. Take a vessel containing ice, and plunge it into mercury at the temperature of 200°, and place a thermometer in both the water and the mercury, and watch the effect produced upon them. There will be immediately a conduction of sensible heat from the mercury to the ice, the thermometer in the mercury will begin to fall, and it might be expected that the one in the ice would begin to rise, but this does not happen; it remains stationary, though the ice melts rapidly. By the time that the ice is melted, the thermometer in the mercury will have fallen considerably, though that in the ice will still be at the freezing point, the temperature of the water being the same as the ice, though the mercury has communicated to it so much sensible heat. Only one opinion can be formed as to the application of the heat which has been received by the ice; it has entered among its constituent particles, and has a latent existence. A certain quantity of caloric is required for the performance of the process of liquefaction, and on this account it has been sometimes called the caloric of fluidity. Nor is it more singular that the agent should lose its power of affecting the senses and the thermometer, than that the properties of two or more elements should be destroyed in chymical combinations.

From these facts it may be deduced, that in the process of freezing as much heat must be given out as is received in liquefaction, an opinion which may be easily verified by submitting water to mercury that has been reduced to a temperature below the freezing point.

It is not difficult to determine the quantity of heat absorbed by a body, water for instance, during liquefaction. Take two equal vessels, one containing an ounce of water at 32°, the other an ounce of ice, and immerse them, each vessel having a thermometer, in a mercurial bath raised to a high temperature. By the time the ice is melted, the thermometer in the water will stand at 172°, and consequently a temperature equal to 140° has been communicated to it; but the temperature of the water is nothing higher than that of the ice at the commencement of the experiment, and it may therefore be concluded that it requires a temperature of 140° to liquefy ice. That it is the process of liquefaction which prevents the ice from rising in temperature is evident; for if equal quantities of water at 32° and 172° be mixed, a temperature of 102° will be produced; that is, the whole will have a temperature equal to half the sum of the parts.

Nearly all liquids may be reduced to the condition of solids; but they freeze at different temperatures, and require various amounts of heat. All solids, except carbon, are capable of liquefaction, though many of them require the most intense heat.

These facts may enable us to explain some meteorological results, which would otherwise be exceedingly perplexing. It may have been noticed by some of our readers that the temperature of the air during a thaw is generally colder than when the ground is actually covered with ice, and this is evidently produced by the abstraction of heat from the atmosphere. In order that the ice may be reduced into a liquid state, it is necessary that it be supplied with a certain amount of caloric, which it applies as a constituent principle for the production of liquefaction; this it can only obtain by robbing some other substance of its sensible heat, and it consequently abstracts from the atmosphere, as it passes over it, a portion of its heat, and lowers its temperature. This explanation accounts, on philosophical principles, for the fact that it is colder during a thaw than when ice covers the ground, and the surface of lakes and rivers.

But if a thaw lowers the temperature of the atmosphere, a frost must raise it. When water assumes a solid state, it gives out as much heat as it receives during the process of liquefaction. A large portion of this must be communicated to the atmosphere; and when there are no causes tending to decrease the amount of sensible heat, the temperature must be increased by the quantity supplied by water during solidification.

But we have hitherto only considered two conditions of matter, solids and liquids; it may, however, be presented as a gas or a vapour. If water, for instance, be exposed for a sufficient time to any source of heat, its temperature will continue to rise till it has attained to that of 212°, but above this it cannot be raised, and the only effect produced by the continuation of the cause is the formation of vapour. It now becomes an interesting question, what becomes of the heat that is imparted to the water after its temperature has been raised to the boiling point. This can only be answered in one of two ways; it must either be supposed that it is carried off by the steam, or that it is applied in a latent state, inappreciable to the thermometer, for the formation of the elastic fluid. That it is not carried off by the steam is certain, for the thermometer gives no evidence of its presence, and therefore it must be combined with it in a latent state; and we might have expected this analogy between the causes of liquidity and the vaporous state.

It is possible, by a very simple experiment, to form an approximate estimate of the quantity of latent heat necessary to convert water into aqueous vapour or steam. Take a vessel containing five and a half ounces of water, at a temperature of 32°, and let the beak of a retort, containing one ounce of boiling water, pass into it. If the water in the retort be thrown off as steam into the cold water, it will be found that when the whole is vaporized, the five ounces and a half will be raised to the boiling point. From this result we learn that the vapour of one ounce of water contains as much heat in a latent state as would raise five ounces and a half at 32° to a temperature of 212°, or, in other words, as can increase its sensible heat 182°. If, then, the heat necessary for the formation of the vapour could have been received in its sensible state into the ounce of water, it would have raised the temperature to 990°, that is, five and a half times 180°. An ounce of water, therefore, in passing from a liquid to a vaporous state, receives as much heat as would, if sensible, raise its temperature 990°.

Aqueous vapour, or steam, is perfectly invisible, and the white cloudy stream which is observed to flow from a vessel containing boiling water, is the condensation of that vapour produced by its meeting with an atmosphere of lower temperature. Dr. Wollaston invented a pretty apparatus to prove the invisibility of steam, which at the same time shows its two most important properties,—elasticity and condensation It consists of a glass tube about six inches long and three quarters of an inch in diameter, having a bulb at one of its extremities. Into the open end are fitted a piston and rod, both of which are perforated so as to be opened o closed by a screw at the top, the piston being kept in th perpendicular by moving through a cork. A handle is attached by a brass ring to the tube. When the instrument is to be used, a small quantity of water must be placed in the bulb, and raised to the boiling point by a spirit-lamp, the aperture being left open until the air has been expelled. Then close the opening, and raise the steam until it forces the piston upward; immerse the tube in cold water, and the vapour being condensed, a vacuum will be formed, and the pressure of the atmosphere will force the piston downward. This little instrument shows the application of steam as a moving power; but it is not our intention to refer to this beautiful application of a natural agent, as our principal object in this volume is to explain the natural phenomena which depend upon the laws of material existence.

We have spoken of the boiling point of water as being 212° of Fahrenheit's thermometer; the reader is, however, probably aware, that the boiling point is not stationary, but varies according to circumstances. Among other things, it may be mentioned that the boiling point has always a relation to the height of the barometer, or, in other words, to the atmospheric pressure. Now, as the atmospheric pressure varies even at the same place, there will also be a slight variation in the boiling point. But if we measure the pressure at different heights, the variation will be found very considerable, and in those places there will be a proportionate difference in the temperature at which water boils. To show that the boiling point of a fluid is lowered as the pressure is decreased, place a flask containing water at about 200° under the receiver of an airpump, and before the receiver is exhausted the water will boil, for a less pressure is exerted upon the liquid. The same result may be obtained in another way. Boil a small quantity of water in a thin flask, and while the steam is passing off, cork up the mouth of the flask, and remove it from the source of heat. The boiling will almost immediately cease; but if the flask be plunged into cold water, the ebullition will recommence. This singular result is produced by the condensation of the aqueous vapour, which causes the formation of a vacuum above the liquid; and as the boiling point is lowered by the removal of external pressure, the water contained in the flask is again put into a state of ebullition.

It will follow, as a necessary result from these experiments and facts, that an increased pressure will raise the boiling point. There is, indeed, no limit to the temperature to which water may be raised, except that which regulates the amount of pressure under control; water may, in fact, be made red-hot without boiling.

These facts have an evident connexion with results obtained by travellers. It has been frequently observed by those who have visited mountainous districts, that the boiling point of liquids varies in proportion to the height of the place above the level of the sea. From what has been already said concerning the atmosphere, we know that the pressure decreases with the length of the column, and we may hence deduce the reason for the lowering of the boiling point. The converse of this is also true, and in deep mines the boiling point must be proportionally raised.

As in the process of vaporization a large amount of heat must be combined with the particles of the body, an equal amount must be given up by vapours when they return to a liquid state. The vapour produced by a cubic inch of water will occupy a space of seventeen hundred cubic inches; but all the latent heat it contains must be abstracted before it can be condensed into a liquid.

Philosophers have made a distinction between vapours and gases, although there is a sufficient analogy in their physical condition to warrant the supposition that they have the same origin. The gases were probably separated from the vapours, under the supposition that they could never take the liquid form, and were therefore sometimes called the permanently elastic fluids. There is, however, now no doubt, that the gases as well as the vapours may be compelled to take a liquid state; and that, to present them in this form, it is only necessary to abstract from them their latent heat. The greatest amount of cold ever produced is unable to effect this result. Dr. Faraday has succeeded in condensing some of them by another process, and has thus afforded an argument for the inference that others might be reduced, could the obstacles to experiment be removed. It is a well-established fact, that when an elastic fluid suffers mechanical compression, its temperature is raised, a portion of its latent heat being made sensible. The sensible heat may be easily drawn off by the contact of some cold body; so that, by continuing the compression, and abstracting the sensible heat, it may be possible to remove so much of the latent heat as may compel the gas to take a liquid form. By submitting the gases in strong glass tubes to the pressure of their own elastic force, Dr. Faraday succeeded in condensing nine of them. Oxygen, nitrogen, and hydrogen, have resisted a pressure equal to that of eight hundred atmospheres, so that there can be little prospect of knowing any thing about the liquids from which they are produced. When it is remembered that oxygen and nitrogen are the component parts of atmospheric air, there will be little difficulty in deducing, from the facts which have been stated, proofs of the wisdom displayed in the choice and arrangement of materials. If an atmosphere of vapours had been employed instead of gases, it might all have been condensed into a liquid during some inclement season, and the beings dependant on its existence have perished.

EVAPORATION.

The formation of vapour does not altogether depend upon ebullition; or, in other words, it is not absolutely necessary that a liquid should be raised to the boiling point for the production of vapour. A liquid may produce vapour from its surface, and at every temperature, though the amount increases with the temperature. It was once supposed that evaporation resulted from a chymical affinity between the particles of air and the liquids evaporated. This theory, proposed by Halley, has been disproved by the experiments of Dalton; and if we had no other proof, the formation of a vapour in vacuo would be a sufficient contradiction.

Every mass of water on the surface of the earth, and every moist or damp district, will afford an example of evaporation All parts of the earth support a mass of atmospheric air, to which they are constantly imparting aqueous vapour; and there is but one limit to this process, the saturation of the air; the point of saturation being the reception of a quantity that will exert a pressure sufficient to prevent any further evaporation.

As there are many phenomena resulting from evaporation, it may be necessary to refer to some of the general laws which govern the formation and action of vapour under this circumstance, before any attempt be made to explain the phenomena themselves; and should the reader find the details less interesting than their application, he may find some consolation in remembering that there is not even a *royal road to learning*.

In all observations upon the process of evaporation, it is absolutely necessary to consider the temperature of the liquid from which the vapour is rising. When the temperature is high, the force exerted against the evaporation by atmospheric vapour is altogether inappreciable, but when the temperature is low it must be taken into account; for then it may have a force almost equal to the vapour itself. It appears from Dr. Dalton's experiments, that at all temperatures between 212° and 138°, the rate of evaporation is exactly proportional to the elastic force or tension of the vapour; but as the temperature lowers, the law becomes subject to greater variations, for the tension of the rising vapour, while that contained in the atmosphere comes nearer to an equality. In order, therefore, to determine the elastic force of the vapour which rises by evaporation from a liquid, it is necessary to determine the amount of pressure exerted by the vapour in the atmosphere.

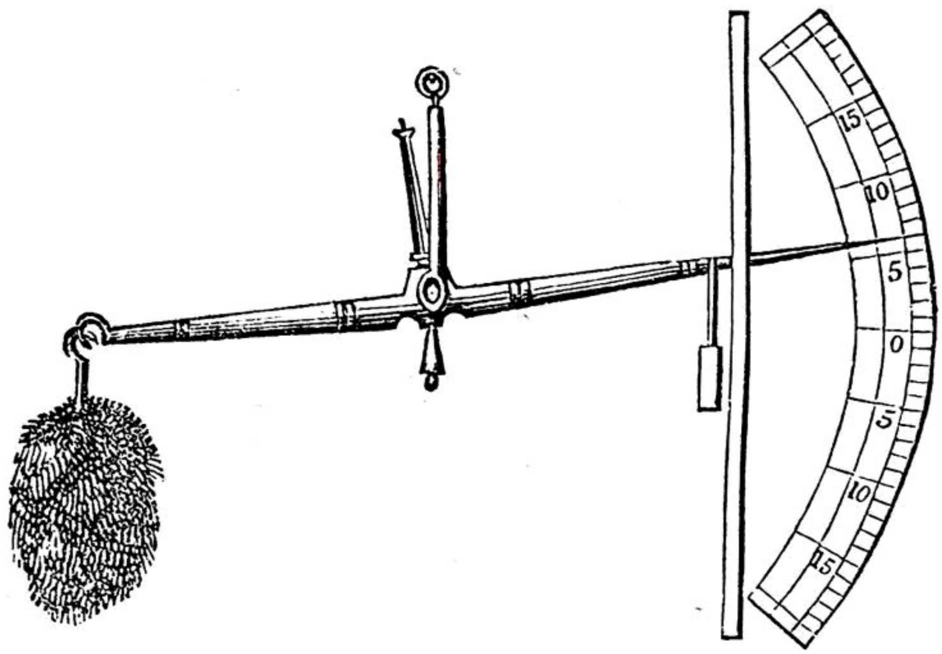
To ascertain the quantity of vapour suspended in the atmosphere at any particular time, instruments are used called hygrometers. The principle of their construction is the application of a substance capable of absorbing moisture, in such a manner as to measure, by a mechanical contrivance, the amount of aqueous vapour that may be contained in any space.

M. de Luc employed for this purpose a piece of whalebone, a substance that absorbs moisture very readily, and to this attached an index capable of an easy motion round a graduated face. The difference between the several indications will enable the observer to form a proportion between the several conditions of the atmosphere.

M. Saussure's hygrometer consists of a human hair, previously boiled in a caustic ley. The hair is fastened at one end to a hook, and a weight is attached to the other. As the hair expands or contracts, it, moving round a grooved wheel, gives motion to an index which passes over a graduated arch.

The hygrometers generally employed by philosophers give the proportional differences of aqueous vapour at distinct periods without estimating the weight of water contained in the atmosphere at the time of experiment. We have employed a little instrument of our own construction, which will measure, in grains, the weight of water contained in a given space, and consequently enable the observer to deduce the amount contained in a given extent of the atmosphere. It consists of an accurately balanced beam, to one end of which is attached a square foot of tissue paper, and to the other a scale-pan. These were adjusted under circumstances that prevented the interference of aqueous vapour, and it is always easy to ascertain by the instrument the relative proportions of vapour contained in a portion of air at different periods, or, with particular precautions, the quantity contained in the atmosphere itself.

A somewhat analogous instrument has been sometimes used by meteorologists, but this, as well as others, estimates the variation in degrees by angular motion and not by weight. It consists of a balance-beam, having a piece of sponge at one end,



and a slender rod or index at the other. The sponge, which may be rendered more hygrometric if steeped in pearlash and water, rapidly absorbs moisture from the air; and as its weight increases the index rises, and gives a proportional estimate of the vapour which may be present in the atmosphere.

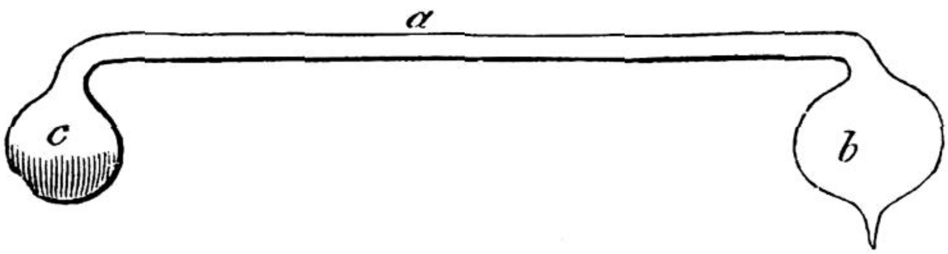
The hygrometer invented by Mr. Daniells is more frequently used by meteorologists than any other, and is more accurate, though it requires a greater time to register an observation. The delicacy of this instrument is very remarkable, a circumstance which gives it a value to the experimenter which the student can scarcely appreciate.

We have already proved that, in the formation of vapour by ebullition, there must always be a considerable absorption of heat. In the production of vapour by evaporation, this is equally true, whatever may be the temperature of the liquid at the time. There are many interesting experiments by which this fact may be proved. If the bulb of a thermometer be surrounded by a wet sponge, and exposed to the action of the sun, the thermometer will rapidly fall; and the same result will be produced if it be covered with ether, a substance which evaporates very quickly. For the production of vapour, under all circumstances, heat is required, and *in these experiments it can only be obtained by abstracting* from the bodies in contact with it, and from its own substance, *the sensible heat which they possess.*

The same process is going on in nature on a large scale. When, by the action of the solar rays, vapour rises from the surface of water or from damp districts, the temperature of the atmosphere immediately resting upon that portion of the earth is consequently lowered; for, in order to produce the vaporous state, the bodies near to, or in connexion with the liquid, must be robbed of their sensible heat.

There is a very interesting experiment connected with this subject, which is generally observed with surprise by those who are unacquainted with its cause. If some ether be poured upon the surface of water in a flat shallow vessel, and placed under the receiver of an airpump, the air being withdrawn, the ether will boil, and the water will freeze. These apparently opposite results are evidently produced by the same cause, the vapour formed from the ether. The boiling point of the ether is lowered by the removal of atmospheric pressure; vaporization goes on rapidly; *the sensible heat of* the water is abstracted to form the vapour, and at last so much is taken away, *that, being reduced to the freezing point,* it is consolidated.

Dr. Wollaston *invented an instrument called a* cryophorus, which illustrates the same principle. This instrument is a glass tube, having a bulb at each end, at right angles to its length. From the bottom of one of these, *b*, there proceeds a small tube, through which a liquid, water being usually employed, is introduced. When removed to the opposite bulb, *c*, it is boiled, so that the whole of the instrument may be



filled with its vapour, and then the tube is hermetically sealed. Now if the water be accumulated in one bulb, and the opposite be immersed in a freezing mixture, the vapour will be rapidly condensed and a vacuum be formed; new vapour is then produced, causing an abstraction of caloric to so great a degree as to freeze the water. This philosophical toy very admirably proves that temperature is lowered by evaporation.

We have not attempted to give the reader a systematical explanation of the science of heat, but only to describe those facts which may enable him to understand the appearances that result from the existence and action of the agent. Some of the statements which have been made may appear to have little or no relation to atmospherical phenomena, but the reader will be able to decide whether this be true or not when he has read to the end of the chapter.

The various circumstances under which caloric acts upon bodies, and the subtlety of its influence, have prevented the natural philosopher from tracing with precision its agency in many changes, which are no doubt in some degree dependant upon it. When investigating the appearances presented by external material objects, it is possible to give an undue prominence to those occult agents which are supposed to hold control over matter, without attention to the influence which matter may have upon them in subduing or restraining their effects. The reader need not then be surprised that our knowledge of the phenomena which are most common should be so limited, but rather that there is a trace of certainty upon the surface of some of our speculations.

CLOUDS.

Clouds are found to be unvarying indicators of the operations of atmospheric causes, and of the changes which may be expected from them. It has been often said that man is a meteorologist by nature, and in a limited sense he is so; for so active are the influences of external material agents on the animal system, and so close the connexion between the material framework and the thinking principle of man, that rapid or violent changes in external circumstances are felt as well as seen. But many advantages result from the possession of that knowledge which enables us to predict the changes that are in the process of accomplishment, and this knowledge is especially advantageous to those whose engagements are at all influenced by the weather. The husbandman and the mariner, by a constant attention to the forms and combinations of clouds, are generally able to predict, with some certainty, the probability of changes, and often to avoid evils which would result from ignorance. The face of heaven is indeed an unfailing index, and upon it can be read "times and seasons." But the principles from which the man who is "weatherwise" gathers his prophetic skill are so indefinite in his own mind, that he can seldom give an explanation of the reasons for his judgment. The meteorologist must be in all things governed by experience; but, unless the results he obtains can be connected by system, and based upon a knowledge of philosophical causes, his information can be of no value to others, and afford him but little satisfaction.

Many attempts have been made to explain the formation of clouds, but there are difficulties connected with all the theories that have been proposed which cannot be at present removed There can be no doubt that clouds have their origin in the combination of aqueous vapours carried into the atmosphere by the process of evaporation. But by what process are the particles of aqueous vapour united, when they form clouds and become visible to the eye? There is no philosophical principle that can of itself account for the formation of clouds; they are not always formed by the saturation of the air, for the atmosphere has seldom reached the point of extreme moisture when they make their appearance; nor can they be attributed to a diminution of heat, for the clouds are sometimes warmer than the surrounding air; and if the mere coldness of the atmosphere produced a condensation of vapour, then the night should always be attended with fogs or clouds, as the result of the condensation of the vapour raised during the day.

An extremely high temperature is sometimes continued for a long time without the formation of clouds. It is stated that in January, 1785, the mean temperature during the month was 66½°, a temperature that must have greatly aided evaporation, and yet not a drop of rain fell, and the moisture of the air diminished so rapidly that it at last almost disappeared. Such a phenomenon cannot be easily explained.

It is generally admitted that clouds are combinations of aqueous drops, and it is almost universally acknowledged that their parts have a vesicular structure. Saussure states that, when passing over the Alps, he saw a multitude of small globules, like soap-bubbles, the component parts of a cloud, floating before him, being generally about the size of a pea, and apparently covered with an inconceivably thin coating. These particles, being charged with electricity of the same name, repel each other, and they are from this cause prevented from taking a liquid state and falling as rain. M. Pouillet, for whose talents we entertain the highest respect, as one of the best teachers and most discriminating observers in Europe, has stated that electricity is not given off during evaporation without chymical change; but we have made experiments of so decided a character, as to enable us to state that this result is not to be depended on, for we can prove that in every case of evaporation electricity is developed. We shall take this result as though it were proved, leaving the enumeration of our experiments, and the statement of the means by which the fact was ascertained, to another occasion. Now, if electricity is given off during evaporation, and the vapour be formed into vesicles, they must all be similarly electrified, and consequently repel each other; but if there be no truth in the principle we have stated, there are ample means of accounting for the accumulation of electricity from the action of other causes.

CLASSIFICATION OF CLOUDS.

In order that meteorologists may compare their observations and results, a system has been adopted by which they are able to class the several kinds or modifications of clouds. There are seven modifications; three of which are simple, two intermediate, and two compound. The following table will form the basis of the remarks we shall make upon the several kinds:—

Simple Modifications.

1. CIRRUS; parallel, flexuous, or diverging fibres, extensible by increase in any or in all directions.

2. CUMULUS; convex or conical heaps, increasing upward from a horizontal base.

3. STRATUS; a widely-extended, continuous, horizontal sheet, increasing from below.

Intermediate Modifications.

1. CIRRO-CUMULUS; small, well-defined, roundish masses, in close horizontal arrangement.

2. CIRRO-STRATUS; horizontal, or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward or undulated, separate, or in groups consisting of small clouds having these characters.

Compound Modifications.

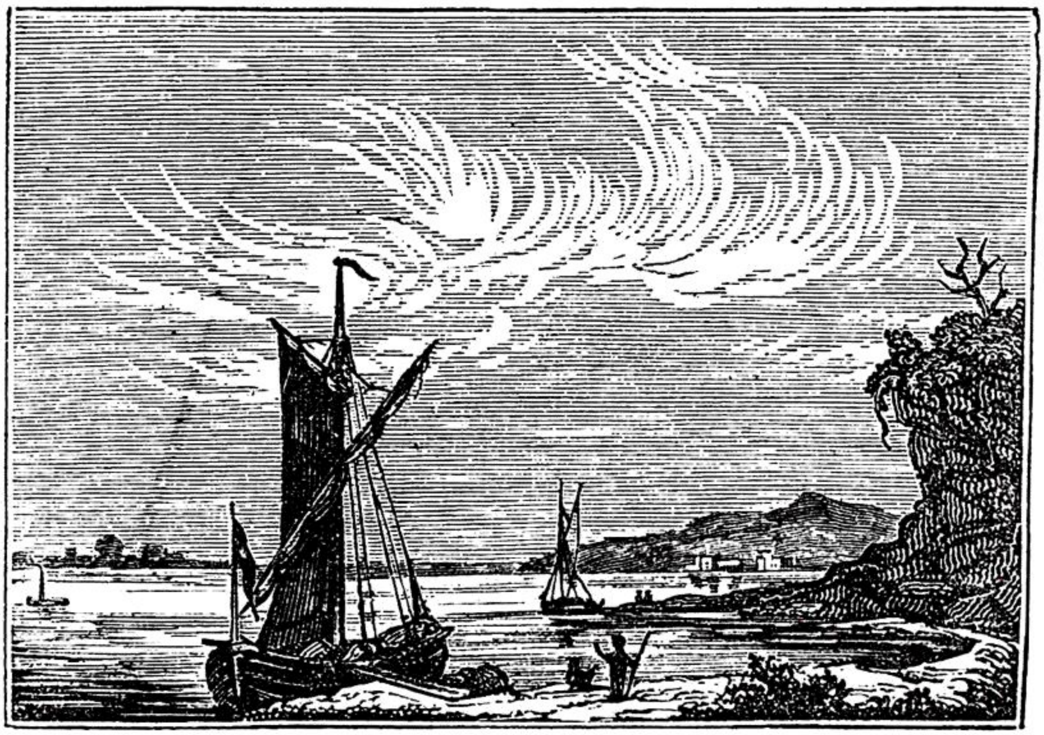
1. CUMULO-STRATUS; the cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, or superadding a wide-spread structure to its base.

2. CUMULO-CIRRO-STRATUS, or NIMBUS, the rain-cloud. A cloud, or system of clouds, from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

For this classification of clouds, which is sufficient y accurate for the present state of the science of meteorology, we are indebted to Mr. Howard, who has rendered more than ordinary services to this interesting branch of physics. The eye of the casual observer may rest upon the broad expanse of heaven a thousand times, year by year, and in it he may find nothing in form to "stir the soul to ecstasy," much less to induce a philosophical discrimination of causes. But although there may be little to interest the man whose highest aim is the personal satisfaction of his grosser nature, or him who traverses the earth without knowing more of its condition than it knows of itself, and never for an instant imagined the sense of the phrase, "the poetry of nature," yet there is a language in the most fickle of all things, the morning cloud. As the face of man portrays the passions by which the man is governed, and their intensity, so the clouds of heaven give evidence of the causes by which the atmosphere is held in control, and a philosophical knowledge of the influence of those causes enables an individual to prognosticate future results from present appearances.

THE CIRRUS.

This modification of clouds has a less density, and generally a greater elevation, than any other. Sometimes it



may be seen stretching over the half of the hemisphere, and at other times it may appear as small thin streaks, here and there pencilled upon the clear blue sky. Its duration is as variable as its extent; for, although it will frequently retain the same form for many hours, it does occasionally change in appearance so rapidly as not to be recognised, after a few minutes, as the cloud which was first observed. Its direction is not less various. From the primitive threads which are first wove, others are thrown, some laterally, others upward or downward, some or all becoming in time the branches of new shoots; while, under some circumstances, transverse lines are formed, which, intersecting the lateral threads, produce a reticulated structure. There is, in fact, no modification that is so various in its extent, duration, and form, as the cirrus; but we think it will be found more constant in all these particulars when formed at great heights, than when at small elevation.

The cirrus has been considered the sign of wind; but it is ever desirable to remember, that when we prognosticate atmospheric changes from the presence or appearance of clouds, we must be careful to consider the circumstances under which the cloud was formed. Horizontal sheets of cirri frequently attend wet weather, ever changing here and there into cirro-stratus; and small groups of the same cloud are generally distributed over the sky during fine weather. When the cirrus precedes a storm, it is lower and denser than under any other circumstance; and generally rises in a direction opposite that in which the storm advances.

It is now generally supposed by meteorologists, that the cirrus acts the part of an electric conductor from cloud to cloud, or from one mass of air to another. This supposition is warranted by the form of the cloud; and it is worthy remark, that phenomena usually attributed to electricity frequently attend the long-continued presence of this cloud, when accompanied with dry easterly winds.

The cirrus has been, not inappropriately, called the Proteus of the sky. The variety of form it assumes may possibly at first confuse the student, but a little perseverance, and an attentive examination, will soon enable him to detect it under all the varied forms it presents. It might be desirable to arrange the cirri in different classes, for we are convinced that the several kinds cannot be traced to precisely the same causes, and are not the harbingers of the same results. Dr. Forster appears to have made an arrangement of this kind, and we may be permitted to quote his judicious remarks on the subject. "Of late, by way of distinction, I have used certain specific names for the various forms of each modification. I have called this net-like feature the reticular cirrus. Those which are local and detached, and which ramify in many directions, giving the idea of a distended lock of hair, may be denominated comoid cirri. Sometimes numerous little filaments appear, like bundles of thread, which I have called filiform cirri. In fair dry weather, with light gales, obliquely descending bands of fibrous texture are often seen, and frequently move slowly along from the lee-ward in a supervening current. I by no means intend by the above account to infer that the appearances of the different kinds of cirri, or indeed of any cloud, are ever quite uniform; on the contrary, scarcely two occur exactly alike; and there are many features so various and so mixed, that a particular description of each can scarcely be attempted. In some kinds of weather, the numberless and ever-changing figures which this cloud is continually presenting to the eye baffle all attempts at description. Observation affords the only means of becoming acquainted with them." Some such arrangement as that adopted by Dr. Forster is desirable; but it should be entirely founded upon observation, for in such a one all meteorologists might agree.

THE CUMULUS.

The cumulus is a dense hemispherical lump of cloud, rising from a horizontal base, and is generally formed in the lowest regions of the atmosphere. Its first appearance is as a small

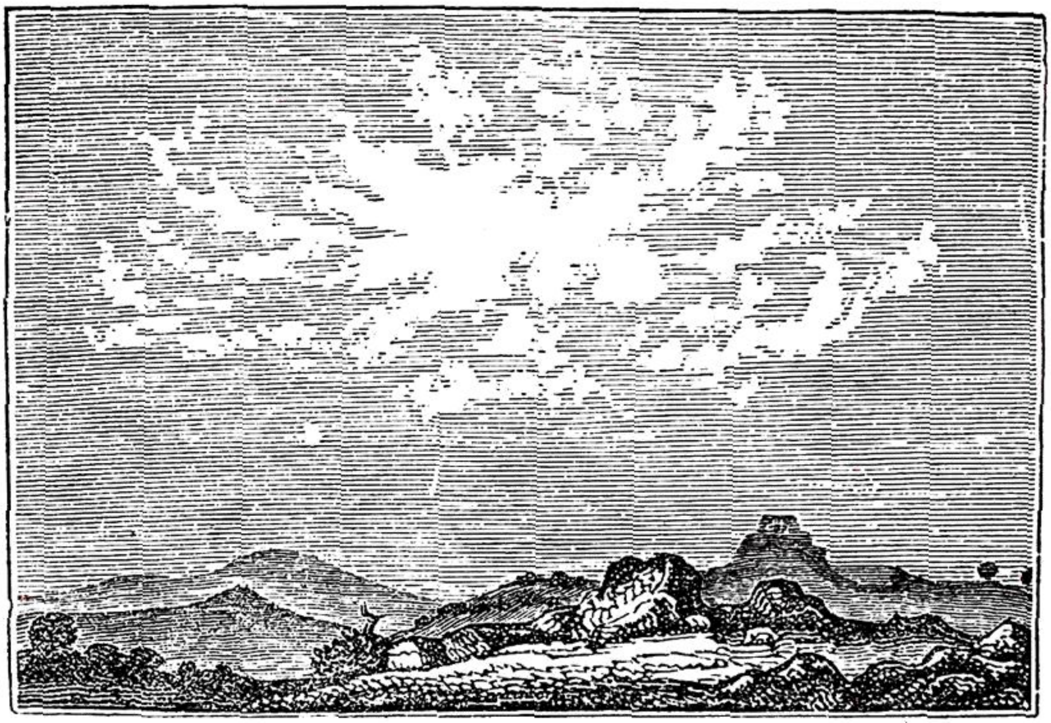
irregular cloud, but previous to rain it rapidly increases in size, mass rolls upon mass, often presenting the appearance of an aerial mountainous scene; hill capping hill, lighted up with an ever-varying light. When it is the harbinger of rain, its surface presents a fleecy appearance, and is formed in dense masses in lower strata of the atmosphere than usual. In fair weather, the cumulus has a well-defined rounded surface, and frequently increases or diminishes with the temperature, lasting in one form or the other throughout the whole day. Mr. Howard, speaking of this modification of clouds, says, "independently of the beauty and magnificence it adds to the face of nature, the cumulus serves to screen the earth from the direct rays of the sun; by its multiplied reflections, to diffuse, and, as it were, to economize the light; and also to convey the product of evaporation to a distance from the place of its origin. The connexion of the finer round forms, and more pleasing dispositions and colours of these aggregates, with warmth and calmness; and of every thing that is dark, and abrupt, and shaggy, and blotched, and horrid in them, with cold, and storm, and tempest, may be cited as no mean instance of the perfection of that wisdom and benevolence which formed and sustains them."

THE STRATUS.

The term stratus includes all those creeping mists which, during the night, and particularly in the summer, are seen to rise from low or damp situations. It is spoken of by writers as the lowest of all clouds: there are others, however, which, like itself, rest their lower surface upon the earth. The stratus generally rises after sunset, and vanishes soon after sunrise, being gradually separated from the earth, and ultimately evaporated. This modification has been long known as the harbinger of fair weather, and it is almost invariably followed by a serene and cheerful day.

THE CIRRO-CUMULUS.

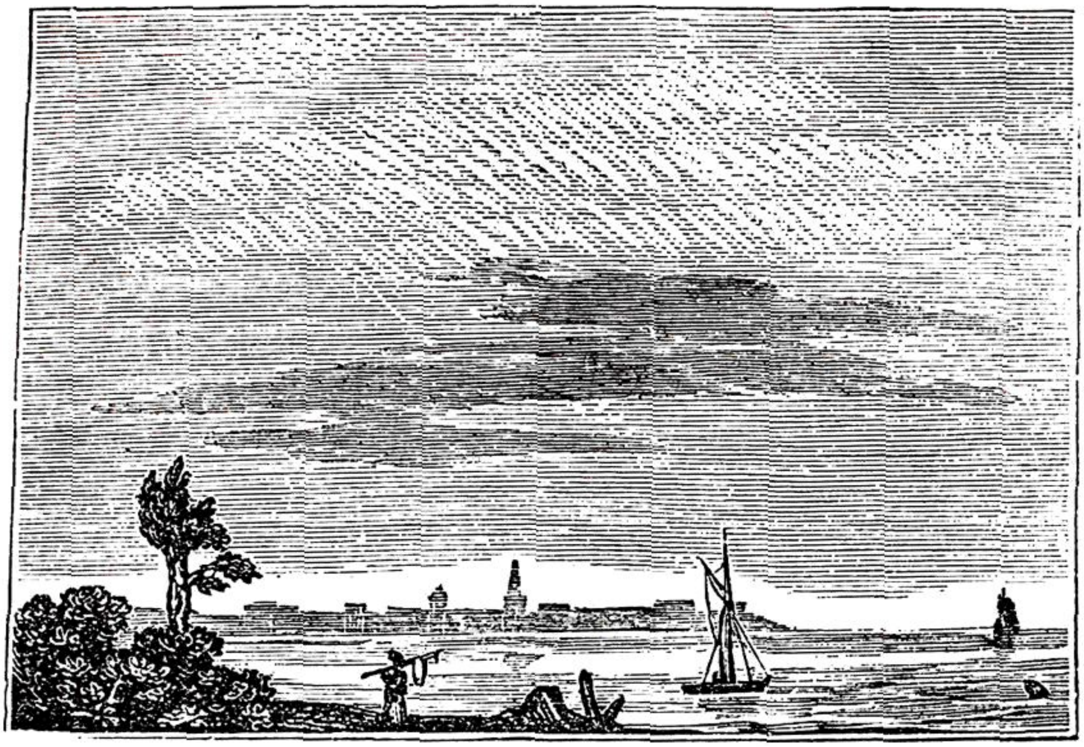
The cirrus sometimes loses its fibrous character, and its streaks seem to contract and form themselves into globular or irregular masses, arranging themselves horizontally, and sinking in the atmosphere—this is the cirro-cumulus. It has been supposed by some, that this alteration of form results from the cessation, either from an alteration in its structure or in the condition of the air, of its office as the electrical conductor of the atmosphere. The cirro-cumulus is frequently seen in dry summer weather, and, under certain circumstances, in the interval between showers. The nubeculæ of the cirro-cumulus sometimes almost cover the sky on a fine summer's evening, while at other times they are well defined, and far separated from each other. The varying forms of



this cloud are peculiarly beautiful; and there is no modification so likely to attract the attention of an observer of nature. But although it is usually the forerunner of fine weather, it is not always the indicator of peace; for when it makes its appearance with the cumulo-stratus, it is sure to be followed by a storm.

THE CIRRO-STRATUS.

The cirro-stratus varies in form almost as much as the cirrus itself, from which it is frequently produced. It is, like the cirrus, a fibrous cloud, but the fibres are more dense, and generally more regular, than in that modification. Its appearance is commonly followed by rainy and windy weather. It is that modification in which the halo most frequently appears, and hence it is, in all probability, as Mr. Howard suggests, that this phenomenon has been considered a prognostic of foul weather. The cirro-stratus has, under certain circumstances, so much the appearance of shoals of fish, that it has been called the mackerel-back sky. But at other times it presents a structure which warrants the designation, waved



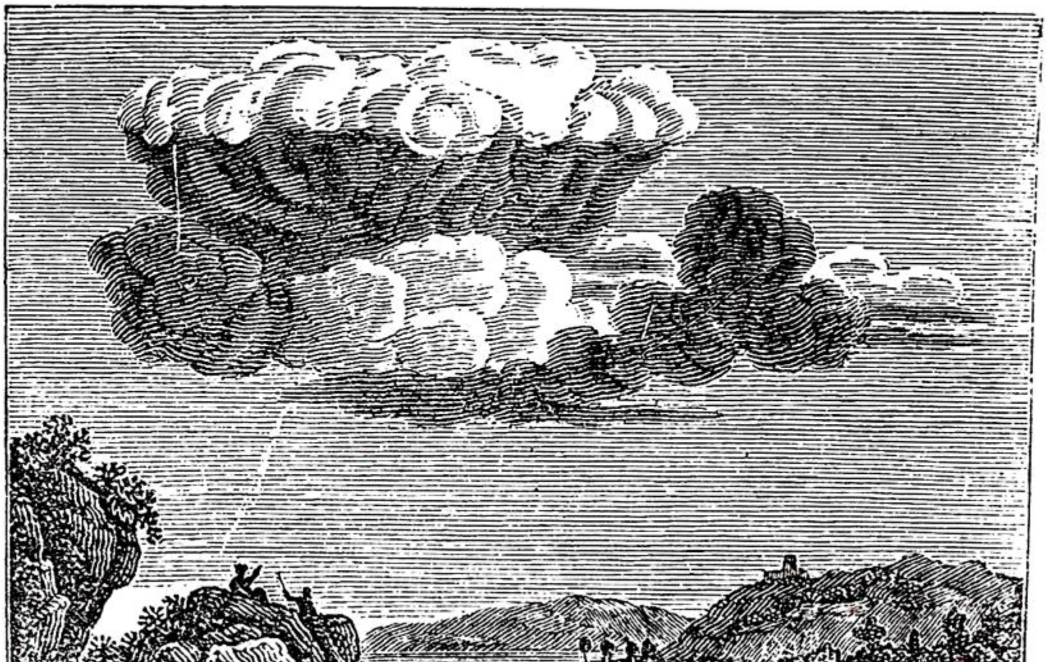
cirro-stratus, and is then generally attended by high temperature and thunder-storms.

THE CUMULO-STRATUS.

The cumulo-stratus is a compound modification, and being a common gradation between those clouds which indicate fair and those which bring rough and rainy weather, it is frequently seen in all those countries subject to sudden and repeated atmospheric changes. It consists of cirro-stratus blended with cumulus, and frequently appears as vast banks of cloud with overhanging masses. The ever-varying forms of this cloud are such as the painter durst not imitate, lest he should be charged with a mimicry of nature. We have often found amusement in the days of childhood, and in riper years, in tracing the outlines of well-known forms in burning embers, but these do not furnish half so prolific a field for the exercise of imagination as the cumulo-stratus. Here are pictured, in bold and determined outline, the ruined tower, with its heroes and demigods, the majestic mountain, giants, fairies, and scenes of by-gone days: but who can attempt its description?

"Sometimes we see a cloud that's dragonish,
A vapour sometimes, like a bear or lion
A towered citadel, a pendent rock,
A forked mountain, a blue promontory,
With trees upon't that nod unto the world
And mock our eyes with air.
That which is now a horse, even with a thought
The rack dislimns, and makes it indistinct
As water is in water."—SHAKSPEARE.

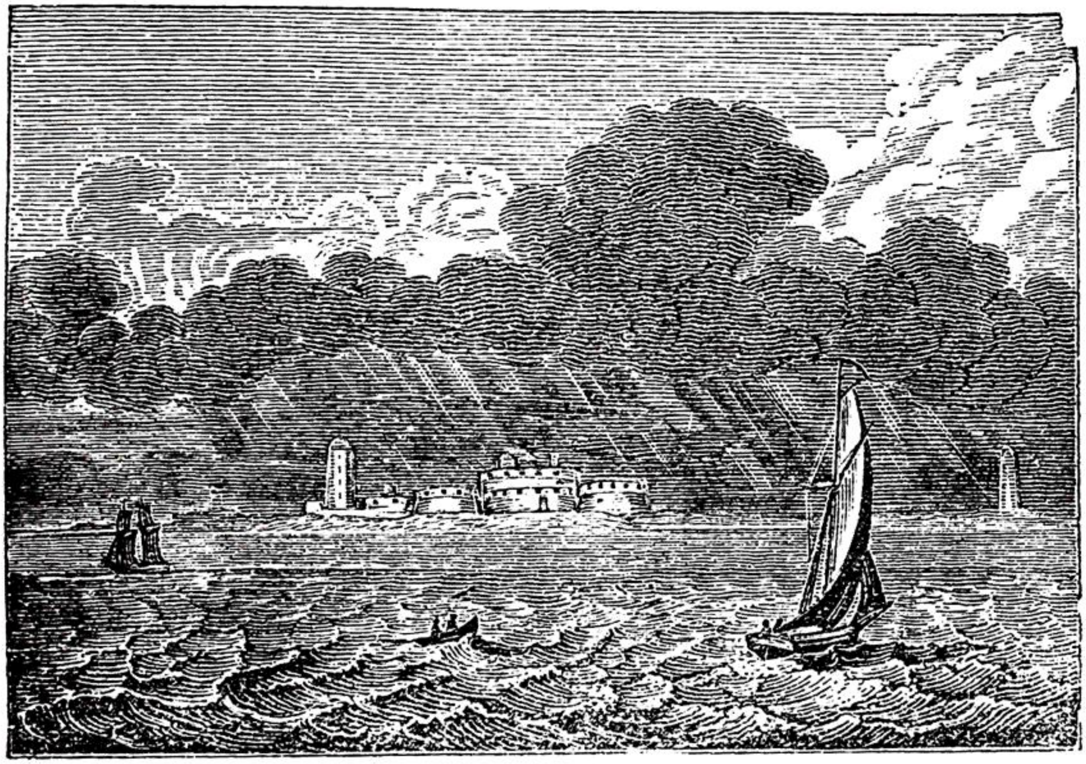
The cumulo-stratus gives a very majestic character to mountainous scenery, and Mr. Harvey accurately described its appearance to an observer, when he said it resembled a curtain dropping among the hills and enveloping their summits, the hills themselves reminding us of the massy Egyptian columns which support the flat-roofed temples of Thebes and Tentyrra. The usual appearance of this cloud, however, is



that of a fungus with a thick stem. Its appearance may sometimes induce a casual observer to imagine the speedy fall of rain, but it is stated by Mr. Howard and others that rain never falls from the cumulo-stratus.

THE CUMULO-CIRRO-STRATUS, OR NIMBUS.

The nimbus has generally its origin in the cumulus. Vast masses of cumuli may, under favourable circumstances, be seen, in rough weather, previous to the fall of rain, to lift themselves into towering mountains of cloud, and by an insensible change to take the structure of the cumulo-stratus. After a short interval this modification becomes more dense, and increasing in irregularity and extent, forms itself into the nimbus or rain-cloud. It is worthy of remark, that when the cumulo-stratus is formed, lengthened masses of cirro-stratus often cap it, and the quantity of rain seems to be in some degree proportional to the extent of the cirri.



There is no cloud that is so readily distinguished as the nimbus, and those who are least acquainted with the configuration and structure of clouds can generally detect it, although the cumulus and cumulo-stratus frequently assume a darker and more threatening aspect. Experience, however, guides us, and we frequently gain insensibly that knowledge which we cannot describe. We have often heard persons say that rain would fall from this, and not from that cloud, who yet have been unable to explain the reason of their opinions, always satisfying themselves with the assertion, "I know it, I have seen it before."

Clouds are so often in an electrified condition, that Beccaria and others have thought that their formation is attribu table to this cause. But whether this opinion, which in the present state of our knowledge can neither be proved nor disproved, is founded in truth or not, we do know that clouds are frequently the reservoirs of electricity of great intensity. In August, 1772, a bright cloud was observed covering a mountain in Cheribon, in the Island of Java, and loud sounds, resembling the discharge of artillery, were heard from it. A part of this cloud detached itself from the mass, and covering over a circumference of about three leagues, was seen to rise and fall, as though it were perpetually under the influence of two opposing forces, discharging large globes of fire, which illuminated the whole country. Its effects were most terrible for seven leagues round; houses and plantations were destroyed, and upward of two thousand persons were killed. There are, however, some cases in which electricity from the earth strikes the cloud. A very remarkable instance of this is mentioned by Brydone, in which the electric action of the earth melted part of the tires of a cart's wheels.

Other modifications of cloud are sometimes charged with electricity, but the nimbus is always in an electrified condition, although it is not always placed in those circumstances which cause the electric agent to assume that free state in which its presence is displayed to the senses. The nimbus is always present during a thunder-storm; and its dark and apparently compact structure seems to be rent by the violent expanding force of the devastating agent, as it darts from cloud to cloud, or cleaves its way to the earth. The form of the rain-cloud is modified by the intensity of its accumulated electricity, but in what degree has not been determined.

There are appearances sometimes assumed by clouds which cannot be assigned to any of the classes which have been described; but these are transient, and quickly take some of the modifications we have explained. Many other particulars have been ascertained concerning the constitution and structure of clouds, their appearances, position, and results, which we cannot now attempt to enumerate.

RAIN.

The vapour carried into the atmosphere by the process of evaporation is frequently brought to the earth again as rain.

It is easy to account for the fall of rain, but philosophers have differed in their theories of its formation, and of those diversities which regard the quantity that falls in different countries. No subject connected with general physics is more involved in mystery than this. The difficulty partly depends upon our inability to account for the change of temperature which is supposed to be the cause of rain, and partly from the impossibility of understanding how the change of temperature does produce the phenomenon. Even in places where there is little or no variation in the annual mean temperature, there may be a great variation in the annual quantity of rain, a circumstance which induces us to believe that there are local and temporary deranging causes which it is almost impossible to estimate. We can only attempt to explain the opinions which have been entertained by philosophers, and to mention a few of those facts which have been established by experiment or observation.

It is universally agreed, that rain is produced by the condensation of vapour drawn into the atmosphere by the process of vaporization. The question of dispute is, why does the vapour separate from the atmosphere and fall in a liquid state to the earth? We might suppose it to arise from the coldness of the atmosphere at the time; but it not unfrequently happens that rain falls very abundantly when the air is most heated. We have little doubt that this subject, and many other branches of meteorology, will be relieved from the perplexing circumstances which now attend their explanation, when we are better acquainted with the influence of atmospherical electricity, an agent already known to exert an immense influence upon the conditions of terrestrial phenomena. Neither vaporization nor liquefaction can be effected without its development; and, existing as it does in all matter, it may be supposed to exert some influence in all the changes it suffers. Some philosophers have attempted to explain the phenomenon of rain by a reference to this agent, but we are not sufficiently acquainted with its conditions to determine its true influence upon atmospheric phenomena.

Dr. Hutton's explanation of the production of rain is very ingenious, and has been adopted by many meteorologists as better explaining the facts than any other theory. Rain, according to Hutton's hypothesis, results from the union of extensive strata of air, charged with moisture, and having different temperatures. It is well known to philosophers, that the quantity of aqueous vapour that can be contained by atmospheric air, differs according to the temperature of the air at the time. Air at a given temperature may be saturated, and the condition under which this effect is produced has been already explained; but, raise the temperature, and it receives a capability of absorbing more moisture; lower the temperature, and it must part with some that it possesses. Let it then be supposed that two saturated masses of air, having unequal temperatures, and consequently containing an unequal amount of humidity, meet each other; their contact will produce a conduction of heat tending to give an equality of temperature. A mean temperature will be produced, which must be lower than the temperature of one of the masses, and, if the quantity of moisture be too great for the degree of heat, a portion of it must be precipitated as rain. The whole of this explanation, then, depends upon the fact, that temperature and solution do not increase by equal increments. Many objections have been made to the theory, and there are many facts for which it does not readily account; but these cannot be urged as a proof of its inaccuracy, as they may depend on local circumstances which modify the common results.

Mr. Harvey has so well illustrated by numerical examples Dr. Hutton's theory, in an excellent paper, worthy its place in the Encyclopedia Metropolitana, that we cannot deny ourselves the pleasure of a quotation. "Let it be required to mingle two volumes of air, of the temperature of 40° and 60°, each being saturated with humidity. The force of vapour at these temperatures is known to be respectively 0.263 and 0.524 inches of the mercurial column. The compound mixture will evidently have a mean temperature of 50°, and the mean of the elastic forces is at the same time 0.393 inches of the same column. But if we now inquire whether air at the temperature of 50° requires an elastic force of this last mentioned magnitude to saturate it entirely with vapour, we shall find that it does not; and that, at the mean temperature here referred to, the measure of entire saturation is really 0.375 inches of quicksilver. The difference of the two columns, or 0.018 inches of mercury, is hence the amount of moisture that must be precipitated in some way or other from the compound mass.

"To prove, moreover, that this precipitation cannot be constant for equal differences of temperature, let us farther take the example of the temperatures 60° and 80°. In this case we shall find the elastic forces to be 0.524 and 1.000; and that at the mean temperature of 70°, the force of vapour is 0.721 inches. But the mean of the two elastic forces is 0.762, thereby proving that a quantity of vapour corresponding to 0.041 inches of the mercurial column, must be discharged the moment the aerial volumes are united.

"The order of nature, however, requires that rain should not always result from the mingling together of opposite currents, and the theory before us amply confirms it. Two volumes of the temperature of 50° and 60° may be blended, one of which contains vapour denoted by 0.2 inches of mercury, and the other by 0.3, the mean being 0.25; whereas the quantity necessary for entire saturation, at the mean temperature of 55°, is 0.443. In such a case it is obvious no precipitation can take place. One volume, again, may have a temperature of 52°, and be in a state of entire saturation, its elastic force being 0.401; but the volume to be united to it, with a temperature of 70°, containing moisture equivalent only to 0.589. The mean amount of moisture will therefore be 0.495, whereas the humidity necessary to produce saturation, at the mean temperature of 61°, is 0.542, so that no precipitation can take place. It is evident, indeed, that combinations of this kind may be endless, the absence of precipitation, as well as the amount of it when it takes place, depending on circumstances so varied and uncertain, as to afford, on the one hand, a shower so gentle as hardly to bear the designation of rain, and on the other to supply the torrents which occasionally deluge the tropics. Not only the existing state of the moisture in the mingling columns must be subject to innumerable changes, but their different degrees of heat must be altered also; the elevation of their mean temperature, too, as well as the extent of combination which takes place among all the moving volumes, must impress necessarily upon the whole of the phenomena the greatest diversity."

The quantity of rain that falls in a place seems to be in some degree affected by these circumstances:—its position in relation to the equator; its proximity to the sea; and its elevation.

1. The largest quantity of rain falls at or near the equator. and progressively decreases to the poles, a fact which seems to be in some degree substantiated by the fulness and magnitude of the equatorial rivers. Humboldt has given the following table as the result of the calculation he made of the proportional quantity of rain in different latitudes.

Latitude.	Mean annual depth of Rain.
0°	96 inches.
19	80 "
45	29 "
69	17 "

But although we speak of a relation between the latitude of a place and the quantity of rain that falls there, it must not be supposed that there is any constant average throughout a parallel. Local causes interfere to prevent such a result. A less quantity of rain falls upon the sea than on the land, there being on the former no elevation around which the clouds are attracted; and a greater quantity will fall in mountainous than in lowland districts.

2. Rain falls more abundantly on seacoasts than in inland places, although they may be in every other circumstance similarly situated, and have the same general physical features. It has been supposed, and not without evidence, that atmospheric humidity decreases in a geometrical proportion with the distance from the sea. This is an effect which might be expected, as the supply of vapour is most abundant in the vicinity of the sea. But it is still to be determined why it should be more condensed on the coast than inland, and must be explained according to the theory that is adopted.

3. Mountainous countries are always more humid than level ones. Mountains, when acted upon by the sun, heat the air which is in contact with them, even in the cold regions of the upper atmospheric strata. These heated masses of air absorb the moisture from the colder columns around; but, meeting with humid masses of lower temperature, or cooled by the constant abstraction of their heat, the humidity becomes too great for the temperature, and rain is produced. At Keswick and Kendal, in England, both situated among the mountains of Cumberland, the annual fall of rain is about

sixty-seven and fifty-nine inches respectively, while the average in places situated in the interior is not more than twenty-four inches. The quantity of rain that falls in the Julian Alps is estimated at 100 inches annually, though in the valley of Lombardy it does not exceed thirty-five inches.

There are some countries in which rain falls during particular periods of the year; there are others in which it has not the character of periodicity, though it may fall in greater abundance in one part of the year than in another. This is the case in Great Britain, the greatest quantity of rain generally falling in September, October, and November. In India and many other countries, the fall of rain is confined to certain months, an unclouded sky being presented at all other times of the year. There is no fact that proves more strongly the importance of considering local causes, than the circumstance that, by these, the rainy periods are sometimes decided. In Bombay, for instance, the heavy rains fall in June and the four following months, but on the Coromandel coast in the opposite months, a result produced, in all probability, by the Ghauts. Those places where the atmosphere suffers a periodical change in the direction of its currents, are subject to periodical rains. This is the case with the islands situated under the line in the Indian Ocean. Heavy rains fall during the summer solstice in the tropical regions of Africa and Asia, for the place of the heated air is occupied by a humid atmosphere from the neighbouring seas, and the vapour is condensed.

During the continuance of the tradewinds, rain is a very uncommon circumstance in the places over which they blow. On account of the uniformity of temperature, the aqueous vapour is carried upward, and steadily moved onward, without a chance of condensation. But, as soon as it is beyond the influence of these winds, it meets with masses having different temperatures, and rain is produced. It is a singular circumstance, that the heavy rains of India fall during the shifting of the monsoons; and it must have been observed that in England, a dry season is always attended by an almost uniform wind, while wet seasons are as constantly accompanied by an unsteady and variable motion of the atmosphere.

There are some places in which rain is almost constantly falling. A small rain falls every day in a zone on that side of the equator on which the sun is situated, and when it ceases at night it commences on the other side. But there are also some places in which rain seldom or never falls, as in the great desert of Africa, and on the arid shore of Peru, between the 15° and 30° of south latitude.

SNOW.

As the atmosphere as well as the earth is subject to a variation of temperature, the moisture which is precipitated by the union of atmospheric masses of unequal temperature and humidity, may fall in a solid as well as in a liquid state. In the winter months, even in England, when a decreased radiation reduces the temperature of the atmosphere below the freezing point, snow is a constantly occurring phenomenon.

When flakes of snow are carefully examined with a microscope, they are found to be composed of a mass of beautiful crystals, having a more or less perfect and regular shape. Dr. Nettis, of Middleburgh, was the first to describe these appearances, which he did in 1740. This observer very carefully delineated some of the figures which the crystallization presented, and of these there is an almost endless variety. But we are chiefly indebted to Captain Scoresby for our information on this interesting subject, who availed himself of his opportunities, during his polar voyages, of not only sketching some of the most remarkable figures, but of measuring the crystals themselves. This gentleman has classified the several modifications of form he observed, but it would be unsuited to the character of this work to detail his results.

The amount of snow falling at any place is of course regulated by the mean temperature, or, in other words, by its latitude, elevation, and position. According to Mr. Scoresby, it snows nine days out of ten during April and the two following months in the polar regions; the heaviest falls always happening when a humid stratum of air from the sea is met by a cold breeze from the surface of the ice. The inhabitants of these inhospitable climes immure themselves in their huts during the most inclement season, and it is then necessary to stop every aperture, so as to prevent the entrance of the cold atmosphere, or the vapour of the confined air would be immediately frozen and fall as snow.

Snow has been sometimes observed to take, in the polar regions, a red or orange colour. This appearance is supposed by some persons to arise from the presence of mineral substances in the condensed vapour, or rather the frozen water, while others suppose it to arise from the presence of animal or vegetable matter.

Snow-storms sometimes present a luminous appearance. This singular phenomenon has been frequently observed, and we have one very remarkable instance on record. It was seen in the year 1813, by a party of gentlemen on Loch Awe, in Argyleshire, and it not only gave to the surrounding scenery the appearance of an immense sheet of fire, but illuminated the persons of the individuals who composed the party.

Natural snowballs are sometimes formed by the passage of a high wind over the surface of the fallen snow. When once formed, their size rapidly increases by a continued motion; for, as they roll along, they collect, and sometimes attain a considerable size. Mr. Sherriff states that in February, 1830, he observed many of these balls in East Lothian, some of which were a foot and a half in diameter. They were produced by a westerly wind, and had left their track impressed upon the snow. In one village much exposed to the west they were exceedingly numerous.

We can scarcely avoid a remark, which may appear to be little, if at all, connected with an explanation of the fall of snow, though it cannot fail to assist in the proof of a statement already made, that electricity is always developed by atmospheric changes. Snow is universally in an electrified state, and, as far as our own observations have extended, generally positive, but the condition is changed by liquefaction. There are many persons who entertain a skeptical notion of the universal influence of electricity, and in the present uncertain state of the science, so far, at least, as regards the condition of the atmosphere, and the causes which influence it, they need not be at a loss for arguments to support their opinions. But when we discover that so simple a process as that of congelation cannot be carried on without the development of the agent which in other states produces some of the most awful phenomena we behold above and around us, there can be nothing very absurd in the supposition that it may have something to do with many, if not all, the meteorological changes. This is not merely an opinion; it is, we think, warranted by our own experiments, and rendered probable by the experiments which have been made by others.

HAIL.

In England we are fortunately little subject to violent hail-storms, and this may account for the small attention we have given to the subject. In the south of France they are frequent, and produce the most destructive effects: the French philosophers have therefore closely studied the phenomenon.

From among the many theories which have been invented to account for hail, we may, first of all, select that which was proposed by the celebrated Volta; a theory which altogether depends upon the admission that clouds are in opposite electrical conditions. If we take two metallic plates, and place them horizontally one above the other, connecting the upper with the prime conductor of a machine, and the lower with the ground, pith balls or figures lying between the plates will, as soon as the upper plate is electrified, be attracted to it; but, receiving a part of its electricity, will then be repelled, because bodies having the same electric condition repel each other. As soon as the ball or figure touches the lower plate, it parts with all its electricity, and is again attracted by the upper; so that there is a constant oscillation produced by the disturbance and restoration of electric equilibrium. Now Volta supposes the same thing to be going on in the clouds: he substitutes the black clouds which produce hail for the metallic disks, and supposes the particles of hail existing between them to undergo the same oscillatory motion.

This celebrated philosopher accounts for the first formation of hail in the following manner:—"The clouds are formed of hollow vesicles, the external surface of which is fluid. The myriads of these, which form the upper surface of a cloud, must undergo, towards the south, a strong evaporation, both on account of the intensity of the solar rays and the dryness of the air in which they swin. The elastic vapour thus produced by the solar heat must first saturate the dry air through which it passes, and at length, by the low temperature of some superior stratum, become again reduced into a vesicular state, forming another cloud. differing in its electri cal condition from the first. The upper cloud will have positive electricity, on account of that species of electricity being developed during the precipitation of vapour, the lower having changed its character to negative, in consequence of the evaporation it has undergone. A diminished temperature at length may produce, between the clouds, icy particles, or hail in a nascent state, which the opposite electrical states of the upper and lower clouds will cause to oscillate, until, by gathering matter from the surrounding moisture, they become at length enveloped in compact and opaque ice, and attain a size which, overpowering the electric forces, compels them by gravity to descend."

It has been objected to this theory, that hail sometimes falls so early in the morning, that the sun could not have acted on the clouds except on the previous day, and it must then be admitted that the hailstones began to oscillate between the clouds eight or ten hours before they fell. Arago urges a still more powerful argument against the theory, when he asks how it is that the clouds are not brought together, for they are moveable, and may be supposed to attract each other as well as the hail. It might also be asked, how it has happened that the oscillatory motion has never been observed; for it is more than probable that some traveller must, when in mountainous countries, have passed between hail-clouds, or at least must have been so near to them as to see the motion, had it been existent. Arago's objection is the only one which can be fairly urged against the theory, and it is fatal unless answered upon the laws of electrical attraction.

Mr. Harvey, to whose paper on meteorology in the Encyclopedia Metropolitana we have already referred, adapts Hutton's theory of rain to this phenomenon, and supposes that a difference of temperature is of itself sufficient to account for the formation of hail. But to this theory it is objected, that hail-storms are not always most abundant in cold climates, nor most frequent during the winter months; that hail-clouds are generally low, and that the hail is sometimes so large as to forbid the supposition that they were produced by a change of temperature uninfluenced by other causes. But at the same time it must be acknowledged, that hail and rain frequently proceed from the same cloud. There is, in fact, a great uncertainty concerning the origin of hail; facts seem to combat with each other; and the theory which readily ex plains some of the circumstances which attend its fall, is found to be altogether inadequate for the explanation of others. In France and Spain it generally hails in the hottest part of the day, chiefly in spring and summer, and but seldom during the night, or in the winter months. In the present great uncertainty in which all meteorologists feel themselves to be placed, in attempting to account for the formation of hail, we shall only remark, that there is some evidence of the interference of electricity in this as well as in other atmospheric changes. The electrometer is always in a state of agitation upon the approach of a hail-cloud, the electric condition of the atmosphere frequently changing from one state to another ten or twelve times in a minute; and some suppose that the rattling noise which precedes the fall of hail. is attributable to the collision of the stones in differently electrified conditions.

Mr. Stewart has given a very interesting and graphic account of a remarkable hail-storm in the Pyrenees. "In August, 1813, the British army occupied a range of mountain district extending from Roncesvalles to St. Sebastian. About this period, the forces under Marshal Soult were anxious to get possession of the pass of Maya, situated at the top of the Pyrenees, and one of the few roads on the western ridge by which cavalry or artillery can enter Spain. A division of British infantry were ordered to take possession of the pass, and remain there till two o'clock: the day was very warm, and the sky clear and cloudless. About three o'clock, the summits of the adjoining hills were enveloped in a cloud of pitchy darkness, and leaving but an obscure light as it quickly passed over our heads, and producing a peculiar noise among the rocks. As the troops began to descend the mountain, they were overtaken by a violent hail-shower, which lasted about twenty minutes, and created more alarm among its victims than the approaching contest. Contrary to my expectations, the storm was unaccompanied with either thunder or lightning, while the stones increased from the size of a bean to that of a hen's egg. These were transparent masses of ice, round in form, and having on their surface icicles about the length and thickness of the prong of a common silver fork. From this circumstance, I am induced to believe that the hail had been twice as large in the higher regions of the atmosphere, and before they reached the surface of the earth, as the stones themselves; and the sp cure or icicles on the surface, had all the appearance of being partially melted down by heat. Fortunately, the troops had their backs to the storm, else many of them must have lost their eyes, and been otherwise maimed, from the weight of the stones, and the force with which they fell. I have heard some of the men say, their tin-kettles were *dinged* (or dimpled) by the shower; and I am inclined to believe so from the circumstance of my being rendered lame for twenty-four hours by one of them falling on my toe. The rattling of the stones on the canteens and kettles of the men, and their gradually increasing in size for some time, rendered the scene truly alarming, even to those who had been in the daily habit of exposing their lives to the dangers of war. I am not aware of the extent of the shower, nor have I been able to ascertain its injurious consequences, from the French or Basque journals; but from the damage done to the orchards and grains at the bottom of the Pyrenees, I should suppose it to have occupied a range of three miles, proceeding from Roncesvalles into the valley of Bastan."

DEW.

The term dew is employed to signify that spontaneous deposition of moisture which is observed on certain substances exposed to the air, at a time when no aqueous vapour or rain is apparently falling.

Previous to the publication of Dr. Wells' "Essay on Dew," it was disputed among philosophers whether the phenomenon was produced by vapours rising from the earth, or by the descent of atmospheric vapour. Dr. Dufay, a French philosopher, made a very singular experiment for the purpose of determining this question. He took two long ladders, and fixing them so that they met at the top, and were wide apart at the bottom, attached to the several steps large panes of glass. He observed that the lowest surface of the lowest pane was first wetted, then the upper, then the lower surface of the one above it, and so on until the same effect had been produced upon them all. From this effect he deduced that dew is occasioned by the exhalation of vapours from the earth during the night. He afterward substituted cloth for the glasses, and weighing the pieces separately, imagined that he detected a progressive increase of weight in the several pieces, the lowest being the heaviest; but this result, he says, was not so decided as in the former experiment.

In opposition to this theory, and in proof of the descent of vapour, it was urged that in cloudy weather little or no dew is formed. But Dr. Dufay had observed the deposition of dew on the under as well as the upper surface of the bodies, a fact which seemed to be directly opposed to the supposition that it owed its origin to the descent of atmospheric vapour. In answer to this it was stated, that as more rain falls at the base than on the summit of mountains, though there can be no doubt that rain falls downward, so dew may descend, and yet be formed upon the under surface of bodies. The appearance of dew on the lower surface before the upper, was attributed to the cooling of the inferior mass of the atmosphere before the superior.

Neither of these hypotheses, however, can be maintained. Dr. Wells has proved, by a most beautiful inductive process, founded on an ingenious though simple series of experiments, that dew is produced by the condensation of the atmospheric vapour surrounding the bodies on which it is deposited. We may, however, learn from the history of the opinions which have been entertained on this subject by men given to philosophical pursuits, the absolute necessity of building all our opinions upon authenticated and well-investigated experiments, fully carried out, and under the guidance of legitimate deductions.

These difficulties stood in the way of the determination of the first question, Does the vapour producing dew rise or fall? The next subject of inquiry was still more perplexing. There are some substances which receive the deposition of dew more readily than others, and there are some on which it cannot be deposited; glass receives it readily, but on the metals it is never formed. "The reason of this," says a writer of that period, "is probably because metals promote evaporation more than glass does. Thus, if a piece of metal and a piece of glass are both made equally moist, the former will be found to dry in much less time than the latter. Hence it would seem that there is between metals and water some kind of repulsion, and this may be sufficient to keep off the very small quantity that falls in dew; for whatever tends to make water evaporate after it is actually in contact with any substance, also tends to keep the water from ever coming in contact with it. On this subject several curious particulars are mentioned by Dr. Percival, relative to the attraction and repulsion between dew and glass or metalline vessels. The experiments were made by M. Dufay, who, in order to determine with certainty whether the difference between vitrified substances and metals was the same in all cases, set a china saucer in the middle of a silver plate, and on one side adjoining to it was placed a china plate, with a silver dish very much resembling the saucer in the middle. In this experiment, the china saucer was covered with dew, but the plate, though extending four inches round it, was not moistened in the least. The china plate also had become quite moist, while the silver vessel in the middle had not received the smallest drop. M. Dufay next endeavoured to ascertain whether a china saucer, set upon a plate of metal as already described, did not receive more dew than it would have done if exposed alone. To accomplish this design, he took two watch crystals of equal dimensions, and placed the one upon a plate of silver, the other upon a plate of china, each with its concavity uppermost. That which was upon the silver plate he surrounded with a ferule of the same metal well polished, that no watery particles might attach themselves to the convex surface of the glass. In this situation he exposed the crystals for several days successively, and always found five or six times more dew in that which was on the china plate than in the other placed on the silver."

From this quotation it will appear, that the early experimenters were acquainted with the fact that dew is not deposited on all substances equally, though they were unacquainted with the cause. There is a curious passage in the writings of Dr. Watson, Bishop of Llandaff, in relation to this subject. "By the means of a little beeswax," he says, "I fastened a half crown very near, but not quite contiguous to the side of the glass, and setting the glass with its mouth downward on the grass, it presently became covered with vapour except that part of it which was next the half crown. Not only the half crown itself was free from vapour, but it had hindered any from settling on the glass which was near it; for there was a little ring of glass surrounding the half crown to the distance of a quarter of an inch, which was quite dry, as well as that part of the glass which was immediately under the half crown; it seemed as if the silver had repelled the water to that distance. A large red wafer had the same effect as the half crown; it was neither wet itself, nor was the ring of glass contiguous to it wet. A circle of white paper produced the same effect; so did several other substances, which it would be too tedious to enumerate."

The statements to which we have alluded are true, but the deductions founded upon them are not tenable. It is true that both the under and upper sides of a body may be covered with dew, and that some bodies receive, under the same circumstances, a larger deposition than others. The beautiful theory proposed by Dr. Wells, and now universally adopted by philosophers, depends upon two principles;—the radiation of heat, and the condensation of invisible vapour. Before dew can be deposited on any substance, it must become colder than the surrounding atmosphere. It has been long known that dew is cold; for, as Dr. Wells states, both Cicero and Virgil apply to it the epithet "gelidus;" and Herodotus, speaking of the crocodile, says, that in Egypt it passes the greater part of the day on land, but that it passes the night in the waters of the Nile, they being warmer than the nocturnal atmosphere and the dew. But it was universally supposed that dew was the cause of the cold, instead of which it is the effect, and is produced by the radiation which bodies suffer.

Bodies possess different powers of radiation, dependant on their constitution; metals, for instance, are, in this respect, inferior to vitreous substances; and, as a general law, it may be stated that bad conductors, or bad reflectors of heat, are in general good radiators. But the power of radiation greatly depends upon the surface, polished surfaces radiating less than those which are uneven.

In the consideration of the phenomenon in question, it may be necessary to mention, first of all, the facts which have been ascertained, and then to give a reason for them.

1. A plate of glass placed in a horizontal position, or a piece of wool, receives very readily the deposition of dew. The pendent drops upon the delicate fibres of the gossamer must have been frequently observed by every lover of nature; but no such effect is produced upon a polished piece of metal; it retains its lustre, though every blade of grass may be drooping with the pressure of the vapour that has been condensed upon it. But why do some bodies admit the for-

mation of vapour upon them, and others resist its deposition? All bodies radiate heat, and at all times, but some do so more than others. Substances that have a close and compact texture do not generally radiate so readily as those which are open or porous; the metals belong to the first class, cloth, wool, and swan'sdown, to the second. It is a singular fact, that those substances which radiate most readily are the worst conductors of heat; and these facts lead at once to the deduction, that, during the night, the temperatures of substances must be different, and that they must, in this particular, be governed by their powers of radiation and conduction. These statements are easily proved by a thermometer; for, if wool and a metal be placed under the same circumstance, the temperature of the former will be invariably lower than that of the latter.

2. The vapour of the surrounding air will be condensed upon the bodies whose temperature is lower than that of the air itself. The deposition of dew depends upon the production of a lower temperature in the body bedewed, than in the atmosphere which surrounds it. Now all the bodies which radiate more heat than is conveyed to them by the earth, or any substance with which they may be in contact, when thus lowered, are covered by a condensed vapour which we call dew.

But it has been stated, that some conditions of the atmosphere are more favourable to the deposition of dew than others. Clouds prevent the deposition of dew; for as all bodies radiate heat, clouds do so as well as terrestrial substances, and therefore there is a mutual action between them—both giving, and both receiving; and thus the temperature is in some degree equalised, and no dew is formed. The same effect will be produced if any terrestrial body intervenes between the sky and the radiating substance. Even a thin wire gauze, suspended over a substance which readily admits the deposition of dew, will be sufficient to prevent the effect. Dr. Wells, to whom we are indebted for the theory we attempt to explain, a man equally admirable for his amiable manners, humility, perseverance in examination, and powers of generalization, gives his authority to the statement:—"I had often," he says, "in the pride of half-knowledge, smiled at the means frequently employed by gardeners to protect tender plants from cold, as it appeared to me impossible that a thin mat or any such flimsy substance could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned that bodies on the surface of the earth become, during a still and serene night, colder than the atmosphere, by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless. Being desirous, however, of acquiring some precise information on this subject, I fixed, perpendicularly, in the earth of a grassplot, four small sticks, and over their upper extremities, which were six inches above the grass, and formed the corners of a square, the sides of which were two feet long, drew tightly a very thin cambric handkerchief. In this disposition of things, therefore, nothing existed to prevent the free passage of air from the exposed grass to that which was sheltered, except a cambric handkerchief. The temperature of the grass which was thus shielded from the sky was upon many nights afterward examined by me, and was always found higher than that of the neighbouring grass which was uncovered, if this was colder than the air."

A house or a tree will vitiate the result of an experiment as much as a cloud, or a substance stretched immediately over the body that would be under an open sky bedewed. It must have been frequently observed by those who have been accustomed to examine nature under circumstances uninfluenced by the interference of the works of man, that dew is much less abundantly deposited over that spot protected from the atmosphere by the spreading branches of the forest-tree, than in the open space beyond them; and, in the days of boyhood, they may have frequently solicited their shelter, as though they could escape the effects which a long wandering through the high and bedewed grass had already produced. Milton, the English poet and patriot, acknowledges and adopts this fact, when he says—

"Full forty days he passed, whether on hill
Sometimes, anon on shady vale, each night
Under the covert of some ancient oak,
Or cedar, to defend him from the dew."

HOAR-FROST.

Hoar-frost is produced by the congelation of the dew which has been deposited upon bodies. The condensation of vapour must always precede the formation of hoar-frost. From what has been stated in relation to the cause of dew, it will not appear singular that hoar-frost may be produced when the temperature of the air is above that which is necessary for freezing water. The temperature of bodies is lowered by radiation, or dew could not be formed; and it may be reduced so low as to freeze the water which has been condensed upon the radiating bodies. Nor is it impossible that there should be a frequent change, during a few hours, from one state to the other, according to atmospheric circumstances. But, in general, hoar-frost is formed when the temperature of the atmosphere is below the freezing point; and in the ever-varying climate of England, this is not uncommon even in the summer months, though it is but seldom that the temperature remains below zero for many hours.

The formation of hoar-frost, its abundance or scantiness, must be regulated by the same conditions as regulate the formation of dew. The wide-spreading uninterrupted plain, fully exposed to the sky, may be covered with a hoary vesture of whiteness, when the little patch of verdure beneath the shadow of a shrub or a tree has not a leaf with so much as a single crystal on its surface. This must have been frequently seen, though it may not have been observed, by all who have walked abroad, when

"The gray-eyed morn smiles on the frost'ning night,
Checkering the eastern clouds with streaks of light;
And flecked darkness, like a drunkard, reels
From forth day's pathway, made by Titan's wheels:"

who have seen

"The sun advance his burning eye,
The day to cheer, and night's dank dew to dry."
Shakspeare

MISTS.

The term mist is very erroneously applied to all those accumulations of vapour which are visible upon or immediately over the surface of the earth. It is a generic designation, and as such may be appropriately employed; but, at the same time, it is desirable to remember that all mists are not produced under the same circumstances, and do not present the same appearances.

Mists are frequently, perhaps we might say usually, formed over masses of water. The cause of this is very evident; and an examination of the circumstances which attend its activity, will probably lead us to a tolerably accurate estimate of the agency by which mists are commonly produced.

When the sun ceases to throw its rays upon the surface of the earth, exceedingly different results are produced on the land and water. The earth radiates its heat rapidly; but while the transmission of heat from the land is confined to an immoveable surface, the surface of water is constantly changing; and as quickly as the one is cooled, whether by radiation or evaporation, it sinks, and gives opportunity for the presentation of a new body of water. The superficial extent of water is therefore continually changing, until the whole mass is reduced to the point of maximum density. If this be true, then the atmosphere resting upon the surface of water ought to have, and it has, a higher temperature than that which superposes the land. When these several masses of air, having different temperatures, and being charged with aqueous vapour, intermix, a mist is produced. Sir Humphrey Davy states, that the mists formed over the Danube are attributable to these causes, and that in all his experiments, made during the presence of this phenomenon, he found the air over water to have a temperature from three to six degrees above that resting upon the land; and that when the mist dispersed, the temperature of the air over the land was invariably higher than of that over the water.

The reader must be already aware that we are much inclined to suppose that electricity has an extensive agency over atmospherical changes; but it is possible to carry theoretical opinions, which are based upon well-authenticated experiments, to the brink of speculation, or to launch them upon its unexplored and unfathomable waters. It does not become us to say that the opinions maintained by Professor Hansteen have, upon any subject, this character; but we shall not be charged with presumption in stating, that we cannot conceive how the polar lights can in any way cause the formation of mists. This highly-esteemed and discriminating philosopher imagines the atmospheric vapour to be traversed by electric meteors, which have, he says, a tendency to give it an opacity of structure and appearance, or, in other words, to produce mist

Dense mists, or fogs, are frequent in large cities. Those who reside in London are well aware that a winter scarcely, if ever, passes without the occasional appearance of this phenomenon, which is sometimes sufficiently impenetrable to stay the progress of all the enterprise and engagements of the metropolis, though its environs may be at the same time enlivened by an unclouded sky. We have frequently stood upon the hills which surround the mighty city, and command a view of its wide expanse, and have seen it enveloped by a dark cloud, which could only be resembled to that which frequently shrouds a country that has experienced the terrible activity of a volcano. Nor is this confined to London Fourcroy has described one which, in November, 1797, covered the city of Paris, and was so impenetrable, that men came in contact with each other with torches in their hands, and in Amsterdam, a fog so dense enveloped the city, at the close of the year 1790, that upward of two hundred persons were drowned in the canals, having lost their paths.

M. Defrance states, that these fogs, which usually occur in winter, are to be attributed to the fall of vapours, or, rather, to descending atmospheric currents, which prevent the ascent of smoke. This is a simple, and probably an accurate explanation of the origin of those dense fogs which sometimes hang over large cities.

It is interesting to trace the varied effects of a physical agent, governed or directed by the constitution of the substance upon which it acts, or the circumstances by which it is affected. From the very casual examination of that principle called caloric, which we have made, the reader must have been impressed with this fact. Many of its operations, and phenomena known to be occasioned by its agency, cannot always be accounted for by any of the principles of action which regulate its movements and influence. The science of heat is intimately connected with that of meteorology, but they are both in an imperfect state, and offer tempting inducements to the persevering investigator.

CHAPTER V

PHENOMENA DEPENDANT ON THE DISTRIBUTION AND CONDITIONS OF LIGHT.

IN this chapter we shall endeavour to give a general description of the most remarkable terrestrial phenomena which result from the conditions of light, and to explain the laws by which they are governed. It is not our intention to make any extended remarks on the opinions which have been entertained concerning the nature of light as a physical agent, a subject which has always been involved in doubt, or rather in inexplicable mystery; nor can we refer minutely to those physico-mathematical laws which govern its intensity, distribution, and colour, though it will be necessary to refer to some of these for the explanation of the phenomena that properly come under consideration. We will admit the existence of a principle called light, and that the organ it is adapted to affect is the most extensive and accurate of all the mediums of sense, the best calculated to add to our pleasures, and to increase our intellectual resources. From these admitted facts we will endeavour to trace the peculiarities which, under various circumstances, produce the different luminous appearances around and above us. Indeed, no science is more worthy of investigation than the science of optics, although it is generally less understood than many others. By a knowledge of the properties of light, man has received a marvellous increase to the extent of his vision;—things too distant or too near for the natural range of his sight, are brought within the compass of his observation by a mechanical application of this science; and, in a limited acceptation, he possesses the power of giving sight to the blind, by relieving the misfortunes of some, and the infirmities of others.

PRODUCTION OF LIGHT.

Light is produced under various circumstances, and by means which we cannot very readily explain. It has been supposed by some authors that light is capable of entering into all bodies, and that it is, in fact, a component part of them: and, whatever objections may be made to this statement, there can be no doubt that many substances have the property of emitting light in the dark, after exposure to the solar rays. Thus, sulphate of barytes, Baldwin's phosphorus, and other compounds, become phosphoric after exposure to light; and it has been stated that a diamond, which, after being placed in the solar rays, was immediately covered with black wax, shone for several years after the wax was removed. But none of these substances emit light of the same colour as that which falls upon them, a circumstance that may be attributed to a partial absorption.

There are also some insects that seem to have the power of absorbing light, and its emission is in some measure under their own control. The glow-worm, which is the *Lampyris noctiluca* of Linnæus, is common in some parts of England, and shines with a strong sulphur-coloured light. This property, however, seems to be only possessed by the female, which is a wingless insect, and resembles in form the larva of a beetle. There is, however, a species of *Elater*, a native of the West India islands, that is still more strongly endowed with this property. This insect is not more than an inch long; but the light, which it emits from two transparent eye-like tubercles placed upon the thorax, is so intense, that the smallest print may be read by moving one of these insects over the page. It is said that the luminous insects derive their peculiar property from a liquor which they secrete, and that they lose their brilliancy if it be suffered to dry upon the hand. It is not therefore true that the luminous appearance is altogether voluntary, and this is still farther proved by its continuance for some time after the death of the insect.

Certain fishes also possess the same property. The *Pholas* and the *Lampyris* have been long known to emit phosphorescent scintillations, and the Roman epicures were accustomed to darken their apartments when feasting on them, that they might gratify two senses at the same time.

There is another luminous appearance, commonly called Will-with-the-wisp, or Jack-with-the-lantern, which is supposed by the uninformed peasantry to be the visible representation of an evil spirit, that delights to delude the benighted traveller, conducting him by its light into bogs and morasses, and then leaving him to extricate himself as he can rom his perilous situation—

"A wand'ring fire,
Hovering and blazing with delusive light,
Misleads the amazed night-wanderer from his way
To bogs and mires, and oft through pond or pool,
There swallowed up and lost, from succour far."

Milton.

Mr. Bradley supposed this appearance to be occasioned by a swarm of luminous insects, and Mr. Ray was of the same opinion. It is generally produced by the presence of phosphorated hydrogen gas, which inflames at the common temperature of the atmosphere, but it may be sometimes occasioned by a strongly electrified animal vapour. And here it may be observed, that the incipient decomposition of animal and vegetable substances is generally attended with luminous appearances, and this is particularly the case with fishes.

Light is also given out during combustion, and it may also be produced by a variety of mechanical means. When two pieces of lump sugar, agate, or quartz, are rubbed violently together, a vivid yellow light is produced. The New Zealanders and other savages produce fire by the friction of two smooth pieces of wood, and forests are inflamed by the same means when two branches or trunks of trees, agitated by the wind, are violently rubbed together.

Under all these circumstances light is produced, and its appearance would almost lead the observer to imagine that it is a constituent part of bodies. Some philosophers do believe it to be a component part of combustible bodies, an opinion which seems to be justified by the experiments of Dieman and Pacts. These chymists exposed to a high temperature a mixture of sulphur and zinc, excluding every substance from which they might obtain oxygen. The two substances united without oxydation, and formed a sulphuret of zinc, and at the moment of combination gave out a vivid light. Without admitting light to be a constituent of combustible bodies, it is almost impossible to account for the variety of coloured flames produced by substances, and the principle of absorption would lead to the same result. There must, however, be some primary source from which all the luminous bodies on the earth's surface derive their property, and solar light is that source,—a principle that pervades the system of which our little world is a member, emanating from, or influenced by, the orb of day, and flowing, as it were, from a centre to the very boundaries of its acknowledged attractive influence. But although this principle is so widely distributed, and exerts so important an influence upon living animals and vegetables, we can only form conjectures upon its nature, our observations and experiments being confined to its influence on bodies, and the laws by which it is governed under particular circumstances.

NATURE OF LIGHT.

Two theories have been proposed to explain the nature of light, and it may be necessary to mention them. One of these was advanced by Newton, who supposes light to be a material substance, emitted in extremely minute particles from all luminous bodies; these particles, impinging upon the retina of the eye, produce the sensation of light. This theory readily explains the greater number of luminous appearances, but there are some of which it does not offer a very ready explanation. For a long time it was universally adopted, and is still acknowledged by many philosophers, though it has been greatly superseded by the doctrine of undulations.

It has been long known that sound is occasioned by undulations excited in atmospheric air, or some other conducting medium, by a vibrating body; and, in consequence of this, probably, it was suggested by Des Cartes that light also might be produced by the undulations excited in an ether of extreme rarity filling all space. This hypothesis, however, is due to Aristotle, who supposed light to result from the motion of a pure, subtile, homogeneous medium, or ether, excited by the solar rays. But it owes its present form to the successful labours of Euler, Young, and Fresnel. According to this theory, the elastic medium pervades not only all space, but all substances, and is excited in the solar system by some undefined action of the sun. Professor Airy has supported the hypothesis with the most refined analysis; and if we did not know that many things pronounced mathematically certain have been found experimentally false, we could not withhold our belief in the doctrine; but it is always difficult to speculate upon the nature of occult agents, and it may be doubted whether the question proposed in Milton's beautiful apostrophe to light has been or ever will be answered:—

"Hail, holy light! offspring of heaven, first-born,
Or of the Eternal co-eternal beam,
Bright effluence of bright essence increate—
Thy fountain who shall tell? Before the sun,
Before the heavens thou wert, and at the voice
Of God, as with a mantle, didst invest
The rising world of waters dark and deep."

GENERAL FACTS.

The elementary principles of a science are sometimes so distinctly exhibited in natural appearances, that the most casual observer may acquaint himself with them, though he may not perceive their connexion or importance. But in other instances they can only be ascertained by close observation or by minute analysis. Without an acquaintance with these principles, the student only accumulates difficulties as he increases his knowledge; it may therefore be necessary to make a few preliminary observations in relation to the nature, habit, and character of light under ordinary circumstances, when uninfluenced by the disturbing forces to which it is subject.

1. *Light requires time for its propagation from the luminous to the enlightened body.* On account of the immense velocity with which light moves, this fact could never have been ascertained by the observation of terrestrial phenomena; for although it is true that the flash of a gun or the light of a beacon may be seen by a person one mile distant when it is invisible to a person at the distance of two miles, yet, if it were possible to measure the hundredths of a second with the same accuracy as we measure seconds, we could not ascertain the fact; it is only by reference to the celestial bodies that we can discover the velocity of light. Aristotle taught the instantaneous progression of light; and Chrysippus, the stoic, who was the successor of Zeno, says that its transference is like to the motion of a long rod, which moves equably through its whole length when pushed at one end. For a long series of ages philosophers acknowledged and taught this error, and M. Roemer, a native of Jutland, discovered the truth when making observations on the satellites of Jupiter. When the earth is between Jupiter and the sun, eclipses of the satellites of that planet happen eight minutes thirteen seconds earlier than they should do according to the calculations of astronomers; and when the sun is between

the earth and Jupiter, they happen eight minutes thirteen seconds later. These results can only be accounted for by admitting the progressive motion of light; and light, requiring about $16\frac{1}{2}$ minutes to cross the orbit of the earth, consequently travels at the rate of 192,500 miles a second. Roemer's observations have been since confirmed by the results obtained by Bradley, in his calculation of the aberration of the fixed stars, more especially of χ Draconis, which fixes the velocity of light at 191,515 miles in a second.

2. *Light moves in straight lines.* If we take a series of metallic plates or cards, each plate having a small aperture, we shall not be able to see through the holes unless they are placed in a right line, nor can we see through a bent tube; in this respect light differs from sound. The form of the shadows of bodies also proves that light moves in straight lines; for when they are received on plane surfaces they have a figure similar to the section of the body which casts them.

3. *Light proceeds in all directions and from every part of the luminous body.* Thus, if a ray of direct light pass from a luminous body through an aperture upon a screen in a darkened apartment, a representation of that body will be formed upon the screen, so that rays of light are thrown in every direction and from every part of the luminous substance.

It has been stated that light moves in straight lines; but there are certain circumstances under which it may be affected by forces dependant on the constitution of bodies, and compelled to deviate from the paths it would otherwise take. Light may, in fact, be either reflected or refracted; it may be arrested in its progress, and thrown back into a direction opposed to that in which it was moving; or it may be bent from its right line, and compelled to move in some other right line or in a curve.

REFLECTION.

The fact that light is capable of reflection was known from a very early period. In the writings of Moses, mirrors or looking-glasses are mentioned as being constructed of brass, and used by the Israelitish women. The Greeks are well known to have been acquainted with the reflection of light by polished surfaces. Callimachus, the Cyrenean, says in his Hymn to Pallas, "She never looked into water or a mirror of orichalcum," the word orichalcum being usually translated a dark-coloured brass. In those ancient poems ascribed to Homer, frequent allusion is indirectly made to the effects produced by the reflection of light. To take but one example, we may refer to the poet's beautiful description of the lance and breastplate of his hero Achilles, in the twenty-second book—

> "The Pelian javelin in his better hand
> Shot trembling rays, which glittered o'er the land;
> And on his breast the beamy splendour shone,
> Like Jove's own lightning or the rising sun."

In one of the fables of Æsop an optical effect is described, which of itself might lead us to imagine that the Greeks were better acquainted with the science of optics than might be imagined, had we not evidence of their knowledge. There is a result well known to opticians, that images reflected from a plane surface appear as far behind that surface as the body itself is before it. Æsop must have been acquainted with this fact when he wrote the beautiful fable of the dog and his shadow.

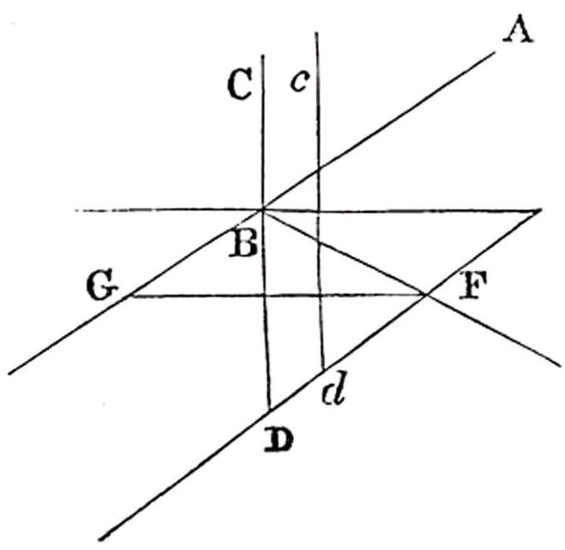
Aristotle supposed twilight to be occasioned by the reflection of solar light by the atmosphere, and maintained that a similar reflection prevents shadows from appearing totally black. This celebrated philosopher also stated that rainbows and haloes were produced by the same influential cause.

Euclid of Alexandria, who lived one hundred and eighty years before Christ, wrote a work on catoptrics, or the reflection of light, which is supposed to be lost, as the volume that bears his name is not characterized by that elegance and accuracy which distinguish the works of the author of "The Elements of Geometry."

In mentioning the names of some of the most celebrated ancient philosophers who were acquainted with the reflection of light, we cannot omit that of Archimedes, for his burning mirrors will never be forgotten as long as science is esteemed by men. Some writers in modern times have treated the story as a fable; but the united testimony of Lucian, Eustathius, Zonares, and others, is sufficient evidence to remove the most scrupulous doubts. An ancient historian says, "When the fleet of Marcellus was within bowshot, the old man, Archimedes, brought an hexagonal mirror, which he had previously prepared; and at a proper distance from this he placed other small mirrors of the same kind, made to move in all directions on hinges, the which, when placed in the sun's rays, he directed on the Roman fleet and reduced it to ashes." Eustathius, the Archbishop of Thessalonica, in his commentary on Homer's Iliad, says, "Archimedes by means of a reflecting mirror burnt a Roman fleet at the distance of a bowshot." If any other evidence were necessary to prove that Archimedes did that which is attributed to him, the testimony of Zonares, the historian, might be adduced, who informs us that Proclus, in imitation of what Archimedes had done at Syracuse, burnt the fleet of Vittelion at the siege of Constantinople; and that the instrument employed was a reflecting mirror, composed of twenty-four small plane reflectors, which, directing the rays of the sun to one point, excited an intense heat.

But if we had no written evidence of the attention paid by the ancient philosophers to the phenomenon of reflection, it would be impossible to suppose the early inhabitants of the earth to have been unacquainted with the fact. If they had been unattracted by every other natural appearance, they could not have failed to observe the rising and setting sun reflected from the peaceful bosom of lakes, rivers, and oceans.

The effects produced upon light by reflections from the surface of bodies, depend upon the form of the surface from



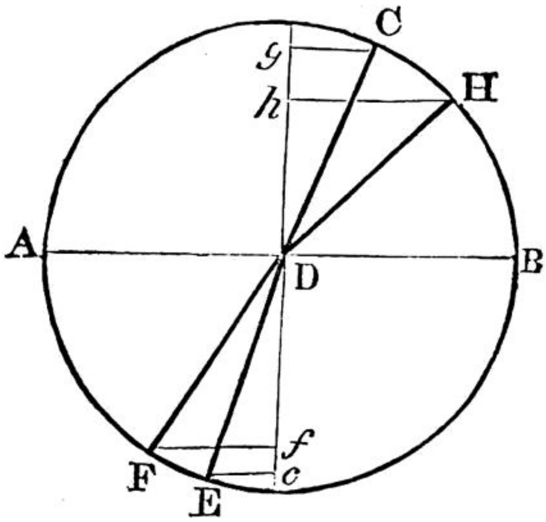
which they are reflected. There is, however, one general law by which the result is always governed; for although parallel rays falling upon a concave surface are converged, and upon a convex surface diverged, yet in every case the angle of reflection is equal to the angle of incidence. To prove this statement we must refer to a mathematical diagram. Let A B G be the direction in which a ray of light is moving, and C D a plane mirror by which it is stopped and reflected, it will pass off in the direction B F, and the angle A B E, which is the angle of incidence, will be equal to the angle E B F, which is the angle of reflection. But if a ray should fall upon the mirror in a direction perpendicular to the reflecting surface, it will be thrown back in the same line as that in which it came, though in an opposite direction.

REFRACTION.

The phenomenon of refraction, or the influence of fluids in bending the rays of light from their usual direction, must have been observed as early as those appearances which result from reflection. The bent or broken appearance of a stick, or the stem of a plant, when plunged into water, must have been frequently noticed, and it is possible that the whole science of dioptrics may have arisen from this observation.

When light passes through a fluid medium it is bent, or refracted, from its rectilinear path, the amount of refraction being always governed by the nature of the substance. There are some fluids that refract more than others, but still there is a general law which holds good in all cases in relation to the same medium. Alcohol refracts light more than water, oil more than alcohol, and glass more than oil. But, on whatever medium a ray of light may fall, there is a constant relation between the sine of the angle of incidence and the sine of the angle of refraction. This law may be otherwise expressed in the following manner; when any two rays of light fall upon the same medium at different angles of incidence, the sines of the angles of refraction will have a constant proportion to the sines of their respective angles of incidence.

Let A B be the surface of a medium having a greater density than that by which it is superposed; and let C D, H D, be two incident rays, and D F, D E, their respective refracted rays; *g* C and *h* H are the sines of the angles of incidence, and *e* E, *f* F, are the sines of the angles of refraction. Now, it may be proved by experiment, that there is a constant relation between the sines of the angles of refraction and the sines of the angles of incidence. The proportion in water is as 1.336 to 1, and whether the ray has the direction C D, H D, or any other, it will remain constant; *g* C will have that relation to *e* E, and *h* H to *f* F.



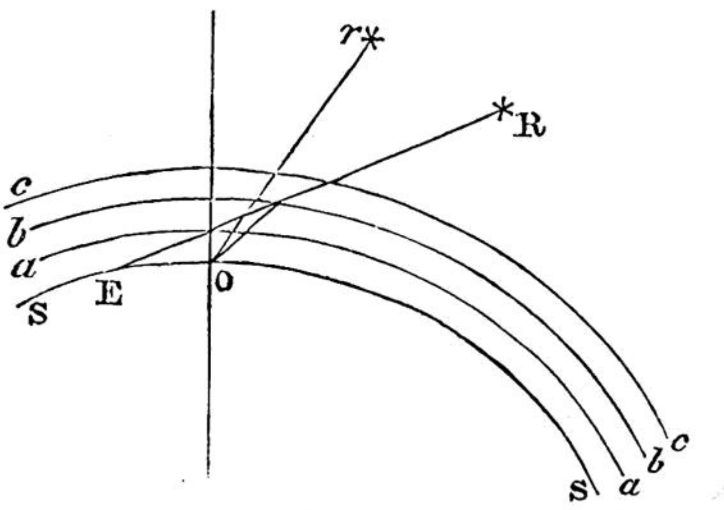
All the effects produced upon light by its passage through gases, liquids, and lenses, are to be traced to the existence of this law. In some cases parallel rays are converged, and in others diverged, but the student may always determine what effect will be produced by a consideration of the fundamental law, at the same time bearing in remembrance that when light passes out of a rare into a dense medium, as from air to water, the angle of incidence is greater than the angle of refraction; but when out of a dense into a rare medium, as from water to air, the angle of incidence is less than the angle of refraction.

There are many phenomena in external nature which result from the reflection of light, for nearly all substances possess the power of reflecting, in some degree, the light which falls upon them. Some rocks seem to be, if we may use the expression, almost impermeable to light, and reflect a great portion of that which falls upon them. The intensity of the reflected light from chalk, and from some limestones and sandstones, is, in an unclouded summer's day, too intense for the eye to bear with quiet; and there are other rocks whose colour assures us that they stifle all the light incident on their surfaces; yet it is quite certain that the intensity of light in districts, at least, is in some measure produced by terrestrial eflection.

The atmosphere and clouds, also, have some influence in producing the present illuminated condition of the earth's surface. If there were no atmosphere, the solar light could only illuminate that spot on which it actually fell, and all beyond it would be enveloped in impenetrable gloom, for the straying rays reflected by terrestrial substances could only throw an uncertain light around the edge of the spot on which they fell; but by the diversion of the solar rays, in consequence of repeated atmospheric reflection, the light is scattered abroad, the gloom which would have been otherwise produced is dissipated, and we behold Nature in all her most splendid teints.

But as heat is blended with light, so this repeated reflection must tend to raise the temperature of the atmosphere, which in some cases acts as a conductor, and heat is carried from clime to clime on the wings of the wind. The temperature of a mass of air resting upon a spot of the earth's surface is then in some degree regulated by the amount of reflected light which it receives, for calorific rays are blended with the luminous, and are equally capable of reflection.

Many of the phenomena observed around and above us are results of refraction. The earth is surrounded by an ocean of gas, in which it is, as it were, floating; and this body of elastic fluid has a great effect upon light, bending the rays out of their course, and causing all celestial phenomena and bodies to appear in a false situation. This effect would be produced if the atmosphere had uniform density throughout,



but its density increases with its nearness to the surface of the earth, and consequently a ray of light is more and more refracted from the moment it enters the atmosphere until it reaches the earth.

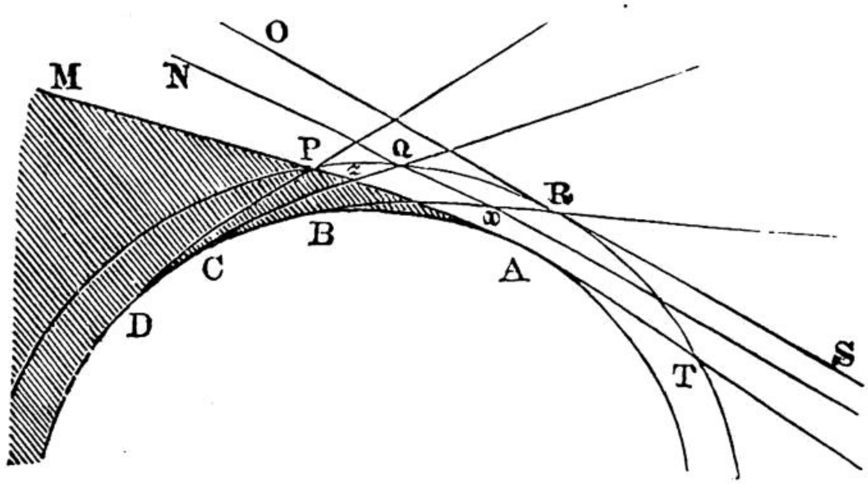
Let S S represent the surface of the earth, and *a b c* successive layers of the atmosphere, the lowest being the most dense, and let R E be the direction in which a ray of light from a star would pass to the earth, if there were no atmosphere; but in consequence of its having to move through the air, it is bent out of its course in a curvilinear path, and, instead of reaching the eye of an observer situated at E, it strikes upon the point O. But an observer situated at O would not see the star in its real position; for it is a law in optics, that an object is seen in the direction of the ray at the moment it enters the eye, and therefore the object will appear to be situated at a greater height than it really is, as at *r*, and this is the constant effect of atmospheric refraction. The same cause will also explain the statement frequently made, that a celestial body may be seen for some time after it has descended beneath the horizon; for the rays of light proceeding from it entering the atmosphere, are refracted, and meet the eye of the observer in such a direction as brings into sight bodies which are considerably below his horizon. The amount of refraction increases from the zenith to the horizon, being at the latter equal to about 33′, a quantity very appreciable.

The direct beneficial effect of this atmospheric refraction is to lengthen the duration of celestial light, by prolonging the activity of the sun and moon. But the deceptive positions it gives to celestial phenomena have a tendency to derange the calculations of astronomers. Tables have been formed by which the error may be in part corrected, but it may be doubted whether the tables are in all cases adequate for this purpose. It may appear a simple problem to determine the variable amount of refraction from the zenith to the horizon, but there are many difficulties connected with the investigation. The amount of refraction depends upon the density, and the density is variable; for, though it decreases with its height above the earth's surface, yet the amount of its decrease is not accurately known, being subject to those changes which are produced by a local or general alteration of temperature. But this is not the only cause which affects the amount of refraction, for the atmosphere is unequally loaded with vapour at different times, and the presence and quantity of the vapour sensibly affect the refracting power of the atmosphere.

TWILIGHT.

Twilight is a pnenomenon produced by reflection. When the sun has descended so low beneath the horizon as to give no opportunity for the influence of direct rays by refraction, the solar beams, passing over the earth's surface, strike upon the atmosphere, or the clouds which float in it, and are reflected downward, producing that secondary illumination called twilight; the effect of which is to shorten the duration of darkness, by prolonging the apparent continuance of the sun above the horizon. Such, at least, is the explanation which may be given upon the admission of the materiality of the agent. Upon this subject we must be silent, for it is useless to contradict that which cannot be disproved; but it may be remarked, that if light be an inconceivably minute ethereal fluid, such as the advocates of the theory maintain, there is nothing remarkable in the circumstance that the air itself should be able to oppose its progress, reflect it, and illuminate the earth's surface with its indirect rays.

Sir John Herschell's demonstration of this phenomenon is so beautiful and explicit, that we may be permitted to quote it:—"Let A B C D be the earth: A is a point on its surface where the sun S is in the act of setting; its last lower ray, S A M, just grazing the surface at A, while its superior



rays, S N, S O, traverse the atmosphere above A without striking the earth, leaving it finally at the points P Q R, after being more or less bent in passing through it, the lower most, the higher less, and that which, like S R O, merely grazes the exterior limit of the atmosphere, not at all. Let us consider A B C D, each more remote than the last from

A, and each more deeply involved in the earth's shadow, which occupies the whole space from A, beneath the line A M. Now A just receives the sun's last direct ray, and, besides, is illuminated by the whole reflective atmosphere, P Q R T. It therefore receives twilight from the whole sky. The point B, to which the sun has set, receives no direct solar light, nor any, direct or reflected, from all that part of its visible atmosphere which is below A P M; but from the lenticular portion, P R X, which is traversed by the sun's rays, and which lies above the visible horizon B R of B, it receives a twilight, which is strongest at R, the point immediately below which the sun is, and fades away gradually towards P, as the luminous part of the atmosphere thins off. At C, only the last or thinnest portion, P Q *z*, of the lenticular sequent, thus illuminated, lies above the horizon, C Q, of that place: here, then, the twilight is feeble, and confined to a small space in and near the horizon which the sun has quitted, while at D the twilight has ceased altogether."

MIRAGE.

In consequence of the variable temperature of the atmosphere, it has different refractive powers, and this is the usual cause of that phenomenon called mirage. Light passing through a vacuum, or a medium of equal density, moves in right lines; but when it enters a medium of different densities, in curves. If a ray of light passes from an attenuated to a very dense medium, a portion of light will be reflected, and a part refracted. These several causes acting upon light, bending and distorting its rays, produce a variety of singular optical deceptions, sometimes throwing the images of bodies upon dense clouds, and at other times investing terrestrial phenomena with unnatural and almost magical appearances.

In all climates exposed to an extreme temperature, whether of heat or of cold, the results of unequal refraction are observed. In the deserts of Africa the traveller is often surrounded with appearances which cheer his drooping spirits, with the expectation of soon reaching a place where he may rest himself under the shade of a verdant foliage, and bathe himself in cool streams or widely-expanded lakes; but he gazes on an airy vision, which is less substantial than the morning cloud. And so the chilled traveller in arctic climes beholds before him mighty cities, with their battlements and towers, which, alas! can give him no shelter, for they are but the distorted forms of the iceberg, and the snow-capped pinnacles of barren rocks.

M. Monge, who accompanied the French army into Egypt, states that in the desert, between Cairo and Alexandria, the image of the sky was so mingled with that of the sand as to give the appearance of a rich and fertile country. The travellers seemed to be surrounded with green islands and extensive lakes, together forming a beautiful landscape in the midst of a sandy plain. But in vain did the exhausted party press forward to reach this happy spot, for neither the islands nor the lakes were there, nothing but a continuation of the same heated desert over which they had passed so wearily.

Dr. Clarke observed a very similar appearance near Rosetta. The city seemed to be surrounded with a beautiful sheet of water, and the Greek interpreter, who accompanied the traveller, could not be persuaded that the appearance was a delusion; but they reached Rosetta without finding water, and when they looked back upon the country over which they had passed, it appeared as a vast blue lake.

In more temperate climes this phenomenon is sometimes observed. Dr. Vince has given a description of an appearance of this kind, which he saw in 1798 at Ramsgate. The topmast of a ship approaching the shore was just seen above the water in the horizon, and, immediately above it in the sky, two images of the whole vessel, one erect, and one inverted. But, as the ship came into view, the images became less distinct, though they were both visible after the ship had risen above the horizon.

From the description already given of refraction, it is easy to determine how a single upright image of a vessel below the horizon might be formed, but it may not be so evident how the inverted image is produced. The sun is seen after it has descended beneath the horizon by ordinary refraction, or, rather, in consequence of the refraction of the atmosphere resulting from the common variation of density. But when a mass of air has its density increased or diminished by local causes, then an uncommon refraction is the result, and the line in which the light moves being more convexed than usual, the object is proportionally thrown upward, and an erect image may be seen at a great apparent distance above the horizon. The inverted image is produced by the crossing of the rays before they reach the eye; that is to say, the light from the hull of the vessel is so curved, that it crosses that which proceeds from the masts before reaching the eye, and consequently the image is inverted. To produce this appearance, a peculiar constitution of atmosphere is required, but it is not necessary that we should enter upon this question at present.

Many instances of the appearance of ships in the air are upon record, but the images are generally described as being in an upright position. Three persons have described this phenomenon, as seen in different places during the year 1662.

Dr. Vince also states, that at Ramsgate he has seen the four turrets of Dover Castle over a hill between Dover and Ramsgate. But the most remarkable case mentioned by this eminent philosopher, was that which he observed on the evening of the 6th of August, 1806, when the image of the castle was so vividly projected on the Ramsgate side of the hill, that the hill itself could not be observed through the image.

The Brocken, a peak of the Hartz Mountains, which rises to the height of about three thousand three hundred feet above the level of the sea, has been, for centuries past, the site of spectral appearances. M. Haue has, unfortunately for the lovers of the marvellous, enabled the natural philosopher to explain the cause, and has thus divested the site of all that interest which arises from a belief in supernatural visitations. This philosopher had been long anxious to view the phenomenon, and had ascended the mountain many times for the purpose, but without success. On the 23d of May, 1797, he was early on the summit of the mountain, waiting the sunrise; and, about four o'clock in the morning, the luminary made its appearance above the horizon. The sky was clear, and the rays of the morning sun were tinging the summit of the hills with its golden hue, when he saw on a cloud, in a direction opposite to that on which the sun rose, towards the Achtermanshoe, a gigantic human figure, with his face towards him. While gazing on the prodigious spectre with a feeling not free from terror, a sudden gust of wind threatened to blow away his hat; but lifting his hand to detain it, he saw the spectre mimic his action, and was at once freed from the terror which had already crept upon him. He then changed his attitude and place, and found that the figure always followed his motions. M. Haue was then joined by a person who had accompanied him to the top of the mountain, when a second colossal spectre made its appearance, and soon afterward a third. The figures first seen were evidently produced by the projection of the shadow of the two persons upon the clouds by the horizontal rays of the sun. The appearance of the third figure was, no doubt, caused by the duplication of one of the figures by the unequal refraction of the atmosphere.

The fata morgana is another illustration of the same illusive appearance. This curious phenomenon is seen at the pharos of Messina, in Sicily, and has, for centuries past, been celebrated in the annals of superstition. A spectator, standing on an elevated place in the city of Reggio, commanding a view of the bay, with his back to the rising sun, may often observe, when the rays form an angle of about 45° with the horizon, the objects on the shores vividly painted on the surface of the water. Palaces, castles, towers, and arches, are distinctly reflected from the surface of the water as from a mirror; and men, horses, and cattle are seen rapidly passing from place to place, presenting together a beautiful picture, which the spectator gazes upon with a feeling of superstitious admiration.

Similar appearances have been frequently seen upon the lakes of Ireland, with all of which some legends are connected. The story of O'Donoughoo, who haunts the beautiful Lake of Killarney, is well known to those who are lovers of the marvellous. O'Donoughoo was a celebrated chieftain, who possessed the art of magic. Being strongly solicited by his lady to give her some proof of his skill, he assumed the shape of a demon, and, her courage failing, he suffered for his temerity, and disappeared. Ever since he has been accustomed to ride over the lake on a horse shod with silver, his punishment being to continue the monotonous exercise until the shoes are worn out. On the morning of the 1st of May, thousands assemble around the lake to see him, and there can be no doubt that the figure, said to have been observed by credible travellers, is the shadow of a man on horseback riding upon the shore.

Mr. Scoresby has mentioned in his "Account of the Arctic Regions" several curious instances of unusual refraction, observed by him during his polar voyages. While sailing along the coast of Spitzbergen, with an easterly wind, he observed a singular transformation of the Foreland, or Charles's Island. There seemed to be a mountain in the form of a slender monument, and near it a prodigious and perfect arch, thrown over a valley, at least a league in breadth. This scene, however, did not last long, but was presently followed by the appearance of castles, spires, towers, and battlements, which changed their forms so rapidly, that the metamorphoses seemed as though they were the work of an occult agent. "Every object," says Mr. Scoresby, "between the northeast and southeast points of the compass, was more or less deformed by this peculiar refraction."

At other times, Mr. Scoresby observed similar results produced, and, from the whole of his observations, he deduces:

1. That the effects of unusual refraction occur in the evening or night after a clear day.

2. That they are most frequent on the commencement or approach of easterly winds.

3. That the mixture, near the surface of the land or sea, of two streams of air, having different temperatures, and the irregular deposition of imperfectly condensed vapour, are the causes of these phenomena.

Man is given to superstition; and the unassisted senses being frequently incapable of giving accurate information as to the authenticity of the natural appearances by which he is surrounded, sometimes aid the innate propensity, and lead to erroneous conclusions. Yet all the sensations by which we become acquainted with material existence, are produced by external nature acting upon the organs of sense; and we are consequently exposed to deception, either from the accidental construction of the organs, or the false impression conducted to them by the objects which act on them. Thus it is that the sensations produced by natural phenomena, uncorrected by a philosophical examination of causes, may encourage the superstitious feelings of our nature; and in this way we may account for many of those opinions which are to be found among the illiterate in all nations.

We are not, however, on this account, to discard the testimony of our senses, but to receive it with care, if not with suspicion. The conditions under which the senses are acted upon should be considered, and the capabilities of the organs should not be overrated. The senses are not the causes of the deception in the appearances which have been described but they are the agents by which the deception is conveyed to the mind. To correct the errors which are not compensated for by the senses, is one of the objects of natural philosophy. We are deceived by the phenomenon of refraction, because the eye is unable to detect the manner in which the appearance is transmitted to the organ of sight. By experiment, it is discovered that in passing through a fluid medium the rays of light are refracted, and hence we infer that the same effects must be produced when they pass through the atmosphere. The eye might have been for ever fixed on the heavenly bodies, without discovering that their apparent is not their real place; and we might still imagine the heavens to have a diurnal revolution round the earth, if experiment and extended observation, guided by reason, had not discovered the circumstances under which our senses are acted upon. But it must not be supposed that the organs of sense are insufficient for the purposes for which they were formed. Such a sentiment would be derogatory to the skill displayed in their construction, and their adaptation to the nobler principles of our nature. The organs of sense are sufficient to enable man to supply his wants, and to gather pleasure from external nature; and, if we may be deceived by appearances, the improvable reason may detect the error, and explain the cause.

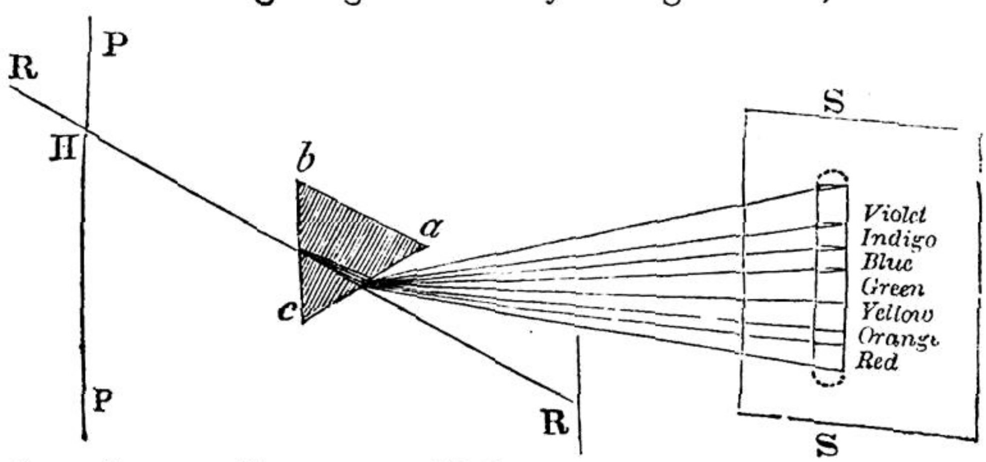
COMPOSITION OF LIGHT.

It might be supposed, by a person unacquainted with the facts which have been ascertained by experiment, even by an intelligent observer, that solar light is a white homogeneous substance. But it has been proved, both by analysis and recomposition, that it is composed of seven elements, if we may so express ourselves, characterized by different properties and colours. The colours of the elementary parts of solar light are red, orange, yellow, green, blue, indigo, and violet. Now there are two ways in which this statement may be proved; that is to say, by refraction and by absorption; and of these we may speak separately.

DECOMPOSITION OF LIGHT BY REFRACTION.

Sir Isaac Newton discovered the composition of white light, and he employed the process of refraction. If a ray of solar light be admitted into a dark room, through a small hole in the window-shutter, or otherwise, it will pursue a rectilinear course, and a small round white spot will be formed at the opposite side of the room. But if a glass prism be placed between the shutter or screen and that side of the room on which the white spot is formed, in such a manner that the ray of light must pass through it, entering at one surface and emerging at the same angle from the second surface, then, judging from the laws of refraction, we might suppose that it would be bent out of its course, and that the little white spot would be shifted to another place; in fact, that an effect would be produced upon the light similar to that which is occasioned by its passage through air, water, and other transparent substances. But this is not the effect produced; for instead of a small white spot, an oblong image, called the solar spectrum, is formed, consisting of seven colours, in the following order: red, orange, yellow, green, blue indigo, and violet. These colours may be produced with great brilliancy, but they are not equally bright; and it is extremely difficult to determine the limits of the several colours, the gradations are so imperceptible from the shading off of one colour into another.

This will perhaps be better understood by an explanation of the following diagram: a ray of light R R, admitted



through a small aperture H, into a dark room, may be supposed to fall upon a screen, where it will form a white spot of nearly the same size as the aperture through which it is admitted. But let a glass prism, *a b c*, be interposed between the aperture and the screen, and in such a position that the ray may fall on the surface *b c*, and emerge from the surface *a c* at equal angles, and the ray will be not only deflected, but decomposed, and a coloured image of the sun will be formed on the screen S S.

Having ascertained that white light is capable of decomposition, a new subject of inquiry is immediately suggested to the mind: is it not possible that the component rays themselves may be compound, and that the same process which decomposed the white light may also decompose them? Sir Isaac Newton made the experiment; but after examining each coloured ray, making them in their order to pass through a small hole in the screen, and to fall upon a second prism placed behind it, he discovered that the colours could not be again decomposed, but obeyed the common law of refraction, that which governs white light under ordinary circumstances. From these results it may be deduced, that the coloured rays resulting from the decomposition of white light are homogeneous, and they are therefore called the primary colours; while those which are formed by the combination of two or more primary rays are denominated secondary.

Only one thing is now necessary to fully prove the compound nature of white light, and that is to recompose the seven colours, and to produce from them the original colour. To accomplish this object, take a second prism, made of the same kind of glass, and having the same refracting angle, and place the two together so that they may form a parallelogramic figure, and all the seven rays that are produced by analysis with the first prism, are reunited and combined by the second, a single white spot being formed. In this experiment the separate results may be distinctly seen; the decomposition by the one, and the composition by the other.

That the seven primitive colours produce white light may be proved by painting a circular board in such a manner as to represent the intensity and proportion of the seven colours. When this board is put into rapid revolution, the primitive colours are resolved into an almost pure white.

DECOMPOSITION OF LIGHT BY ABSORPTION.

Having proved the compound nature of light, both by analyis and synthesis, it will be only necessary to state that light may be decomposed by absorption. When light falls upon a transparent body, one portion is transmitted through it, another is dispersed by irregular reflection, while a third is stopped, or absorbed, by the substance itself. There are some substances that seem to give an equally ready passage to all the component rays of white light, while others absorb some particular ray in preference to others, as though they had some powerful affinity for it. There are, however, no perfectly transparent bodies, as, on the other hand, there are none that do not possess the property in some degree; both water and air, though they do not retard one ray more than another, absorb a portion of the light that enters them; and the densest metals may be beaten so thin as to give a passage to some portion of an incident ray.

Many philosophers have entertained the opinion that only a part of the seven colours composing the prismatic spectrum are primitive. Dr. Wollaston maintained that there are only four primary colours, red, green, blue, and violet; and Dr. Young enumerates three, red, yellow, and blue; in which analysis Sir David Brewster coincides. The last mentioned philosopher has examined the spectra produced by various bodies, and the changes they undergo when viewed through differently coloured media, and discovered that the colour of every part of the spectrum may be changed by the action of varying media. From his experiments generally, he deduces that the spectrum consists of three equal parts, which are severally red, yellow, and blue.

COLOUR OF BODIES.

Colour is not an inherent property of bodies, for any substance may be made to impress the eye variably, according as it is placed in one or the other of the prismatic rays. A body may be yellow in white light, but placed in the red ray it will be red, and in the violet it will be violet, a new colour resulting from a change of circumstances. It will therefore follow, that the colour of any substance will be regulated by the colour of the ray that it reflects. From what has been said concerning absorption, it will be evident that this theory proposed by Newton will, in many cases, readily account for the infinite variety of shades that are observed in nature and artificial objects, resulting from the intermixture of rays one with another, in all possible proportions. But this theory can be only applied to one class of phenomena, and does not at all aid us in explaining the colours of fluids and transparent solids. In some instances colour is produced by the peculiar property which the bodies have of stifling or absorbing rays of a certain colour, while they suffer the passage of others without exerting any detaining influence upon them. But whether colour be produced during the process of reflection or refraction, the result being in some cases dependant on the one, and in some on the other, we cannot but admire the great variety of appearances that are produced by comparatively simple means. The ever-varying teints of leaves and of flowers, of feathers and of furs, might well be supposed to result from a complication of causes almost beyond the reach of human ingenuity to discover, and yet we may account for all that we see when we know the principles of reflection, refraction, and absorption. Water and air, in small quantities, are white, because they absorb all the rays equally, and yet transmit a large portion of each; coal is black, because it absorbs and stifles all the rays that impinge upon it. If the infinite variety of colour which we observe in nature did not exist, then all the forms, however beautiful, which decorate the earth, would lose their charm, and the eye would ever rest upon a dull monotonous scene, incapable of exciting a single feeling of interest.

COLOUR OF THE CLOUDS.

There is as much beauty of colouring in aerial as in terrestrial scenery. It is scarcely possible to trace the successions of colour in clouds, whether in the light and resplendent hues of the evening cloud, or in the deep and sombre teints of the threatening nimbus. These varied appearances are produced by the absorption, refraction, and reflection of light.

Light, in its passage through the atmosphere, is in part absorbed, and the amount transmitted is in some degree governed by the density of the medium through which it passes; and hence it follows, that when the rays of light impinge upon a thick cloud, they are but feebly transmitted. It must have been observed that the edges of clouds are generally much more luminous than their centres, which may be traced to the thinning of the body of vapour at its edges, so that we may determine the density of a cloud by its colour.

This same cause, absorption, may influence the colour of clouds by the abstraction of a portion or the entire of one or more constituent rays. Atmospheric vapour may be variously constituted, and its effects on light may be different, according to its character and mode of combination; thus, one cloud may absorb the blue, and another the red rays, or such proportions of each may be successively taken away as shall produce a rapid and evanescent series of resplendent colours. It is scarcely possible to determine what those changes of constitution may be which assist in the production of all that variety of colouring and blending of shades which distinguish clouds; but whatever may be the source of those changes which pass over the vapour itself, its action upon light may be traced to absorption.

The position of clouds in relation to the sun has no small influence in occasioning those rapid changes of form and colour for which they are remarkable. It is scarcely possible to imagine that the clouds, which at sunset may be absolutely drenched in golden hues, have before floated over the hemisphere as colourless and flaccid masses; yet we cannot watch a mass of vapour over the face of the heavenly vault, without observing the infinite variety of colours and shades which it assumes, as fickle, and frequently not less vivid, than the hues of the celestial bow.

The cirro-stratus is often marked with rich and even splendid colouring; its crimsons, purples, and scarlets, are such as art cannot imitate. Mr. Howard describes the appearance of the sky at one time as being covered with cirri passing to cirro-stratus, the whole hemisphere being tinged with varied but most beautiful hues. We shall not readily forget the appearance of the same modification viewed from a mountain summit on a summer evening. The broad mass of cloud was as though died with the deepest crimson, while the cirri pencilled upon the meridian graduated from a light red to a deep blue.

RAINBOW.

Of all the natural appearances dependant on the action and conditions of light, the rainbow is the most beautiful and the most striking. Maurolycus, Baptista Porta, and Antonio de Dominis, made observations upon it, and attempted to explain its cause, but Newton was the first who gave an entire and satisfactory explanation of the phenomenon.

We have avoided as much as possible the very appearance of mathematical demonstration in the explanations we have given of natural phenomena, which may possibly have occasioned a want of precision in many parts of the work. Should we be charged with this fault, we may remind the critic that these pages have been written to implant or nourish a love of science in the minds of those who, from natural predilections or the force of habit, have devoted more time to the cultivation of the imagination than to the acquisition of philosophical knowledge—for those who have been accustomed to think the pursuits of science derogatory to an intellectual and poetical mind. We cannot, however, explain the formation of the rainbow without a reference to a diagram, which may remind the reader of a mathematical demonstration.

The rainbow is always seen in that part of the sky opposite to the sun. There are, however, two bows, of which the interior is the stronger, being formed by one reflection, the exterior by two. Supernumerary bows have been occasionally seen. The primary or inner bow, which is commonly seen alone, consists of arches of colour in the following order, commencing with the innermost: violet, indigo, blue, green, yellow, orange, and red. These, as we have already stated, are the primitive colours, and we may be led to a suspicion of the cause of the rainbow by the fact that they have the same proportion in the bow as in the prismatic spectrum. The rainbow is in fact a number of spectra produced by the reflection of light from the falling drops of rain.

The formation of the rainbow primarily depends upon the

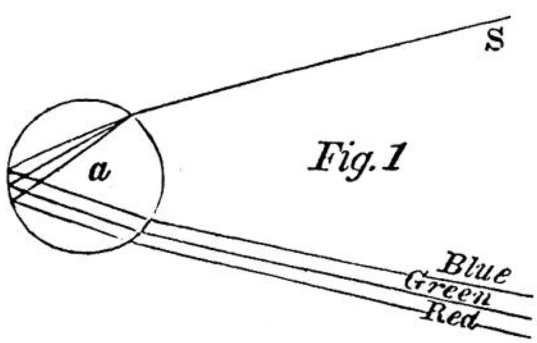
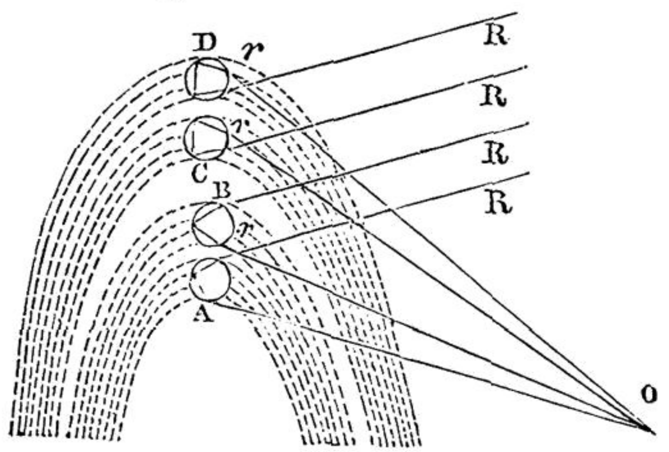


Fig. 1

different degrees of refrangibility belonging to the differently coloured rays of light, and the separation of these rays is occasioned by their suffering two refractions and one reflection. Let *a* be a drop of water, and S a beam of light, which, when it falls upon the drop, is refracted and decomposed into the primitive colours; but on the second surface the several rays suffer reflection, and are a second time refracted, and may reach the eye of an observer in their separate or uncombined state. The same effect is produced when a glass globule is held between the eye and the sun, for a spectrum will be seen reflected from the second surface of the globe. Supposing an infinite number of these globes to be between the sun and the observer, and to have every possible position in relation to the eye, their spectra would be united, and continuous lines of light, or a bow, would be produced.

Let A B C D be drops of rain, and R A, R B, R C, R D, be rays of light falling upon them. The light may fall upon the drop in every possible position, and the effects produced will vary according to the incidence of the rays. If they



should fall upon the axis they will be transmitted without refraction; if near to the axis on either side, they will be refracted to some point called a focus, behind the drop; those which fall near the top or bottom of the drop will be refracted, but, falling very obliquely upon the second surface, will be *reflected*, as *shown in the diagram*, *either once or* twice, according to circumstances, and be carried by refraction to the eye of the observer.

When a ray of light falls upon the top of the drops and is reflected, as in A and B, it may be refracted and meet the eye of the observer at O, or it may suffer a second reflection and be thrown upward. But when the ray falls upon the under side, as in C and D, the ray usually meets the eye after the second reflection; but in consequence of two reflections and two refractions, the violet will form the upper and the red the under part of the spectrum.

The lower bow A B is called the primary bow, and there is no doubt that it is produced by one reflection and two refractions, for by calculating the inclination of the red and violet rays to the incident rays R A, R B, it is found that one is 42° 2′, the other 40° 17′, which gives 1° 4′ as the breadth of the bow, a result which agrees with observation.

It is equally certain that the secondary bow C D is produced by two reflections and three refractions, for by computing the inclination of the red and the violet rays to the incident rays R C, R D, we find it to be 50° 58′ for the red ray, and 54° 10′ for the violet, leaving 3° 10′ as the breadth of the bow. This result agrees with observation, and with the fact that its colours are reversed, the violet forming the upper part of the bow. The secondary bow is frequently seen without the primary, but it is not so vivid, in consequence of the light having suffered two reflections.

Lunar rainbows have been occasionally seen, and are produced by the rays of the moon falling upon drops of rain. Plot, in his history of Oxfordshire, says that he observed one in 1675, but it was without colour; and an appearance of the same character was seen by Mr. Tunstall, in the year 1782. The same gentleman observed another a few months after, which had a singular variety of appearances. It was visible for about five hours, and during this time assumed many peculiarities of form and colour. When it was first seen it was without colour, though the arch was strongly marked; but after a short time it began to assume the appearance of a solar bow, and in about three hours was very brilliant, though less so than the solar. Soon after this the bow failed in the northeastern limit, and the intensity of the colours decreased, until at last they vanished.

Another account of the appearance of a lunar rainbow is given by an anonymous writer, which, however, we must refer to as one of the most interesting and circumstantial accounts with which we are acquainted. "On Sunday evening," he says, "the 17th of August, after two days of rain, attended with thunder and lightning, about nine o'olock, twenty-three hours after full moon, looking through my window, I was struck with the appearance of something in the sky which seemed like a rainbow. Having never seen a rainbow by night, I thought it a very extraordinary phenomenon, and hastened to a place where there were no buildings to obstruct my view of the hemisphere; here I found that the phenomenon was no other than a lunar rainbow; the moon was truly 'walking in brightness,' brilliant as she could be; not a cloud was to be seen near her, and over against her was a rainbow, a vast arch, perfect in all its parts, not interrupted or broken, as rainbows frequently are. Its colour was white, cloudy, or grayish, but a part of its western leg seemed to exhibit teints of a faint sickly green."

Artificial rainbows are sometimes formed by the spray of a waterfall, and by the rising mist from the surface of seas and oceans. Sir David Brewster states, that in 1814, he saw at Berne a fog-bow, which resembled a nebulous arch, in which the colours were invisible.

Several writers have described the appearance of supernumerary rainbows, that is, a succession of coloured arches, usually purple and green, within and in immediate contact with the primary bow. These are accounted for by Dr. Young by the principle of interference.

HALOES.

There is yet one other class of atmospheric phenomena, exhibiting colour, to which we must refer before we leave the subject of this chapter. The sun and moon do not vary either in form or in colour, when the atmosphere is free from vapour and other extraneous substances. But when a body of vapour intervenes between the luminaries and the earth, they suffer an apparent alteration in both these particulars; and many curious phenomena are produced, according to the circumstances under which the cause operates. When the atmosphere is dry and arid, the sun appears to have a deep blood-red colour; when the atmosphere is loaded with vapour, he is shorn of the bright radiations which dazzle the eye of the observer, and presents only a colourless disk. The passage of a light cloud over the face of either of the luminaries is sufficient to change their appearance, and frequently causes the formation of coloured rings, which appear to surround them. But the most singular effect is produced when the atmosphere contains small particles of ice, which, by varied refractions and reflections, have the power so to turn and contort the rays of light as to produce the most complicated phenomena. All these several effects, from whatever cause they may proceed, are known under the general term Halo, but some persons have thought it necessary to make a distinction between those phenomena which result from solar, and those which depend on lunar light; the former are called Parhelia, the latter Paraselenæ.

CORONÆ.

The haloes which are produced round the sun by the intervention of thin fleecy clouds, have been called Coronæ, and are probably occasioned by the passage of light through very small drops of water, suffering the same change as it does in passing through thick plates. Coronæ round the sun are best seen by reflection from the surface of water, for the intensity of the beams prevents the observer from examining them without adopting some such means. Sir Isaac Newton was accustomed to make his observations in this manner. In one instance he observed the sun to be surrounded with three distinct rings; and, by adopting this method, detected their colours, and measured their diameters, which he has given in the following table :—

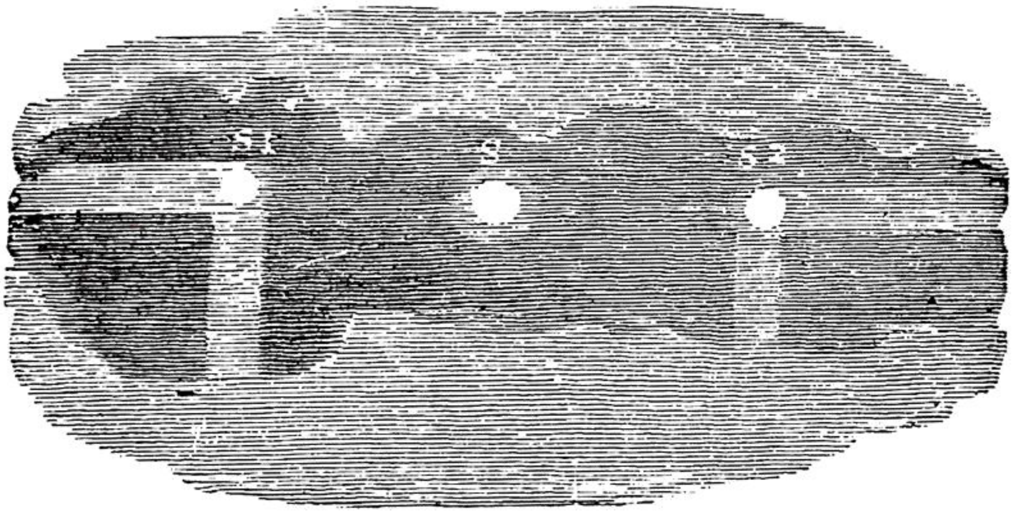
			Deg.
1st ring,	blue, white, red,	Diameter,	5.6
2d ring,	purple, blue, green, pale yellow, red,	Diameter,	9.33
3d ring,	pale blue, pale red,	Diameter,	12

Haloes round the moon are sometimes very beautiful, generally appearing as luminous white circles, but at other times red or reddish green. We have more than once observed the corona to appear and disappear during the walk of a few miles, according as we have been in or above the mists which have been rising from the low grounds. This singular fact might lead us to theorize upon the formation of this curious phenomenon; but it may be doubted whether it is always produced by the same cause. Mariotte supposes coronæ to be formed by the refraction of light by small prismatic crystals of ice descending through the air in every possible direction. It is possible that this explanation may account for some of these appearances; but until the diameters of the coronæ can be determined, there will be no test for its accuracy.

PARHELIA.

Parhelia are images of the sun appearing to be at the same elevation as the sun itself, united by a horizontal circle of light having its pole in the zenith.

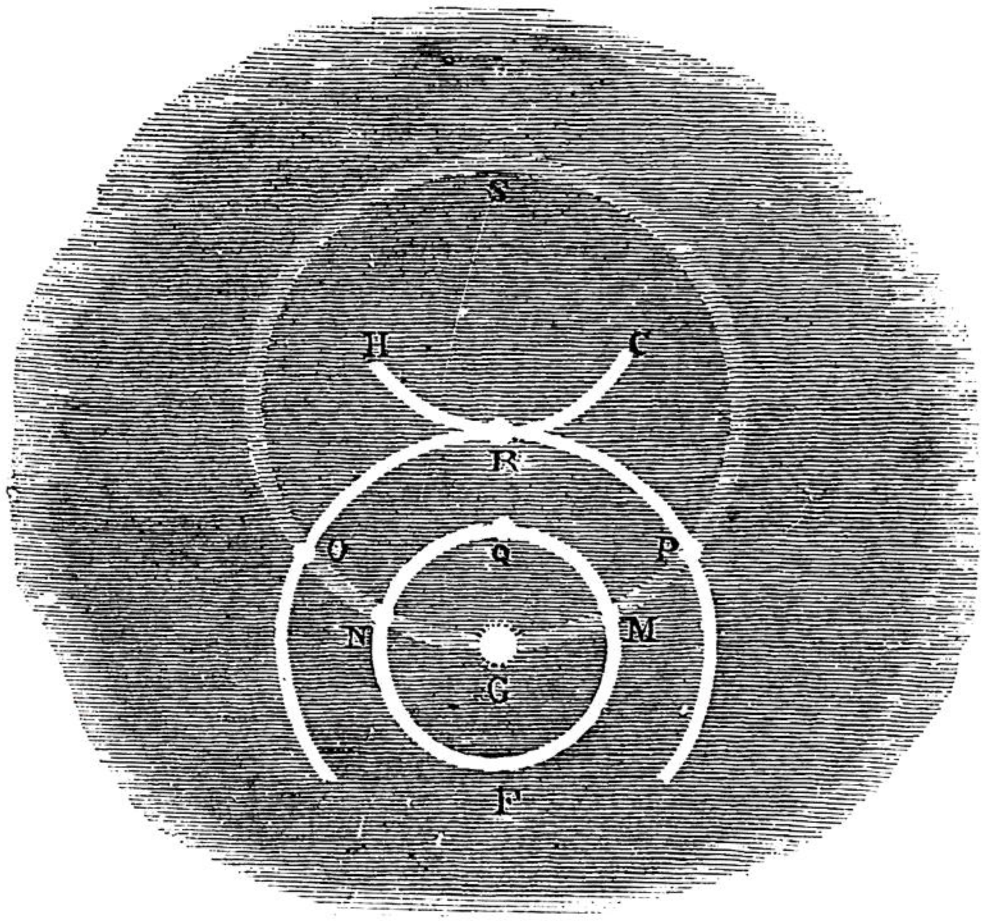
Captain Parry states that when he was in the polar regions he observed two parhelia, one of which was very bright and prismatic, being thrown upon a thick cloud; the other scarcely perceptible, having a blue sky at its back-ground. To each of these mock suns, bright yellow bands of light were attached, as shown in the diagram.



Parhelia are most frequent, and their light most intense, when the sun is near the horizon; as it rises towards the meridian, the image invariably dies away, but will sometimes makes its appearance again as it descends. Instances of this kind prove that the cause is continuous, and, indeed, it has been usually found, that when these mock suns make their appearance, they are not very rapidly destroyed, but often continue in sight for several hours. From all the accounts we have of the natural phenomena observed in the polar regions, it may be gathered that parhelia are not there very uncommon, but by what means these images of the great luminary are projected upon the vapour, which perhaps the sun itself has raised, as though to mock its shadowed glory, philosophers are by no means agreed; but it is almost certain that the haloes on which they are formed are produced by refraction, whether through liquids or icy particles.

A remarkable instance of the exhibition of parhelia was observed by Scheiner in 1630, which, although it has been quoted by Dr. David Brewster and other writers on optics, it will be necessary to transcribe.

"The diameter of the circle M Q N, next to the sun, was about 45°, and that of the circle O R P, was about 95° 20′; they were coloured like the primary rainbow, but the red was next the sun, and the other colours in the usual order. The breadths of all the arches were equal to one another, and about a third part less than the diameter of the sun, though I cannot but say that the whitish circle O G P, parallel to the horizon, was rather broader than the rest. The two parhelia, M N, were lively enough, but the other two at O and P were not so brisk. M and N had a purple redness next the sun, and were white in the opposite parts; O and P were all over white. They all differed in their du-



rations, for P, which shone but seldom and faintly, vanished first of all, being covered by a collection of pretty thick clouds. The parhelion O continued constant for a great while, though it was but faint. The two lateral parhelia, M and N, were seen constantly for three hours together; M was in a languishing state, and died first, after several struggles, but N continued an hour after it at least. Though I did not see the last end of it, yet I am sure it was the only one that accompanied the true sun for a long time, having escaped those clouds and vapours which extinguished the rest. However, it vanished at last, upon the fall of some showers. This phenomenon was observed to last four hours and a half at least; and since it appeared in perfection, when I first saw it, I am persuaded its whole duration might be above five hours.

"The parhelia Q R were situated in a vertical plane, passing through the eye at F, and the sun at G, in which vertical plane the arches H R C and O P R either crossed or touched one another. These parhelia were sometimes brighter, sometimes fainter than the rest, but were not so perfect in their shape and white colour. They varied their magnitude and colour according to the different temperature of the sun's light at G, and the matter which receives it at Q and R; and therefore their light and colour were almost always fluctuating, and continued, as it were, in a perpetual conflict I took particular notice that they appeared almost the first and last of the parhelia, excepting that of N.

"The arches which composed the small halo M N next to the sun, seemed, to the eye, to compose a single circumference, but it was confused, and had unequal breadths; nor did it constantly continue like itself, but was perpetually fluctuating. But, in reality, it consisted of the arches expressed in the figure, as I accurately observed for this very purpose. These arches cut each other in a point at Q, and there they formed a parhelion; the parhelia M and N shining from the common intersections of the inner halo, and the whitish circle O N M P."

Phenomena of the same kind are sometimes seen during the night as the effects of lunar light, and these are called paraselenæ. The most beautiful appearance of this kind which has been described, was that seen by Hevelius at Dantzic, in 1660. When first observed, the moon was surrounded by a white circle, in which there were two coloured paraselenæ opposite to each other. Another circle of light was afterward formed, the lower line of the circumference touching the horizon, and inverted coloured arches appeared on the summit of the circles.

Captain Parry several times observed this phenomenon during his polar voyages. At one time he observed the moon to be surrounded with a halo on which three luminous paraselenæ were formed, and on the following night the same appearance was observed, with the addition of stripes of white light, which gave it a resemblance to a cross.

The natural phenomena which result from the action of light are extremely complicated, and their explanation is involved in difficulties. Our ignorance of the agent itself, and the various circumstances under which it is influenced by repellant and attractive forces, prevent us from tracing the cause of many phenomena which are produced by experiment. There is no branch of philosophical knowledge so little studied by those who have not formally devoted themselves to the investigation of the sciences, as the cause and effects of that principle we call light. Surrounded with uncertainties, we fear lest the explanation given in this chapter should be unsatisfactory to the general reader; but we are chiefly anxious that this circumstance may induce a farther investigation of the subject, and not repress an anxiety for a more accurate acquaintance with this interesting, though subtle branch of natural philosophy.

CHAPTER VI.

PHENOMENA DEPENDANT ON THE DISTRIBUTION OF ELECTRICITY.

Our entire ignorance of that agent which we call electricity, may be urged as some excuse for the vague and unsatis factory manner in which we are compelled to speak of all the natural phenomena that depend upon it as an agent. But, although we are unacquainted with the cause of phenomena universally attributed to electricity, we have ascertained with great precision its habitudes and relations. There are some philosophers who attribute electric appearances to an exceed ingly subtile fluid, while others imagine that there are two such fluids;—some believe electricity to be a property of matter, and others identify it with gravity. But, whatever opinion may be entertained concerning the agent, there is no doubt as to the means by which it may be excited, the conditions it obeys, and the effects it produces.

Supposing electricity to be present in a latent state in all matter, it may be disturbed by five means; friction, chymical action, the contact and disunion of magnetic poles, the unequal circulation of heat through metals, and the muscular action of certain fishes. The electricities derived from these several sources have received different names, but are distinguished from each other by comparative rather than by absolute qualities, all producing the same effects, though not in an equal degree. A few general remarks seem to be necessary for an accurate explanation of the phenomena, to which we must refer.

When electricity is excited upon the surface of a substance, as always happens when two substances, whatever their nature, are rubbed together, it may be transferred, under particular circumstances, from place to place, and even accumulated. But all bodies are not capable of conducting electricity; for, while some absolutely resist its progress, there are others that give it an easy passage. Glass, the resins, and atmospheric air, are not conducting substances; while the metals, water, and aqueous vapour transfer it with great facility. It might, therefore, be expected, that while the one class conducts electricity of the smallest possible intensity, the other can only transmit it when its resisting force is overpowered by the energy of the electric agent.

According to some persons, there are two kinds of electricity, while others acknowledge the existence of but one, though they admit that its conditions may vary. Without attempting to prove or disprove either of these statements, may be mentioned that there is an evident difference of character, according to the manner and circumstances under which the agent is produced. A substance charged with electricity produced by the excitation of glass, will attract one that is charged with the electricity of resin; but if the two bodies be excited with the electricity of either glass or resin, they will repel each other. Now, if we consider that in one case the agent is in a positive, and in the other in a negative condition, this fact may be thus generally stated, that bodies in the same electric state repel each other, in opposite states they attract.

The effects produced upon bodies by the passage of accumulated electricity through them, are various and important. When discharged through steel, it frequently induces the magnetic property; when through magnets, it often destroys or disturbs their magnetism. The temperature of metals is raised when they are employed as conductors; and if the size of the metallic substance be proportioned to the intensity of the electric agent, fusion will be effected. Light is produced when electricity passes through elastic fluids, or liquids that have an inferior conducting power. Chymical effects, such as the composition and decomposition of bodies, may, under certain circumstances, result from the conduction of electricity. When the animal body is made the medium of transference, muscular action of a more or less violent character is produced, and instances are on record in which life has been destroyed. By these effects, the presence of accumulated electricity is determined; and when its quantity and intensity are not sufficient to produce them, the phenomena of attraction and repulsion never fail to give evidence of its presence.

IDENTITY OF ELECTRICITY AND THE AGENT THAT PRODUCES LIGHTNING.

The identity of agents is to be determined by the identity of their effects. Franklin seems to have recognised this principle; for, having observed that many of the effects produced by lightning were in a lesser degree occasioned by accumulated electricity as derived from the machine, he suspected that the agencies might differ in no other respect than in intensity. Among their many points of resemblance, he noticed that their motion from one irregular conductor to another is never in a right line; that they always strike the highest bodies, preferring those that are pointed and good conductors; that they ignite combustible bodies; fuse the metals; affect magnetic polarity; and destroy animal life. This similarity of effect might have been considered by some persons as a sufficient proof of the identity of the cause which produced lightning, and that we call electricity. But Franklin was not satisfied with any thing less than a demonstration, and determined to bring his conjectures to the test of experiment as soon as the spire of the church at Philadelphia, then building, should be finished. But it was not easy to wait with patience when so important a question was to be determined, and he provided himself with other means of inquiry, which were so simple that they could only have been selected and adopted by a truly philosophic mind. The instrument by which Franklin determined to investigate the nature of lightning was a common kite; and he accordingly prepared two cross sticks, over which he stretched a silk handkerchief, and with this he acted the part of the fabled Prometheus. On the first approach of a thunder-cloud he prepared for his experiment; but so apparently childish were his apparatus and his hopes, that, with a modesty frequently the attribute of a great mind, he communicated his intentions only to his son, who assisted him in the experiment. The kite was raised, and for some time no effect was produced; but at last he saw that there was a bristling up and apparent repulsion between the loose threads of the hempen cord; and, shortly after, when the string had been moistened by a shower of rain, he obtained sparks and other appearances demonstrative of the presence of electricity. In this way Franklin discovered the identity of the electricity of the machine and the agent which produces the phenomenon of lightning, and in after experiments succeeded in obtaining by it all the effects which were then known to attend the progress of ordinary electricity.

But, although the honour of this discovery is universally given to Franklin, it is but due to MM. Dalibard and Deler to state, that they, having acquainted themselves with Franklin's hypothesis, made some experiments about the same time, and came to the same results as Franklin himself.

EFFECTS OF LIGHTNING.

The most disastrous effects are frequently produced by the transmission of accumulated atmospheric electricity, and numerous instances are upon record. It seems to be the habit of electricity to seek out a good conductor; and it will, in some instances, make an eccentric course, in order to be transferred by particular substances. When this agent passes through bodies that offer but little resistance to its progress, no mechanical effects are produced upon them, except in those instances where the dimensions of the conductor are too small to convey the accumulated fluid. In one or two instances in which houses have been struck by lightning, the electricity has been conducted away by the bell-wires, for metals are good conductors ; but, on account of the smallness of the wires compared with the intensity of the agent, they have been fused in the act of transference. This choice of conductors is also proved by a fact that must be well known to foresters, that although the oak is frequently struck by lightning, the beech is seldom scathed, and perhaps never, when the royal tree is near to the direction in which the electricity is moving. Human life is frequently destroyed by lightning ; buildings are inflamed, rocks are fissured, and the forest-tree is dismembered or cleft ; but its agency is still more terrible on the broad bosom of the ocean, where the majestic vessel is alone exposed to its fury. We are not generally acquainted with the frequency of those disasters at sea which result from the electric agent, for but few are recorded in the pages of our philosophical journals. One or two instances, however, may be cited. It is stated, by an anonymous writer in the *Philosophical Journal*, that at Port Mahon, on board of a seventy-four gun ship, he saw fifteen men on the bowsprit and jib-boom struck by a flash of lightning, some of them being killed, and others dreadfully scorched. The same writer states that, in 1811, the Kent, a seventy gun ship, then off Toulon, was struck with lightning ; the main and mizzen masts were shattered from the trunk downward, and several of the men then on the yards were severely injured.

If the phenomenon of lightning were free from danger, and the mind from an almost instinctive dread of its effects, every lover of the sublime in nature might be allowed to feel some anxiety to behold a thunder-storm at sea. The mind of man is not insensible to the evidence of a Supreme Power as displayed in nature ; but while, in some instances, it dwells upon the consideration of the benign and salutary influence of material creation, it cannot, at other times, escape the feeling that an omniscient and omnipotent Spirit, capable of anger as well as complacency, exercises control over all. The earthquake and volcano, the hurricane and the tempest, might be sufficient to prove this; but no terrestrial phenomenon can impress the mind with the same reverential awe and consciousness of dependance as a thunder-storm at sea. But habit reconciles us to the most appalling appearances, and the man who has crouched with humble and reverential feeling under this demonstration of Almighty power may acquire confidence by repeatedly beholding the same phenomenon; and at last, when his mind has been divested of terror, he may delight to watch the broad flash of the electric light, and listen with a sensation not devoid of pleasure to the reiterated peal of the thunder.

"Wide bursts in dazzling sheets the living flame,
And dread concussion rends the ethereal frame;
Sick earth convulsive groans from shore to shore,
And Nature, shuddering, feels the horrid roar."—FALCONER.

Dr. Tilesius has given, in a continental journal, an account of some very curious effects produced upon the human body by atmospheric electricity. As two carts were passing through a wood, they were struck by lightning, which was conveyed from one to the other, more or less affecting the persons who were in them; one of the horses was killed upon the spot; and in the cart which it drew, a perforation was made nearly six inches in diameter. Both the persons in the cart were also struck. One of them received so violent a blow that he was thrown to some distance, and remained senseless for a time, but received no permanent injury. The other person was killed on the spot; and when the body was examined, it was found to bear the marks of the electricity. The arms and hands were furrowed to the bone, the sleeves of the coat and shirt were torn, but neither the skin nor the clothes bore marks of burning, but appeared as though they had been torn by the rapid passage of a sharp point. The two persons in the other cart were seriously injured, but soon recovered, though they appear to have afterward suffered under a drowsiness and lassitude which they had never before experienced. But the most singular circumstance, in a physiological point of view, is, that one of these persons was perfectly deaf at the time of the accident; but the electricity, in passing through his body, scratched the inner part of the ear, near the tragus and antihelix, and on the following day he recovered his hearing.

It is not, perhaps, uncommon for electricity to produce a decidedly medical effect in those instances where its intensity or quantity is not sufficient to destroy life. This may be either injurious or beneficial, according to circumstances. Professor Olmstead, of North Carolina, has given an account in the American Journal of Science, of the removal of a paralytic affection by a stroke of lightning. The individual had been attacked with a paralytic affection in the face, which had chiefly settled in the eye. During a thunder-storm he was struck with lightning, and for a time lost his senses, and the use of his limbs; but on the following day he was so far recovered that he was able to write an account of the accident, and had perfectly recovered his sight, though his hearing had been somewhat impaired.

It is not, perhaps, necessary that any other instances of death from the passage of atmospheric electricity through the animal body should be adduced; but we can scarcely be permitted to omit a notice of the unfortunate accident which attended some experiments made by Professor Richman, of St. Petersburgh, more particularly as it may serve to demonstrate the necessity of great care when we attempt to guide or control so mighty an agent as atmospheric electricity. The professor had erected an apparatus for the purpose of bringing atmospheric electricity into his study, wishing to make some experiments with it; and, in order to prevent accident, he attached to his apparatus an instrument to measure the quantity of the electricity that was present. On the 9th of August, 1753, he was making some experiments with Mr. Solokow, when, stooping down to examine the instrument, he was struck on the head by the electricity, and was instantly killed. From an examination of the body, it appeared that the electricity entered the forehead, and, passing through the body, escaped from the left foot, the shoe being burst open. Mr. Solokow, his attendant, was much hurt, and the room injured, the doorcase being split half through, and the door torn from its hinges, and thrown to some distance.

The loss of life by atmospheric electricity has, in most instances, resulted from a want of care, either arising from ignorance or temerity. It is exceedingly unsafe to stand, during a thunder-storm, beneath a tall tree, or by the side of a lofty building; and there are other precautions which a knowledge of the laws of electricity will suggest, and these should be attended to. But there are some persons who indulge a fear, during the presence of this phenomenon, as though God had no other agent of destruction in his power, and as if they were not enveloped with dangers arising from the construction of the human body as well as from external causes. The number of deaths by lightning bears but a small proportion to the number of thunder-storms; for when the electricity passes from the clouds to the earth, it must generally be conveyed at once to the earth itself.

Rocks frequently bear the marks of a fusion that has resulted from electric action. Some years since, Dr. Fiedler brought to London some vitreous tubes that had been obtained in the plains of Silesia and Eastern Prussia; one of which, found at Paderborn, was forty feet long. These fulgorites, as they were called, were undoubtedly produced by the heating effects of atmospheric electricity, and have generally been found to terminate in springs of water; and we may, consequently, be allowed the suspicion, that the direction of the lightning is, in some measure, governed by the character of the superficial rock and its substratum.

CIRCUMSTANCES UNDER WHICH LIGHTNING IS PRODUCED.

Having ascertained the nature of that cause which produces the phenomenon of lightning, some hope may be entertained of discovering the manner in which it acts. From the effects produced by the passage of atmospheric electricity through animal bodies, it is quite certain that it is in an accumulated state; nor is there much difficulty in ascertaining some of the causes which tend to produce an unequal distribution of the electric agent. We may suppose lightning to be produced under three different circumstances; when the electricity passes from one cloud to another; when from the clouds to the earth; and when from the earth to the clouds. In the last two instances it may occasion the destructive effects to which we have referred; in the first, its influence must be confined to the aerial region in which it moves.

When two clouds, charged with opposite kinds of electricity, or, in other words, having opposite electric conditions, approach so near to each other as to enable the electricity to overcome the restraining or coercive influence of the atmosphere, a discharge takes place, which produces a flash of light or lightning. We may, in fact, compare the action of two clouds, one in an overcharged and one in an undercharged state, to that of a Leyden jar, the coatings of which are in opposite conditions. If the jar be charged with electricity beyond a certain tension, there will be a spontaneous discharge, the restraining influence of the glass or the air being too small to overcome the expansive force of the electricity. This is the condition under which lightning is produced in the atmosphere. The attractive power exerted by two clouds charged positively and negatively must be active at a considerable distance, and this draws them towards each other with an accelerating force; but as soon as they have approached so near as to give the electricity an advantage over the constraining influence of the non-conducting medium, atmospheric air, a flash of lightning is produced. But this discharge is not sufficient to restore the electric equilibrium, and there will be successive discharges, proportioned to the distance of the clouds from each other, until this effect has been produced.

It sometimes happens that there is a passage of electricity from the earth to the clouds, and lightning is then produced, as in the discharge between two clouds. It is, however, quite impossible to determine whether the electricity moves from the earth to the cloud, or from the cloud to the earth; for so great is its velocity, that there is no perceptible period of time between the commencement and the completion of its circuit. This statement is beautifully illustrated by an experiment that has been made by Professor Wheatstone. When a spoked wheel is put into rapid rotation, the spokes will be absolutely invisible, on account of the velocity with which they are successively presented to the eye. But, if the wheel should at this time be illuminated by a flash of lightning, the spokes will for a moment be as distinct as though the wheel were at rest; for, however rapid may be its motion, it is not able to move through a perceptible space during the presence of the light, so instantaneous is the progress of electricity.

Many electricians imagine that the earth is always in the negative state, and that the electricity invariably passes to it from the clouds. Mr. Morgan, however, was of opinion, that the deficiency is never in the earth; but we can find no reason, either from the experiments that have been made, or from legitimate deductions, for either of these opinions. It is quite possible, from all that has been yet ascertained, that the earth may be either in a positive or negative state, and that accumulated electricity may pass to or from it, and, being conducted by bodies on the surface of the earth, influence them according to their nature, or the circumstances of the discharge.

THUNDER-CLOUDS.

A thunder-storm may generally be prognosticated by atmospheric appearances. A low dense cloud begins to form in some clear part of the atmosphere, and rapidly increasing on its upper edge, spreads itself out in an arched form. A number of small ragged clouds, which may be said to resemble teaseled flakes of cotton, then make their appearance, and, moving about in various directions, approach and recede from each other; but at last accumulate, and coalesce with the cloud that first appeared. The clouds now begin to thicken, and moving about with great velocity, throw from point to point the vivid flashes, as the heralds of the approaching storm.

The form and colour of the flash, as viewed from the earth, change in appearance, according to circumstances. The density of the medium through which the electricity moves, and the nature of the substances from and to which it passes, are probably the governing causes.

Thunder, that is, the sound which attends the phenomenon of lightning, varies in intensity and character, according to the height and extent of the electric clouds, and the physical peculiarities of the country in which it is heard. When the discharge is made at a short distance from the hearer, an instantaneous crash is produced; when far away, a deep grumbling noise; when it happens over a flat country, or a place where there are no objects to produce a reverberation, a series of regular explosions are produced, increasing or decreasing in intensity with the distance of the cloud; when over a mountainous or broken district, successive claps, irregular both in time and intensity, are generally heard.

The rolling of thunder is produced by the reverberation among the clouds. Arago and others, when making some experiments on the velocity of sound, observed that the explosion of their guns produced a single and sharp sound when the sky was perfectly clear; but when encumbered with clouds, they were attended by a long-continued roll that mimicked thunder.

To determine the distance of a thunder-storm, it is only necessary to ascertain the number of seconds which intervene between the sight of the lightning and hearing the sound, and these multiplied by 1090, the number of feet that sound travels in a second, will give in feet an approximate estimate of the distance of the electrified cloud from the place of observation.

From a series of observations that have been made in Germany, it appears that the general direction of accumulated atmospheric electricity is from west to east. It does, however, sometimes happen, that lightning rises in the north and south, but this is comparatively seldom. Philosophers are not yet acquainted with any general principles by which they can explain these singular circumstances.

LIGHTNING-CONDUCTORS.

When Franklin ascertained the electrical origin of lightning, he immediately perceived that his discovery might be so applied as to decrease the danger resulting from the presence of a thunder-storm. He knew that electricity was readily conducted by metals, and that points transferred it with greater facility than blunt or rounded surfaces, and therefore proposed to attach pointed metallic conductors to buildings, as a security against the effects of lightning. The propriety of this invention is very evident. When electricity passes from the clouds to the earth, the bodies through which it passes act as conductors, some willingly, and others as by force. But if two substances of unequal conducting power be presented to it, there will be a capability of selection, and it will, under all circumstances, choose one in preference to the other. Now the metals are the best conductors, while stones and bricks are very bad ones; and, consequently, electricity will seek to be transferred by the former, and the building will, by their presence, be preserved from those effects which usually attend an electric stroke. From a consideration of these facts, we may imagine Franklin to have been directed to the propriety of applying metallic conductors to buildings. He proposed to fix a metallic rod in such a manner, that one end penetrating the earth for some distance, the opposite or pointed end might rise to the height of a few inches above the highest part of the building. No plan can be more simple or effective than this; but there are some circumstances deduced from observation and experiment that are worthy of notice.

The rods should, if possible, be made of that substance which is the best conductor of electricity. The usefulness of a lightning-conductor will always depend upon its conducting power. Lead and copper are best able to transfer the electric agent; but as the fusing point of lead is much lower than that of copper, the latter metal is generally employed, and, in addition to this consideration, it is the better conductor.

In several instances accidents have been produced by conducting-rods of *insufficient diameter*; and it is equally dangerous to break their connexion, or, in other words, to erect one that is not perfectly uninterrupted. The latter statement is proved by the effect of electricity when it strikes an unprotected house, flying from one conductor to another, destroying all that may oppose its progress. About the middle of last century, the steeple of St. Bride's church, London, was struck with lightning, and in consequence of the large quantity of iron-work that had been employed in its erection, the electricity was attracted from one part to another, and much damage was done. It appears to have entered the vane, and was quietly transferred by the shaft on which it was supported; but then darting towards some cross iron bars, and from thence to the iron cramps which had been employed in its construction, shattered the stones as it passed along.

ELECTRICAL CONDITION OF THE ATMOSPHERE.

M. Monnier appears to have been the first person who observed that the electric excitement of the atmosphere is not confined to those periods when the phenomenon of lightning was observed. Sig. Beccaria afterward examined this subject with great care, and is of opinion that clouds, rain, hail, and other meteorological phenomena, are to be attributed to electricity. In support of this opinion he adduces several arguments, and among others states, that the presence of thunder, lightning, rain, hail, snow, and wind, at the same moment, shows their connexion with a common cause. It is probable that Beccaria's opinion will be ultimately verified, but the reason he has offered is not very capable of convincing the skeptic, or of satisfying a philosophical mind.

The electricity of the atmosphere is generally stronger in winter than in summer, and in the day than in the night, and in open and fine weather is in a positive state. The sources of atmospheric electricity cannot be determined with great accuracy, but it is probable that the overcharged condition of the air may be in a great measure traced to the constant evaporation which is going on from the surface of the earth, a phenomenon which is always attended by the disengagement of electricity. It has been stated by M. Pouillet, that electricity is never given off during evaporation, unless accompanied by chymical action; a result that we do not suppose to be perfectly true, though this is not the place to mention those experiments which have led us to this conclusion. But, however this may be, there can be no doubt that a large amount of electricity is given off by the evaporation which is going on from the surface of water, as well as by those numerous chymical changes which are so abundant in the terrestrial laboratory. These agencies are probably assisted by the influence of those unequal currents of heat which are circulating through the atmosphere, and by the friction of atmospheric strata moving in opposite directions; but we are at present quite unable to assign to any cause its proportional effect in producing the electric condition of the atmosphere.

AURORA BOREALIS.

Although we are not acquainted with the positive amount of influence exerted by the electric agent in the production or regulation of meteorological phenomena, yet there are some few appearances which may without doubt be attributed to its agency. One of the most common and beautiful of these is the Aurora Borealis, or the merry dancer, as it is called in the Shetland Isles. In Sweden, Lapland, and the polar regions, it is so constant during the long winter nights, that it frequently serves the traveller instead of the light of the moon.

"In the northeastern parts of Siberia," says Gmelin, "these northern lights are observed to begin with single bright pillars rising in the north, and almost at the same time in the northeast, 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 spread in the heavens, glittering with gold, rubies, and sapphire."

The aurora is not so common in this country as it was about the year 1800; but when it does appear, it is generally in the spring and autumn seasons, and after a continuation of dry weather. The most beautiful that was ever seen in England was that described by Mr. Dalton, in a very minute and interesting manner: "Attention was first excited by a remarkable red appearance of the clouds to the south, which afforded sufficient light to read by at eight o'clock in the evening, though there was no moon or light in the north. Some remarkable appearance being expected, a theodolite was placed to observe its altitude and bearing. * * * From 9½ to 10 P. M., there was a large luminous horizontal arch to the southward, almost exactly like those we see in the north, and there was one or more concentric arches northward. It was particularly noticed that all these arches seemed exactly bisected by the plane of the magnetic meridian. At half past 10 o'clock streamers appeared very low in the southeast, running to and fro from west to east; they increased in number, and began to approach the zenith, apparently with an accelerated velocity, when all of a sudden the whole hemisphere was covered with them, and exhibited such an appearance as surpasses all description. The intensity of the light, the prodigious number and volatility of the beams, the grand intermixture of all the primitive colours in their utmost splendour, variegating the glowing canopy with the most luxuriant and enchanting scenery, afforded an awful, but, at the same time, a most pleasing and sublime spectacle. Every one gazed with astonishment; but the uncommon grandeur of the scene only lasted one minute; the variety of colours disappeared, and the beams lost their lateral motion, and were converted as usual into the flashing radiations; but even then it surpassed all other appearances of the aurora, in that the whole hemisphere was covered with it."

The aurora is evidently an electrical phenomenon, and may be readily imitated by ordinary electricity. When electricity is passed through a vacuum, beautiful streams of light are produced, which vary in colour and intensity, according to the amount of air contained in the tube There is, however, some connexion between the magnetic poles of the earth and atmospheric electricity, but the nature of their influence on each other is not at present known. Dr. Farraday considers it probable that the aurora is a luminous representation of electricity flowing from the equator to the poles for the restoration of electric equilibrium. But it is not as yet possible to say with certainty whether it is an occasional discharge, or a luminous representation of a constant stream of electricity. That it is a phenomenon occurring in a very attenuated atmosphere, there can be no doubt, and that it is in some way connected with its temperature. In Siberia, one of the coldest inhabited countries, the aurora is so brilliant as to sometimes excite the fears of those who are accustomed to view it from night to night; and it is well known that the electrical condition of the atmosphere is more decided in winter than in summer; a circumstance that tends to support the opinion, that the aurora is in some way connected with the temperature of the atmospheric strata in which it is produced.

ST. ELMO'S LIGHT.

St. Elmo's light is a luminous meteor that frequently settles upon the mast-head of vessels, and is probably of electric origin, though it is never known to produce any of those disastrous effects which so often attend lightning. Sometimes it is confined to the mast-head, while at other times it gradually descends the mast to the deck itself. It was formerly supposed by mariners to be a visible representation of a spirit they call St. Elmo, who is the tutelar deity of those who traverse the mighty deep, and has a prophetic power. When it is confined to the topmast, it is a proof, in their opinion, that although bad weather may be present, yet it will not continue, and cannot injure the vessel. But when it descends the mast, it prognosticates a gale of wind, or a disaster, which will be more or less violent in proportion to the depth of its descent. Falconer has described this phenomenon in his Shipwreck :—

> "High on the masts, with pale and livid rays,
> Amid the gloom, portentous meteors blaze."

This appearance may be readily explained upon the known aptitude of a pointed conductor in transferring electricity from a highly electrical atmosphere; and it is possible that it may, on philosophical principles, be considered as the prognosticator of atmospheric changes, since the agent itself has an evident connexion with many meteorological effects which we at present find some difficulty in explaining.

The phenomenon observed by M. Allamand, in the Canton of Neufchatel, may probably be attributed to the same cause. As this gentleman was walking from Fleurier to Montiers, he was overtaken by a thunder-storm. Having closed his umbrella, lest the electricity should be attracted by its metallic point, he saw that the rim of his hat was surrounded by a broad band of light, which became more intense when he passed his hand over it. This appearance vanished as soon as he came near to some tall trees, which in all probability conducted away the electricity from the highly excited atmosphere.

Humboldt observed the St. Elmo's light during one of his voyages, and we are always glad to avail ourselves of his descriptions. "On observing the appearance of the masts, the main-top-gallant mast-head, from the truck for three feet down, was perfectly enveloped in a cold blaze of pale phosphorus-looking light, completely embracing the circumference of the mast, and attended with a flitting or creeping motion, as exemplified experimentally by the application of common phosphorus upon a board. The fore and mizzen top gallant mast-heads exhibited a similar appearance. This curious illumination continued with undiminished intensity for eight or ten minutes, when, becoming gradually fainter and less extensive, it finally disappeared, after a duration of not less than half an hour."

Philosophers know that in many instances the most occult, and apparently the most feeble agents, are productive of the most important, if not the most violent effects. When we rub a piece of sealing-wax with a woollen cloth, and induce in it a property by which it is able to attract to itself any light substance that may be near, it is scarcely possible to imagine that the same agent governs the formation of clouds, and that the terrific storm which shakes earth to its centre is but its effect. Of its nature we may be ignorant, yet it resides in all bodies, and its absence would probably be their destruction. There are, it is true, causes which disturb the equable distribution of electricity, accumulating it here, and reducing it there, but a restorative force exists, and the broad-faced lightning is but a demonstration that that force is active. The earth may rob the atmosphere, or the atmosphere may rob the earth, but it is only a means to produce an effect necessary to sustain the present terrestrial arrangements, and when this has been accomplished, the equilibrium is again established. The changes which are constantly happening, and the want of perpetuity that characterizes nearly all terrestrial phenomena, are the elements by which the Creator sustains the freshness and vigour of the world destined to support and delight man and the inferior animals under his control.

CHAPTER VII.

PHENOMENA DEPENDANT ON TERRESTRIAL MAGNETISM.

Having described the natural phenomena which result from the agency of electricity, it may be well to make some allusion to those which depend on magnetism. Philosophers are as ignorant of the nature of the magnetic as they are of the electric agent; and they are as imperfectly acquainted with their influence upon and relations to each other. So far as observation has extended, there is no lack of evidence calculated to impress the inquirer with a belief that these causes are intimately connected, if they be not in fact identical. But, before we make any reference to the nature of the agency, it will be necessary to describe some of those effects by which its presence may always be determined.

The fundamental principle of magnetism, or the science which explains the phenomena resulting from an occult agent so named, is that iron and ferruginous bodies in general, in a particular state, have a directive power, one end pointing to a spot near the north pole of the earth, and the other to a corresponding point in the south. There seems, in fact, to be a peculiar affinity between the poles of the earth, or points near them, and the ends or poles of magnets. This attractive power is not confined, as might be supposed, to one pole, but is equally active in both; and, could we entirely neutralize the effect of one, the other would be found sufficient to keep the magnet in its customary direction.

That we may clearly explain the nature of this attractive force, it will be necessary to refer to a few facts that especially relate to artificial magnets.

The magnetic power was first observed in a certain ore of iron. This magnetic iron ore appears to have been known from a very early age; but by what means it became known, or to whom the discovery is due, can only be a matter of conjecture; and fable in this instance, as well as others, supplies the place of truth. The Chinese lay claim to the merit of the discovery, and the Greeks induce us to favour their pretensions, by pleasing the fancy with a beautiful fable. The loadstone, they say, was discovered by Magnes, a shepherd of Mount Ida, who found a piece attached to the iron of his crook, and from this circumstance, it is said, the ore derived its name. The Hindoos are not without pretensions to the honour, and support their right with reasons as feasible as those adduced by other nations. The influence of magnets upon ferruginous bodies was probably known long before its directive power was discovered, which is to us its most important property. It is generally supposed that John de Giova, a Neapolitan, ought to have the honour of the discovery; but Dr. Gilbert and others say that the compass was brought into Italy from China, by Paulus Venetus, in the year 1260.

It is not at all singular that there should be so much difference of opinion upon a subject concerning which no authenticated evidence can be adduced. The magnetic principle of direction may have been discovered in Asia, Africa, or Europe, and various nations lay claim to the honour, each one finding defenders. Europeans have been as anxious to establish a right to the discovery as other nations, and their anxiety has been probably increased by the knowledge that they have long possessed a monopoly of intellectual energy and its consequent. It has been justly remarked by a celebrated writer on magnetism, that if the discovery can be attributed to Europeans, the Norwegians have the best claim to it, not only from the character of their early enterprises, but also from the probability of their meeting with the ore among the rocks of their native country. This supposition is strengthened by the fact that they were acquainted with the art of navigation long before any other European nation, or were at least more practised seamen; and from the daring they evinced it may be supposed, without misapplying facts, that they were acquainted with the directive power of the magnet. It is, however, a matter of little importance, whether the discovery was made in Europe, Asia, or Africa; for, although we should honour the memory of the discoverer, did we but know his name, and perhaps speak of him as "the immortal," he would be nothing the better for our admiration, and we should derive no practical advantage.

The magnetic iron ore, or loadstone, consists of the protoxyde and peroxyde of iron, with a small proportion of silica and alumina. In the iron mines of Sweden and Norway it is very abundant, and is found in Arabia, China, and other Asiatic countries. The appearance of the ore varies according to its composition. When two or more substances are chymically united together, the properties and appearances by which they are individually known are generally lost, and the combination has characters peculiarly its own. It may therefore be anticipated that the appearance of the magnetic iron ore is regulated by the proportional quantities of the several mineral substances which compose it, though a practised mineralogist may generally detect it by its dark gray colour and peculiar lustre. All iron ores are under the control of the magnetic principle; but while some only obey its influence, others are the local habitation of the principle itself. All ferruginous substances are attracted by the magnetic agent, but the magnetic iron ore possesses in itself the attractive power. If we had only two ores of iron, one magnetic, the other not, it would be impossible to determine which possessed the magnetic principle; as soon as they were brought within the sphere of attraction, they would be drawn towards each other; but there would be no means of determining which was the attractive and which the attracted. But, supply us with a second magnet, or fragment of iron, and this is easily determined. If we take the piece of iron and bring it near to the magnet, it is immediately attracted; but if it be brought into contact with the unmagnetized iron, no such force will be in activity. If, instead of the piece of iron, we are furnished with a magnet, an entirely different course of phenomena will be presented. The unmagnetized ore will be attracted by it under all circumstances, in whatever manner it be presented; but the magnetized ore will be sometimes attracted and sometimes repelled, and by this change of effect the magnetic principle is detected.

It has been proved, by many careful experiments, that all metallic bodies, and probably many others, may be invested with magnetic agency, but iron receives it more readily than any other substance. It is said that a metal which contains only 130,000th part of its weight of iron, a proportion which cannot be detected by chymical means, may be magnetized. But the agent has an elective power, and is more powerfully condensed, if we may employ the expression, in that particular ore called the loadstone; why it chooses this combination of substances in preference to any other, the philosopher has no means of determining, and cannot at present pretend to guess.

The mere existence of a magnetic iron ore would be of little importance, if there were no means by which the power could be transmitted into or induced upon other bodies. The process that would be required to reduce the magnetic iron ore into a shape suited for the purposes to which magnets are applied, would have a tendency to destroy the power itself; for both heat and hammering destroy magnetism. But the natural magnet or loadstone can communicate its peculiar properties to iron and other ferruginous substances. If a small piece of steel, as a sewing-needle, remain for a little time in contact with a loadstone, it will become a magnet; and if freely suspended upon its centre of gravity, will direct itself north and south, in the same manner as the substance from which it derives its power. Bars of steel may also be made magnetic by rubbing them with a loadstone or artificial magnet. This singular inductive power, possessed by the magnetic principle, gives great facilities of investigation, as the agent may be called into activity in any ferruginous body. We might speculate as to the nature of this process, but there is an uncertainty connected with it which cannot be very easily removed. It is possible that the agent, whatever it may be, exists in all ferruginous bodies, and that the directive power results from its accumulation; or it may be that it is actually communicated by one substance to another; a supposition, however, not very probable, as by one magnet hundreds may be made, and the original magnet will be stronger after the process than before, a circumstance which cannot be reconciled with the theory of communication.

But there is another result peculiarly characteristic of magnets, or rather of the agent itself, and that is the attractive and repulsive power of magnetic poles between themselves. That end of a magnet which points to the northern hemisphere is called the north pole of the magnet, and that which is directed to the southern the south. But, if we take two magnets, and bring their north poles together, a strong repellant power is called into action, and they fly from each other, and the needles can never come to rest till the south pole of one is directed to the north pole of the other. This is not merely the result of a strong repulsion between poles of the same name, whether north or south, but is partly produced by an attraction between poles of different names, for the north and south poles evince an evident tendency to come as nearly as possible to each other. Acknowledging the force of this law of the magnetic agent upon itself, it will follow that we have misnamed the poles of the magnet. There can be no doubt that the force subsisting between a magnet and the earth resembles that which is exerted between two magnets It would therefore be more proper to reverse the names of the poles; for as poles of opposite names attract each other, that which is directed to the north pole of the earth is the south pole of the magnet. For some reasons, the alteration of terms might even now be desirable; but so many inconveniences arise from a change of nomenclature, that it is generally better to keep an inaccurate term than to confuse facts by the adoption of a better, and especially when those terms are in common use among practical men.

These preliminary statements will enable us to explain the action which subsists between a magnet and the earth, and the variations to which the directive power is subject. The facts will perhaps be more intelligible if we imagine the earth to be a magnet, or rather to enclose a magnet extending from north to south, having a revolution round a small circle in both hemispheres. But, at the same time, the reader must bear in mind that the hypothesis is only employed for the sake of illustration.

The poles of a magnet freely suspended do not point to the poles of the earth's rotation, and hence we may deduce that the poles of rotation and the terrestrial magnetic poles are not situated in the same point. This circumstance may possibly have led the navigators, who first employed the magnet to direct their course over unknown seas, into many errors, and the inaccuracies which we sometimes detect in their observations may frequently be traced to this cause. But the variation, and the changes to which it is subject, do not in any degree affect the practical utility of the magnetic needle, when employed by the mariner to direct him from shore to shore over known and unknown seas.

The application of the directive power of magnets has done more to extend our acquaintance with the superficial character of the earth and the condition of its inhabitants, to extend commerce, to promote manufactures, and to civilize mankind, than any other scientific fact. It is true that navigation in a great degree depends upon astronomy, but it is scarcely possible to imagine how the sailor could dare a passage over the vast wild of waters, had he not the compass as his director. The heavens, covered from day to day with an impenetrable curtain, would be a chilling anticipation to the mariner, sufficient to quench the most enthusiastic ardour for discovery or commerce; but with the magnet he is comparatively safe; for though causes do exist by which the directive power may be destroyed, yet even the voyager may be put in possession of means by which to restore it; and it is a singular circumstance, that the agent which destroys can also restore. Several instances have occurred in which vessels have been struck with lightning, and the passage of the electricity through the magnets has either destroyed or reversed their polarity. It is seldom that the mariner possesses the means of inducing again the same power, though an electrifying machine and a large Leyden jar are all that would be required for the purpose, for it is well known to the electrician, that the magnetic power may be produced by passing electricity in an accumulated state through ferruginous substances. These accidents, however, are by no means frequent, and their number bears no proportion to what might be anticipated from the known frequency of the cause of disturbance, and in no instance has the spirit of discovery been retarded by the fear of accidents; but, with the compass in his hand, man has traversed deserts and oceans, introduced civilization and the arts of life into the most inhospitable and barbarous climes, and established that communication between nations which must ultimately be productive of the greatest possible advantages to society at large.

We are sometimes almost persuaded to believe that terrestrial magnetism was expressly provided to facilitate the efforts of man in extending the beneficial influence of knowledge, and to encourage the feeling of curiosity by which he is so much governed in all his determinations and actions. That this was one of the motives which influenced, if we may so speak with reverence, the Eternal Mind, is probable, but we can assign no limit to the influence of the magnetic principle, as developed on the surface of the earth. Philosophers have been unable to trace any positive connexion between the phenomena which seem to be the necessary results of the terrestrial constitution of matter, and terrestrial magnetism; yet it is possible that climate may be in some degree under its control, electrical phenomena may be governed by it, and the position or activity of volcanoes may be determined by its intensity and force.

The view we are accustomed to take of material creation is so imperfect and confined, that appearances seem entirely independent the one of the other, and the system of the world to be, as it were, disjointed and broken. We ought to use our theoretical opinions as mirrors, not so much for the purpose of looking at them, as of discovering some other objects by their means. The Creator must regard the universe as a mighty individuality, illustrating his wisdom and power; we see but a portion of it, and are compelled to divide and subdivide that which comes under our view, and are fortunate if we can but ascertain the cause and relations of some one, and that perhaps an unimportant phenomenon. Ultimate principles are, we believe, entirely beyond our reach; and the only reason we can give for the existence of the complex phenomena by which we are surrounded, is the will of an Almighty Mind to support the existence of animal life in a pleasurable condition. But, when we look at the causes which are influential in the production of this result, we cannot but feel surprised at the means which have been employed for its accomplishment; for although we perceive their adaptation to produce the result, yet they seem to act the one against the other, and yet without interference, as though they had no other object than to prove the mutability of material existence. Destructive and conservative agents are everywhere acting in concert, and to take away one or both would be to create an inextricable confusion.

POLARITY AND INDUCTION.

From a very early age it was known that the natural magnet or loadstone has the property of directing itself to the north and south poles of the earth, and from the writings of *Plato* we may judge that the ancients were not unacquainted with the fact that the same power might be communicated to bodies containing iron. Whether they were informed as to the conditions which are most advantageous for the reception of the magnetic power is doubtful, but it is now well known that hardness is a property essentially necessary for permanent induction. Soft iron is strongly magnetized by mere contact with a magnet, but the moment the magnet is removed the property is lost. Steel also is magnetized under the same circumstances; but the induction is less rapid, though after a long contact it permanently retains the communicated property, and becomes a magnet.

VARIATION OF THE MAGNETIC NEEDLE.

When a magnet is freely suspended in such a manner as to have the power of horizontal motion, it turns itself nearly north and south, and, if disturbed, returns, after a few oscillations, to the same position. There are few places where it points directly to the north and south poles of the earth, but to the east or west of these poles; this deviation is called the variation of the compass, and differs in amount and direction according to the geographical position of the place in which the experiment is made, although there are some places in which there is no variation.

The variation of the magnetic needle was not known for many centuries after the discovery of the directive power. No experiments of importance were made till the close of the sixteenth century, and yet it appears probable that the simple fact of variation was known as early as the year 1269. Cavallo has quoted from a letter written by Peter Adsiger, dated the 8th of August, 1269, in which the variation is positively stated:—"Take notice that the stone, as well as the needle that has been rubbed by it, does not point exactly to the poles, but that part of it which is reckoned to point to the south declines a little to the west, and that part which looks towards the north inclines as much to the east. The exact quantity of this declination I have found, after numerous experiments, to be five degrees. However, this declination is no obstacle to our guidance, because we make the needle itself decline from the true south by nearly one point and a half towards the west. A point, then, contains five degrees." The authenticity of this letter has been doubted, and many arguments have been adduced to justify the skepticism. It is true that no notice was taken of this fact for two centuries after its discovery, and this may appear singular in the present day to those who do not know that even in this age of enlightened benevolence and disinterested zeal discoveries are too frequently estimated by the wealth and influence of the discoverer more than by their intrinsic value. But a graver charge has been pleaded. It is stated that, if the variation had been observed, it would, at the time mentioned, have been directed towards the west instead of the east. This argument is destroyed by another, which has been considered by the same persons as conclusive against the claims of Adsiger to the merit of the discovery. The instruments employed at the time have been thought inadequate for the discovery of the fact; but we might say with greater propriety that the insufficiency of the means accounts for the erroneous results, though the principle itself is true to nature. But it may be farther stated, that men do not usually fabricate for the purpose of deceiving, without having some interested motive. When individuals practise the arts of deception, they are invariably influenced by personal objects; it would be absurd to suppose a man a deceiver for the public good, and it is almost impossible to imagine so violent a misanthropy as that which would be displayed in an attempt to deceive with the purpose of producing a public evil. With these opinions we cannot assent to the supposition, that the letter bearing the name of Peter Adsiger is the work of one who had no other desire than the deception of posterity. If it were possible to imagine a confirmed misanthropist presenting himself to the world for the purpose of stating an important fact, that he might deceive all men as to the date of its discovery, then, indeed, we might agree with the disputants, that the letter in question was unworthy of credence, and that the fact stated was discovered at a period subsequent to the date recorded. But, as we cannot assent to the premises, so we must be permitted to believe that the letter is not a fabrication, and that the variation of the needle was known as early as the thirteenth century.

There are some places where there is no variation, and the line which connects all these places together is called the line of no variation. This line is very complicated, and appears to have no relation to those great circles which are called by the geographer meridians. It may be traced from the north magnetic pole of the earth, supposed to be situated to the westward of Baffin's Bay, to the United States of North America; crossing this continent, it enters the Atlantic, passing to the east of the windward West India isles towards the northeastern point of South America, over the southern Atlantic into the antarctic circle, but its course here is unknown. It is found again to the south of Van Diemen's Land, and crosses the western part of the Australian continent. In the Indian Archipelago it is divided; one branch crossing the Indian Sea to Cape Comorin, traverses Hindostan, Persia, and the western part of Siberia, and enters the North Sea: the other branch traverses China, Chinese Tartary, and the eastern part of Siberia.

It is almost certain that there are at least two magnetic poles in each hemisphere, but their exact situation is not known. If we could determine the magnetic equator, there would be less difficulty in calculating the position of the poles; but, in the present state of our knowledge, this problem cannot possibly be solved in any other manner than by experiment. Attempts have been made by voyagers; but those who are acquainted with the local disturbance to which the needle is subject, must be aware that the circumstances under which the experiments have been made were so unfavourable that we can scarcely depend upon the results.

It was long supposed by philosophers that the magnetic poles were situated on or near to the surface of the earth, but the accuracy of this supposition was afterward doubted. M. Biot was the first to attempt the solution of this question by calculations founded on the observations which had been made, in various parts of the world, upon the dip and variation, and more especially upon those furnished by M. Humboldt. Professor Kraft, of St. Petersburgh, also undertook the same examination, and the two philosophers arrived at the same law, proving the inaccuracy of the first supposition

ANNUAL CHANGE IN THE VARIATION.

Norman appears to have been the first philosopher who observed with accuracy the variation of the needle in London, but the time of his observation is not known. It was then 11° 15′ east. Mr. Christie, speaking of this subject, says, "No date is given for this observation; but, from the circumstance of Burough referring to Norman's book in the preface to his '*Discourse of the Variation of the Compass*,' dated 1581, it would appear that there must have been an earlier edition of Norman's book than that of 1596, and that his observations must have been made before 1581." This writer, however, was not aware of the fact, that the variation of the needle is constantly changing, though he did know that the variation itself depends upon the position of the place in which the observation is made. "Although," he says, "this variation of the needle be found in travel to be divers and changeable, yet at any land or fixed place assigned, it remaineth always one, still permanent and abiding." We do not pretend to decide upon the claims of individuals to the honour of discovering the important philosophical fact, the annual change of the variation. Some writers give credit to Gunter, and others to Gellibrand; and as they both have claims which cannot be disputed, there is little hope of deciding between them.

In 1660, the line of no variation passed through London, and at that time the needle must have pointed directly north and south. From this period the line of no variation moved westward till 1818, when the variation in London was 24° 30′, and it has since been retrograding, so that, in the course of years, the needle will again point to the north and south poles of the earth, and then take an easterly direction. Paris was on the line of no variation in the year 1664; and in 1824 the variation was 22° 44′ west; at this time, or shortly afterward, it came to its maximum, for M. Arago found that in October, 1829, it was 22° 12′ 5″.

This constant change in the variation of the magnetic needle is a subject of great interest; for, until the rate of change is accurately determined, there must be some degree of uncertainty in the use of the compass. Should the point of direction vary only half a degree, it might be of serious consequence to the navigator Some years must elapse before we can be supplied with the data necessary to determine the law which governs the annual change of variation. It is stated by the author of Magnetism, in the Library of Useful Knowledge, from a table given by Mr. Gilpin in the Philosophical Transactions, that the amount of annual change has been continually decreasing from the commencement of the eighteenth century. From 1622 to 1773, it was only 8′; from 1787 to 1795, it was 5′; from that time to 1802 only 1′ 2″; in 1818, it was reduced to zero. The law which governs these changes may be determined when a more extensive series of observation has been made.

DIURNAL CHANGE IN THE VARIATION.

The magnet is subject to a diurnal as well as an annual change of the variation. This was discovered by Graham, in the year 1772, the greatest westerly variation happening, as he supposed, about noon and the four following hours, the least about seven in the evening. More accurate observations were afterward made by other experimenters, and it has been found that the motion is much more complex than was at first imagined. Commencing our observations at about seven or half past seven o'clock in the morning, we observed the needle to have a slight westerly motion, which continues till about two o'clock in the afternoon. The direction of the motion is then changed, and the needle slowly retrogrades, and returns to the eastward until evening; it then again takes a westerly direction, returning again during the night or early in the morning. Its maximum easterly direction is about seven o'clock in the morning. This daily change of variation amounts, at some periods of the year, to fourteen or fifteen minutes, and is greater during the summer than the winter months, but experimenters are undecided as to the month in which it is greatest. Canton and Wargentin thought its maximum to be in the month of July; but, according to Colonel Beaufoy's experiments, it is greatest in June and August, and in this gentleman's results we may place great dependance, from his known accuracy, as well as from the time he continued to observe this phenomenon.

From the moment that the diurnal change in the variation was observed, it has been a favourite supposition that it has its origin in the action of solar heat; but it is only since Oersted's ever memorable experiments upon the influence of a voltaic circuit on the magnetic needle, and Seebeck's dis covery of the influence of heat in inducing electric currents, that any well-founded theory of magnetic action and phenomena resulting from it has been formed. But we shall hereafter have occasion to refer to the origin of terrestrial magnetism; the diurnal variation in the direction is the present object of attention. If the unequal distribution of heat through metallic, and, in all probability, other bodies, can cause the development of electric currents, then the earth, containing metallic, as well as other substances, and subject *to a constant variation of temperature, in consequence of the* diurnal and annual revolution, must be in an unequal electric condition, and conduct through its mineral crust electric currents of varying intensity and character. The superficial crust of the earth can, in fact, only be considered as a vast thermo-electrical apparatus, and to its influence we may trace the diurnal variation of the needle. Mr. Christie, speaking of a course of experiments he made on this subject, says, "from these I drew the conclusion, that one part of the earth, with the atmosphere, being more heated than the other, two magnetic poles, or rather electric currents, producing effects referrible to such poles, would be formed on each side of the equator, poles of different names being opposed to each other *on the contrary side of the equator; and that different points* in the earth's equator becoming successively those of greatest heat, these poles would be carried round the axis of the earth, and would necessarily cause a deviation in the horizontal needle. On comparing experimentally the effects that would result from the revolution of such poles with the diurnal deviation at London, as observed by Canton and Beaufoy, also with those observed by Lieut. Hood, at Fort Enterprise, and finally by the late Captain Foster, at Port Bowen, I found a close agreement in all cases, in the general character of the phenomena, and that the times of the maxima east and west did not differ greatly in the several cases. The double oscillation of the needle clearly resulted from this view of the subject. Some of the experiments to which I have referred showed, that when heat was applied to a globe, the electric currents excited were such, that, on the contrary sides of the equator, the deviations of the end of the needle of the same name as the latitude, were at the same time always in the same direction, either both towards east or both towards west." The diurnal deviation is greatly influenced by local causes, such as the state of the weather, and especially the temperature, a circumstance which strongly tends to confirm the supposition that it is under the control of those electric currents, excited by the action of unequal currents of heat.

De Saussure made, some time since, a series of experiments on the Col du Géant at an elevation of about 11,300 feet above the level of the sea, with the object of determining the influence of elevation upon the diurnal change of variation. By comparing the result of these observations with those which he obtained at Chamouni and Geneva, he discovered that the change is but little influenced by the altitude of the place, the course of the diurnal variation being the same in the three places, the times of the least and greatest variations being later on the Col du Géant than at Chamouni or Geneva.

DIP.

The needle is subject to a perpendicular as well as a vertical motion. Norman discovered that a needle, accurately balanced, and perfectly horizontal before it was touched by a magnet, always lost its position after the magnetic principle was communicated to it, the north pole declining below the horizon in those countries situated in the northern hemisphere. This ingenious philosopher invented an instrument by which to measure the inclination or dip, and determined it to be, in London, about 71° 50′. This experiment is supposed to have been made in the year 1576. The same philosopher was aware of the fact that the dip changes with the situation of the place in which the needle is suspended, though he was not aware of the circumstances which influence this change.

It may be stated, as a general law, that the dip increases from the equator to the poles. If the poles of the earth's rotation were the magnetic poles, then this would be strictly true, and on the equator the magnet would be horizontal, while at the poles it would be vertical. But, as the terrestrial and magnetic poles do not coincide, neither can the terrestrial and magnetic equator.

The dip may be very well illustrated by suspending a small magnetic needle over a large bar-magnet; when the middle is situated directly over the centre of the magnet it will be horizontal, having no tendency to incline either to one pole or the other. But, as it is removed from this point to either end, the inclination is observed; and when situated over the pole, it would, if uninfluenced by other forces, be quite vertical. The same appearances are observed on the surface of the earth, for it acts as though it were a magnet; and there is a line called the magnetic equator, on which the magnetic needle has no dip, and there are points in both hemispheres where it is vertical.

The magnetic equator is not an exact circle of the sphere, for although it does not recede from the terrestrial equator, north or south, more than 15° or 16°, yet it cuts the equator in three or more places. Captain Duperry crossed the magnetic equator several times during his voyage round the world, which was commenced in the year 1822 and completed in 1825. The results of his observations are given in the "Annales de Chimie et de Physique." The node of the magnetic equator, or that point where it crosses the equator of the earth, is near the Island of St. Thomas, about 3° 20′ to the east of the meridian of Paris. From this point it advances rapidly to the northeast, and crosses the continent of Africa. It then stretches onward, for a short distance, in a line almost parallel to the equator, but, gradually declining, passes through the south of Hindostan, touching the northern extremity of the Island of Ceylon, and forms an irregular line passing through Malacca, the north of the Island of Borneo, and to the south of the Carolines. At about 175° east of Paris it again crosses the equator, and makes but a small angle until it reaches about 100° west from Paris, when it takes an eccentric course through South America, having, in some places, a distance from it of 16°. It then passes, in an irregular line, through the Atlantic towards the Island of St. Thomas. There is, however, a singular circumstance which has been observed concerning its passage through the Pacific Ocean. In longitude 113° 14′ west, the magnetic equator crosses the equator of the earth, and in longitude 156° 30′ it has been traced at some distance to the south of the equator; but in the sea of China, in 113° east longitude, it is north of the equator, and, consequently, must have intersected it in some point between these two places. There are, then, at least three points where the magnetic and terrestrial equators cross each other, and there are strong probabilities that there may be *even more.*

But the dip is subject to change, as well as the variation. When Norman made his experiment, in 1576, the inclination was 71° 50′. In 1828 Captain Sabine found it to be 69° 47′, and Captain Segelcke measured it at Woolwich in November, 1830, as 69° 38′. The magnetic equator is not, therefore, a fixed line, but varies with the position of the magnetic poles. According to the experiments of Captain Sabine, the dip has been decreasing about three minutes annually for the last fifty years.

There are many subjects of great interest connected with the magnetism of the earth, to which we cannot even allude in this outline sketch, but must close the chapter with an account of some of those opinions which have been entertained as to the origin of terrestrial magnetism.

ORIGIN OF TERRESTRIAL MAGNETISM.

The name of Gilbert will ever be associated with the science of magnetism, for we are equally indebted to him for the variety and accuracy of his experiments, and the soundness of his deductions, so far at least as the state of the science in his day admitted. This eminent philosopher, to whose memory posterity has not awarded justice, considered the earth to act upon a needle, as though it were itself a magnet, and that the direction of the magnet was due to the earth's magnetic power. That end of the needle which points to the north pole of the earth he called the south pole of the magnet, and that which points to the south he called the north pole. Although the names of the poles have been changed, they were accurately designated by Gilbert, and the names by which they are now known contradict the acknowledged principle that poles of the same name repel each other.

Halley accounted for the variation and dip by supposing the existence of four terrestrial magnetic poles, two in each hemisphere. One of the northern he conjectured to be about 7° from the pole of the earth, in the meridian of the Land's End, and the other about 15° from the pole, in the meridian of California. One of the south poles he supposed to be situated about 16° from the terrestrial pole of the southern hemisphere, in a meridian about 20° to the westward of Magellan's Straits. The other, which Halley considered the most powerful of the four, he conceived to be about 20° from the pole of the earth, and in about 120° east longitude. One pole in each hemisphere is supposed, according to the terms of this theory, to have a revolution round the magnetic axis in a period of about seven hundred years.

Professor Hansteen has adopted Halley's hypothesis, so far at least as to acknowledge the existence of four magnetic poles, though he supposes them all to be in motion, the northern poles having a revolution from west to east, the southern from east to west. This theory accounts for many phenomena, and has received much attention from philosophers in this as well as in other countries.

There has been much speculation as to the cause of this rotary motion of the magnetic axis. Some writers have attributed it to the progressive oxydation of the metals, some to cold, and others to electricity. But the attention of all observers is now turned towards the application of the wonderful discoveries which have been made in the circumstances and effects of electro-magnetic action, hoping that the time may not be very far distant when the cause of magnetism shall be perfectly understood, and its phenomena accurately traced.

CHAPTER VIII.

INTERIOR OF THE EARTH.

When the semi-diameter of the earth is compared with the depths to which geological researches have extended, it is almost literally true, that we are ignorant of the constitution and condition of its interior. But it is singular that, with so few facilities for investigation, so much should have been determined, which in all probability is nearly allied to truth, if it be not truth itself. A few strong-minded individuals commenced the investigation, and although practical inquiries were for some time retarded by the visionary theories that were successively proposed, such facts have now been determined as enable geologists to form some opinion of the successive changes which the earth has undergone, and the causes by which they were produced.

Curiosity is stimulated by the difficulty of obtaining the kind of knowledge that is desired; and, generally speaking, our anxiety to ascertain the nature and action of a cause, is in proportion to the intensity of the darkness by which it is enveloped. Men have from the earliest ages been asking one another, "Of what is the interior of the earth composed? and by what causes is it acted on?" And, in the absence of all information, they have stated wild conjectures as truths, and have maintained their opinions as though they had been founded on the most accurate experiments, or deduced from undeniable principles. Two antagonist theories, the Neptunian and Plutonian, sprang into existence at the very birth of geological science, and have still their advocates; the one attributes the formation of rocks to the agency of water, and the other to igneous causes. There is now little doubt that both these agents have been active in producing the present state of the earth, and the most decided advocates of the Wernerian doctrines are giving up the contested principles of this theory, and admit that heat may have produced some of the appearances we behold.

It may excite surprise that the geologist should have succeeded in ascertaining by direct observation any valuable facts concerning the rocks which form the frame-work of our globe. Had he depended for information upon the examination of those parts exposed to view by the excavations of the miner, his knowledge must necessarily have been exceedingly limited; confined, in fact, to those few beds which lie upon the surface. But all rocks have, more or less, suffered a change of level, and many of the most ancient, that is, those which are lowest, have been elevated above or through the superficial beds, and thus exposed to examination. The geologist has, therefore, but little more to do than to examine the surface of the earth, and he will there find the rocks which he could have only found in the interior, if they had not been disturbed by some subterranean elevating force.

But the inquirer will not be satisfied with knowing the arrangement and characters of rocks, he will be anxious to ascertain what is beneath them; and however distant the reader may suppose us to be from any information on this subject, it will be hereafter shown that the opinions which have been formed are not altogether conjectural. The subject of the present chapter will, we think, be best explained by first considering the condition of rocks, or the crust of the earth ; and, secondly, of that vast space beneath them, called the interior of the earth.

THE CRUST OF THE EARTH.

That part of the interior of the earth open to investigation, has been appropriately called its crust. It is but the crust in relation to its thickness, as compared with the semi-diameter of the earth ; and it may be found true in another sense, when the laws of the increase of internal heat have been fully determined.

Every one knows that the rocks which are exposed on the surface of the earth are marked by great diversities of external characters and of chymical composition In one place we find a granite, in another a rock that bears upon it the marks of igneous fusion, in a third sandstone, and in a fourth clay ; and all these may occur in an extremely limited district. The investigator will be, first of all, anxious to ascertain if they have any constant relation to each other, and to form some general subdivision that may guide him in identifying the rocks of one place with those of the same kind which may occur in another. Now, there are two great classes of rocks ; one is called the primitive, and consists of those which lie at the basis of the series ; and the other is the secondary, which contains the rocks that have been produced by the transport or sediment of mineral substances accumulated by various causes.

Without entering into any lengthened description of rocks or their superposition, we shall state a few principles which may, it is thought, be fairly deduced from the appearance and condition of the mineral masses ; giving, at the same time, the deductive process by which these principles are ascertained. The reader may thus acquire a general notion of the manner in which geologists trace the physical history of the earth, while, at the same time, he informs himself as to the result of their investigations.

1. The causes which are now active in destroying and forming rocks, must have produced the same effects from the

moment they were brought into existence; and when two rocks are found to be identical in mineralogical composition and character, it is a legitimate deduction that they were produced by the same cause, though it may have been more active, or more continual, in one instance than in another. That rocks are being formed in the present day there is abundant evidence. The beds of rivers and oceans are constantly receiving the débris produced by the action of water upon the surface of rocks; springs deposite in some places large quantities of calcareous and other matter; and volcanoes pour over the surface of considerable districts immense streams of lava. But rocks bearing a close analogy to these are found to compose the crust of the earth, and it may, therefore, be deduced, that the causes which are now active in the production of rocks, did produce those ancient masses which form the framework of our globe.

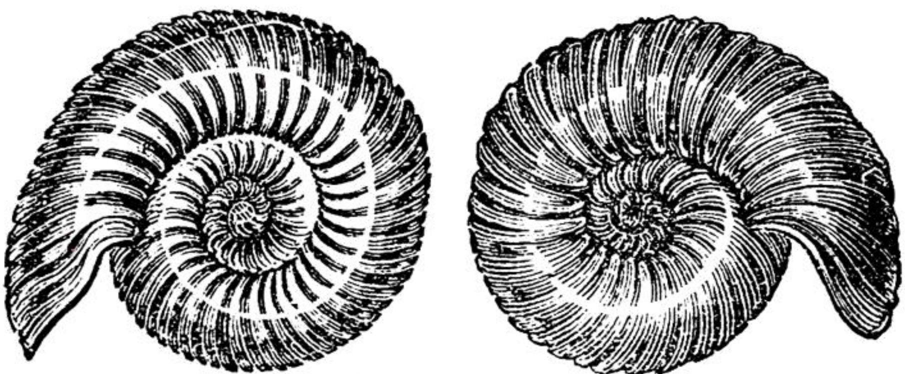
2. The construction of the earth's crust must have occupied a considerable period of time, even upon the assumption that the productive agents were then more rapid in the accomplishment of their effects than they are in the present day. Nearly all the mineral masses that come under our notice are stratified, and were evidently formed by the instrumentality of water; some by the physical power it exerts in transporting the disconnected fragments of pre-existing rocks, and others by a sedimentary process. Of these stratified rocks there are an immense number, some being only a few inches, and others many hundred feet in thickness; a fact which proves that their formation must have occupied a considerable space of time.

3. The circumstance under which a stratum was produced, and, in some instances, the physical condition of the earth at particular periods, may be determined by an examination of rocks. Many of the stratified rocks contain the remains of animals and vegetables that lived at the time of their deposition; and these may be generally employed as evidences of the circumstances under which the bed was formed, and the condition of the earth at the time. In some instances, the organic remains are found in a broken and almost triturated state, proving that the catastrophe which imbedded them was somewhat violent, and, perhaps, somewhat prolonged. In other instances, the most delicate structures of shells have been preserved; and plants are found in such

situations as can only lead the observer to suppose that they were submerged by causes that acted without violence. Some information may also be obtained from an examination of the fossils themselves; for, while some beds contain the remains of animals known to exist in fresh water, others are crowded with the remains of marine animals. Assuming, then, that the habits of these animals were, at the time in which these stratified rocks were deposited, the same as now characterize animals of the same species or genera, a geologist may classify the stratified rocks under the two heads of fresh water and marine. This species of evidence has perhaps been, in many instances, too readily applied, and it is by no means judicious to form an opinion from the presence of one or two specimens. But, when the remains generally have such characters as warrant the observer in the supposition that animals lived in the same medium, he can feel no difficulty in deciding upon the question—was the bed formed in the sea, in a river, or in an inland lake? There are many animals that are known to exist in either fresh or in salt water, and there are many others which may be inured to a change of residence. It may be hoped that this subject will receive a more careful attention than has hitherto been devoted to it; for it is not possible to determine with precision how much dependance can, under certain circumstances, be placed upon the deductions to which we have referred, until it has been ascertained whether animals inhabiting fresh or salt water may not, by a gradual process, be able to exist in, and at last prefer that medium in which they could not live if the transition were sudden. But, however this may be, it is evidently injudicious to form an opinion of a deposite from the presence of a few marine or fresh-water shells, as they may have been brought by some local cause into the situation in which we find them, or they may have had an habitual residence in the fluid by which the bed itself was deposited.

The presence of organic remains in rocks also enables the geologist to compare the present state of the earth, so far as relates to the provisions for the sustenance of life, with its probable condition at the periods when the successive strata were formed. Assuming, again, that the habits of animals were the same then as in the present day, the naturalist may readily determine the conditions which must have existed for the support of these animals. But many of the animals, the remains of which are discovered imbedded in the mineral masses, are now extinct, so far as our knowledge of existing genera extends. The reptiles appear to have had, at one period, a great predominance over all other creatures, and many of them must have possessed forms and habits very different from any that are now known to be borne by animals of the same class.

If we look to those classes of animals known among naturalists as the mollusca and conchifera, we shall find that they also have been destroyed by the ravaging hand of time Some of these have existed in vast numbers, as the multitudes that have escaped destruction and are preserved in the solid strata fully prove; and there are some genera, the Ammonite



Species of Ammonite.

for instance, that contained so many species as to give no slight trouble to the naturalist in his endeavour to find them names. To ascertain the exterminating process which has swept from the surface of the earth so many forms of being, may be a difficult task; there are, however, causes in the present day, independent of the destroying agency of man, tending to decrease the number of certain species; and animals known to be in existence a few years since are not now to be found. Many animals are distributed in localities, frequently of small extent, and any violent physical cause acting upon those spots might destroy the entire race. Australia appears to have a class of animals entirely its own; and should it, at any future period, suffer under one convulsion, similar in intensity to those which were common during the deposition of rocks, and be submerged, a large number of terrestrial animals would become extinct; while an elevation of the bed of the sea would be equally destructive to many marine animals.

The geologist may also gather some information concerning the circumstances under which a deposite was formed from the mineralogical structure of the bed itself. Gravel must be the effect of an impetuous motion of water; it consists of fragments broken from rocks *in situ:* some of these are rounded, which could only be occasioned by the rolling motion given to them by the fluid, and we may therefore always connect an aqueous cause with the existence of a pebble. In these gravel beds we find the fossils which characterize sedimentary rocks blended together, and hence we know that the force which produced them must have acted upon an extensive tract of country. When beds of clay and limestone are found, the observer has evidence of a more gentle, though, in all probability, a more continued action of water, whether of rivers or of springs.

4. Some geologists have imagined that they could deduce, from the character of the animal and vegetable remains found in rocks, a change of superficial temperature. The plants that are found in the coal measures, even in those of our own country, are of a tropical character, and must have grown in countries that possessed a temperature nothing inferior to that of the equatorial regions. There are two hypotheses by which their presence in cold northern climes may be accounted for; either they were drifted by the sea to their present places, which might happen without destroying their texture, supposing them to have been under the pressure of a considerable body of water; or they grew in the countries where they are now found. In the same manner we may suppose the animals, whose remains are found in rocks, to have lived near the places where their remains are imbedded, or to have been transported by causes posterior to that which destroyed life. There is one objection that stands in the way of the former supposition; for if we acknowledge that animals and vegetables lived near to those spots in which their remains have been discovered, it is scarcely possible to avoid the conclusion, that at some former period there must have been an equality of temperature over a large portion of the earth, a supposition that is not consistent with physical principles.

5. From the presence of marine animals in stratified rocks, we may deduce that the dry land must at some former period have been covered by the sea, and that the bed of the ocean must have been more than once elevated by some great con-

vulsive force. The stratified rocks must originally have been horizontal, or nearly so, and many of them were formed in the same manner as the deposites which are always to be found in the beds of rivers and the basins of oceans; but they were afterward acted upon by mighty disturbing forces, which elevated and disrupted them, throwing their strata into a variety of forms. Some were upheaved in a mass by an invisible but omnipotent agent acting beneath them; some were tilted into inclined positions; and others, acted upon in more than one point, were made to assume the form of a basin. These effects have been both local and general, at one time affecting a district not more than a few miles in extent, and at others elevating entire continents and immense mountain chains. The agent, as we believe, that produced these mighty effects, was internal heat; the same cause which in the present day mimics its former results by the exhibition of volcanic action and other phenomena, to which it will be hereafter necessary to refer. The identity of cause is proved by the identity of effects, not only in the disturbance of equilibrium, and in the arrangement of the solid materials of the earth's crust, but also in the character of the ejected matter; for, during the continuance of those mighty disturbances to which the earth was subject when its crust was in the process of formation, immense fissures were frequently formed, and from these the intumescent mass was thrown, producing overlying rocks of various extent and thickness. The summits of mountains frequently consist of these unstratified rocks, which have been elevated into their present condition by the internal force. At other times they are seen between stratified beds, bearing evidence, in their position and construction, of the fact that the upper bed was formed after the consolidation of the volcanic rock that disturbed the inferior mass. Not unfrequently these unconformable rocks, as they are sometimes called, assume a columnar structure, as at Staffa, Egg, and Antrim; and in other situations they may be crystalline or massive. It may, however, be necessary to remark that the ejection of these volcanic rocks did not necessarily attend the exertions of these internal disturbing agencies; for as an earthquake may happen in the present day without the actual ejection of lava, so the same force did in the early ages upheave the crust without any ejection of liquefied rock.

From these remarks it will be evident that the horizontal beds have been elevated; and in proof of this statement we have not only the evidence which is afforded by the presence of marine animals at elevations far above the present level of the sea, but also the existence of rocks which were produced by the action of internal heat. The discovery of marine fossils at considerable elevations is not of itself sufficient to prove that horizontal deposites have been elevated, but when the elevation of these beds has been determined, and the igneous mass that upheaved them is found, there can be no remaining skepticism.

GENERAL REMARKS.

Admitting the statements which have been made, it will appear that the crust of the earth, so far as it is open to investigation, consists of a variety of compound substances, some having been produced by water, and some by intense heat. A superficial examination of these would lead the observer to imagine that they are destitute of arrangement; and, if they should be examined mineralogically, they are so; but, by the united assistance of mineralogical characters and the contained fossils, a tolerably perfect system has been produced; so accurate, at least, that the geologist may generally predict the succession of rocks without much chance of failure. The unstratified rocks have no constant place, but are associated with the deposites of all ages, a circumstance that might be expected from their origin; and the convulsions to which strata have been subject were confined to no particular era, although they appear to have been most violent and extensive during the formation of the older rocks.

Looking at this subject for the purpose of theoretical deductions, we are certainly led to the conclusion that the formation of the earth's crust was a work of time, and was accomplished by secondary agents of varying intensity, such as are now existing and exerting an influence on the surface of the earth. We must not, however, imagine the earth to have been, during this succession of ages, an unpeopled waste; for in every period after the formation of the primitive rocks it appears to have been inhabited by a class of animals, and decorated with vegetation suited to its physical condition; and the imbedded remains are sufficient evidence of this fact. But the violent changes to which the superficies of the earth were subject, could hardly fail to be exceedingly destructive of life, and we accordingly find that many genera which are abundant in certain rocks are not to be found in others, and are now extinct. But it is a singular circumstance, and perhaps scarcely to be accounted for on known principles, that every suite of beds contains fossils peculiar to itself, and by these it may be very readily distinguished.

THE ORDER OF ROCKS.

The term rock is applied to all masses of mineral substances, whether they be granites, clays, sands, or other compounds. The word, in its common acceptation, means a mass of some hard mineral, but it is used by geologists in a more general sense, and signifies a component part of the earth's crust, without reference to the quality of hardness or tenacity, and in this sense a bed of clay or of sand is a rock.

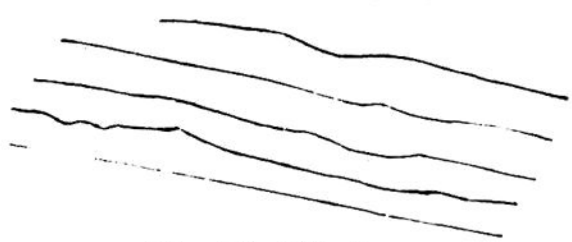
From a partial examination of rocks, it might be supposed that they are indiscriminately situated in relation to one another. This is the common opinion, and is believed by all those who are quite ignorant of the science of geology. The interior of that world which exhibits such wonderful order and skilful arrangement on its surface, is, in their imagination, a very type of confusion. So natural is this supposition, that it is probable we might still indulge the error, had not the investigations of miners insensibly led them to trace the connexion of one rock with another. It was early discovered by these practical geologists, that certain ores could only be found in certain rocks, and that they were always associated with others of a particular character. In their search for ores, after this discovery had been made, they endeavoured to assure themselves of the presence of some of these beds, before they expended either capital or labour in closer examination. The more scientific observations which have been since made, have extended the facts first observed in particular instances to the entire system of mineral masses, and there is now no principle better substantiated than the regular arrangement or order of rocks.

This statement may appear somewhat inconsistent with the remarks already made, and it is quite possible to give it a too minute acceptation. The earth is not composed of a series of beds arranged one over another, like the coats of an onion, nor are the strata so equably spread over each other that it is only necessary to pass through them in one place to know the constitution of the whole globe. If the surface be bored through in different places, the same number of beds will not be found in any two, nor will they generally have the same character; and if they should be at any distance from each other, that rock which is most abundant in one place may be absent in another, which could not be the case if the beds were regularly arranged one over another, extending round the whole globe.

But still it is true, in a more general sense, that rocks have an undeviating order. There are two mineral substances well known to everybody, chalk and coal; and chalk is always above coal in the order of rocks. It would be foolish to search for chalk at Newcastle, for in no instance has it been found beneath the coal-beds. So, again, Portland stone, used for building, could not be found in a country where coal is found on the surface. It is supposed by many persons that coal may be obtained upon Blackheath, in the vicinity of London; but the geologist is quite certain that it cannot, for the beds in that district belong to a formation considerably above that with which coal is associated. It would therefore appear that, as a general principle, rocks are always found in a certain relative position, but it is not true in particulars. In all the most characteristic and important rocks the rule may be depended upon, in those of small extent and of a secondary character it cannot. A geologist could not assert that a bed of clay or sand would be found beneath the surface at any place, but he could tell whether coal, building-stone, or chalk might be expected.

STRATIFICATION OF ROCKS.

Rocks may be divided into two classes, stratified and unstratified; the greater number belonging to the former class.



Stratified Beds.

Strictly speaking, a stratum is a bed of rock having two parallel faces. If a bed be placed in a flat or horizontal position the upper and under surfaces should be parallel to one another; if in a perpendicular direction, its vertical surfaces should be parallel. But the term does not admit of this great accuracy of definition, and those beds that have not strictly parallel planes are considered to be stratified.

It may appear a very easy thing to determine whether a rock is stratified or not; but there are many practical difficulties, and he who examines rocks for the first time is very liable to deception.

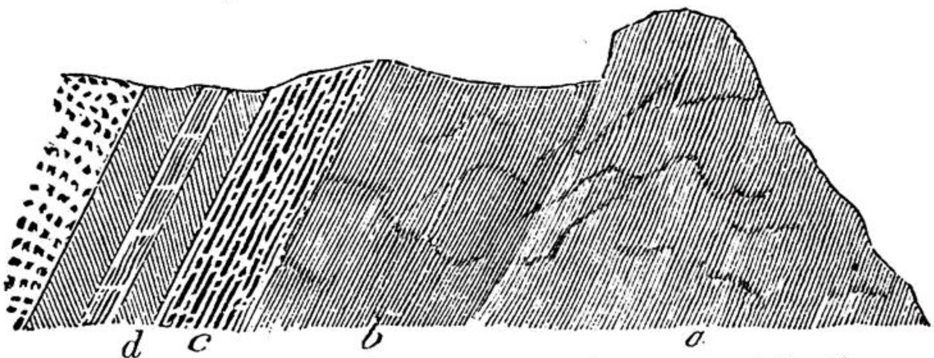
It was once a subject of discussion among geologists, whether granite is stratified. M. Gruber thought the stratification so evident, that he doubted whether the man who was not of his own opinion could see at all. Dr. Mitchell says he traced a stratified granite for sixty miles along the chain of the Risengebirge, and Professor James for one hundred and fifty miles. Yet Von Buch strained his eyes in vain to observe some appearance which should bring him to the same opinion, and, after a diligent search, gave up the pursuit in despair. A celebrated Swedish naturalist says, he never saw an unstratified granite; and an equally eminent English geologist never saw a granite stratum. It is, however, now generally admitted, that granite is not a stratified rock. But it is important to inquire into the circumstances which deceived so many eminent observers, that we may avoid the sources of error that misled them.

CLEAVAGE OF ROCKS.

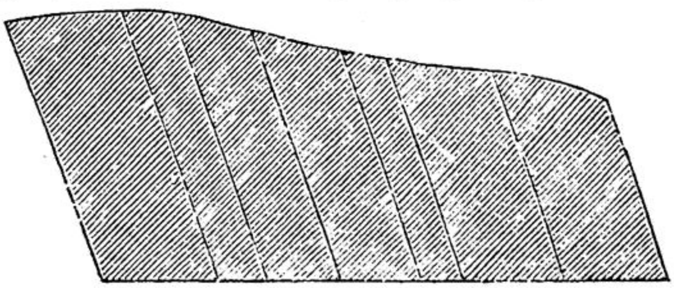
It is well known to mineralogists, that there are certain crystallized minerals which may be more easily split in a particular direction than in others. Some minerals are cleavable only in one direction, others may be cleaved in two, three, or more, and the latter may often be made to assume regular geometrical forms.

Rocks also have frequently a line of cleavage, called by workmen the grain of the bed. Those who work granite are accustomed to look for the direction of cleavage; and although the indications can seldom be detected by a person unacquainted with the practical working, the miner has no difficulty in fixing upon the direction in which the rock will most readily split.

Now, it is this line of cleavage that is frequently mistaken for stratification—it was this that deceived geologists as to the stratification of granite; and when this rock is associated with really stratified rocks, and its cleavage is in the same direction as their strata, a circumstance by no means uncommon, it is almost impossible to convince one's self that there can be any difference between the stratification of the one and the cleavage of the other. Generally speaking, however, the lines of cleavage run into and join one another in such a way as to distinguish them from strata. *d c b*, in the following diagram, represent stratified beds; *a*, a granite rock, having its line of cleavage in the same direction as their strata.



It frequently happens that strata are intersected by lines of cleavage, so as to form an angle approaching more or less to a right angle, as in the accompanying diagram. In the clay

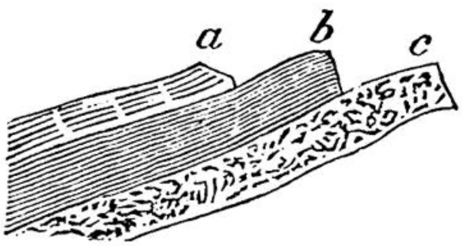


Section of Clay Slate Rock.

slates, this is not an uncommon appearance. We have particularly observed it in Devonshire; and in an attempt to determine the true stratification, it is sometimes the cause of considerable difficulty and of error; but by careful inspection the strata may generally be distinguished.

It must often have been observed by all who have walked over an extensive district, that rocks succeed each other in some constant order; and every one knows that the same rock does not appear at the surface in all places. But, if rocks were placed horizontally, one upon another, the same rock would always appear at the surface. Thus, London is situated upon a clay, called by geologists London or blue clay, and if we bore through this bed we find chalk, that rock being always situated beneath the London clay. Chalk, therefore, could never be found at the surface, if rocks were arranged like a pack of cards upon a table, without the removal of the upper bed. This, however, is not the arrangement we observe upon examination, for at a very short distance from London, Shooter's Hill for instance, chalk is found to be the superior rock.

It is seldom that strata occur in a perfectly flat position, but they are generally inclined, more or less, so that one emerges from beneath the other, as shown in the diagram.



Inclined strata, *a b c*.

In consequence of this arrangement, we may, by travelling over a country, determine the character of the rocks of which it is formed, with even more accuracy than could be attained by piercing through the whole of the beds at the surface of the highest rock.

In this arrangement we cannot but observe a proof of design, for by the present disposition of beds, man is made acquainted with all those which are necessary for his comfort and the advance of the arts of life ; and he can obtain them with little or no exertion. If rocks had been placed in a flat position, it is not probable that we should ever have discovered either coal or the metals ; for as these are situated so low in the series that it would be necessary to bore to the depth of many thousand yards in order to obtain them, it is doubtful whether any inducement to make the attempt would have been offered. But supposing that from any circumstance their existence and properties had become known, their situation would effectually prevent their being obtained in sufficient quantities to supply our wants. It is scarcely to be imagined what would be the result if all the coals and metals were expended, much more to determine the condition in which man would now be if they had never been known ;

but in all probability society could not have been formed, and civilization would have been unknown.

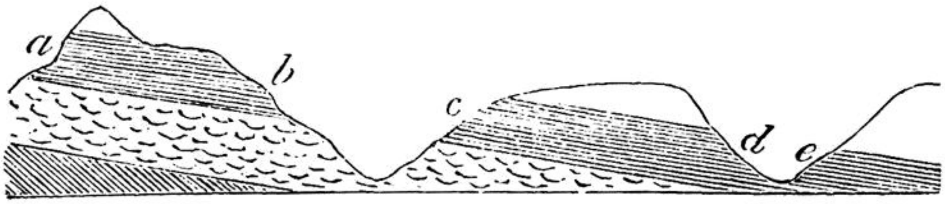
Some of the difficulties which attend the investigator in an attempt to determine whether a rock be stratified have been noticed, but his difficulties will not vanish when he has convinced himself of its stratification; this is only the first step in the practical investigation of a district, and it is not improbable that he will take the apparent for the real stratification. There are two aspects, the front and the side view, in which a stratified bed may be examined. Take a number of boards, a foot long and three or four inches wide, and arrange them so as to represent strata emerging from beneath each other. If these be viewed in the direction of their shorter length, an accurate notion of their stratification will not be obtained, for the real stratification is in the direction of their length.

It will now be readily conceived that a beginner may easily be deceived by mistaking the apparent for the real inclination of the strata, and describe beds as perfectly flat which have a considerable dip. Suppose the beds to range north and south, it is possible that there may be no natural section in that direction by which the true inclination can be seen, and a section in any other direction will make the dip to appear less than it is.

The student must also be careful to examine the relative positions of the beds, for in this respect he may be easily led into error. One bed must not be supposed to be above another, because it is found at a greater height, or forming a hill, while the other occupies the valley. The relative height of two beds is no criterion in determining their relative position.

In examining a district composed of stratified rocks, the student may experience some difficulty from the intersection of valleys. Passing from one place to another he may meet with the same rock two or three times, and be led to imagine that it occurs two or three times in the series. In this manner the beginner is often greatly perplexed, not remembering the relative heights of the places in which he finds the frequently occurring bed.

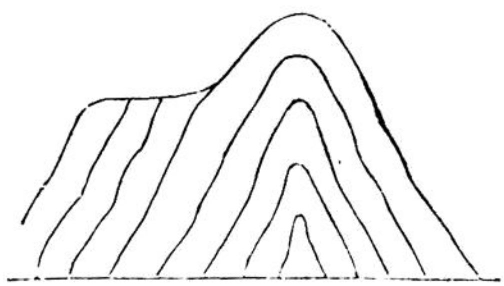
This may be explained by the accompanying figure; for a traveller, walking over the district it represents, would come upon the same rock five different times; and as it is not so easy to see the relation which one rock bears to another when walking over the country in which the rocks themselves occur, as in casting the eye upon a section, the beginner would very probably be deceived by such a result, and ima-



gine that there must be a great want of analogy between it and geological arrangements generally. The section, however, shows that the exposed parts *a b c d e* have been presented to view by the formation of two valleys: for if the line of inclination in one hill be carried on, it will be found to join on with that in the others. This fact is received by geologists as an evidence that the valleys were formed after the deposition of the beds.

But there are other difficulties of even a more serious character than those to which allusion has been made. The strata which compose the crust of the earth are not in precisely the same condition as when they were formed, but have been disturbed by a variety of powerful agents that have acted upon them in various ages. Sometimes rocks have been affected by violent volcanic agents, and at other times they have acted upon one another by pressure, or upon themselves by shrinking and subsidence.

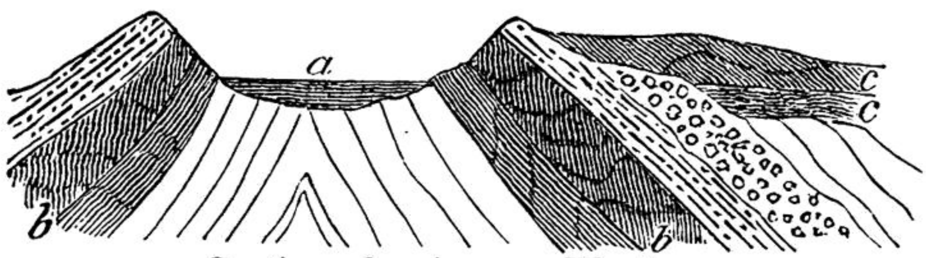
Instead of regularly emerging and slightly inclined beds of which we have been speaking, strata are sometimes found in a position not unlike the roof of a house, piled up on their edges one against the other, forming a steep ridge of rocks.



Saddle-shaped stratification.

This form is called the saddle-shaped stratification. If we take a piece of some resisting substance, and fastening it at the ends, apply a force in the centre sufficient to raise up the central parts, it will either break or bend, and will remain in that form which it assumes as long as the force remains, or as long as there is any resistance below sufficient to prevent it from taking its original form. A similar action in all probability caused strata to take this peculiar position. We may imagine them to have been originally formed almost horizontal, and some force acting from beneath to have afterward tilted them up, piling them on their edges.

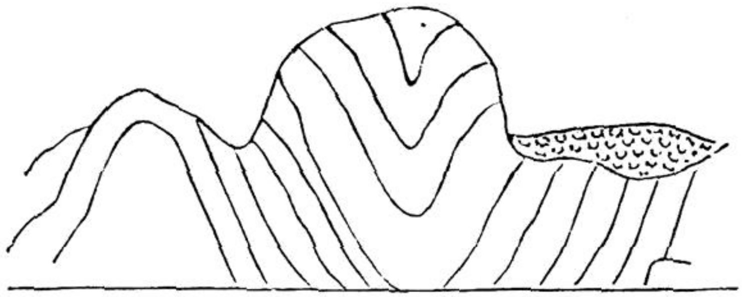
This kind of stratification is sometimes presented in a still more complex form. At Westbury, in Somersetshire, there is an example of a saddle-shaped stratification which would hardly be recognised as such. The upper portion of the strata is in this instance removed, apparently by the action of water, and a valley has been formed, in which a flat stratum



Section of rocks near Westbury.

of gravel has been deposited. *a* represents a valley covered with gravel; *b*, *b*, tilted rocks; *c*, *c*, rocks resting on them in an undisturbed position. But, before we pass on, we may be permitted to draw the attention of the reader to another circumstance peculiarly marked in this section. There are five successive periods distinctly marked in the present condition of the rocks at Westbury. First of all, the formation of the beds, which, if deposited by water, must have been nearly horizontal in the first instance; then their elevation, so as to produce a saddle-shaped stratification; then the deposition of the rocks that rest upon the disturbed strata; then the action of water scooping out the valley; and lastly, the formation of the bed of gravel in the bottom of the valley When the series of active agents employed in producing the present appearance of rocks is considered, it becomes the geologist to make his deductions with caution, and never without careful examination.

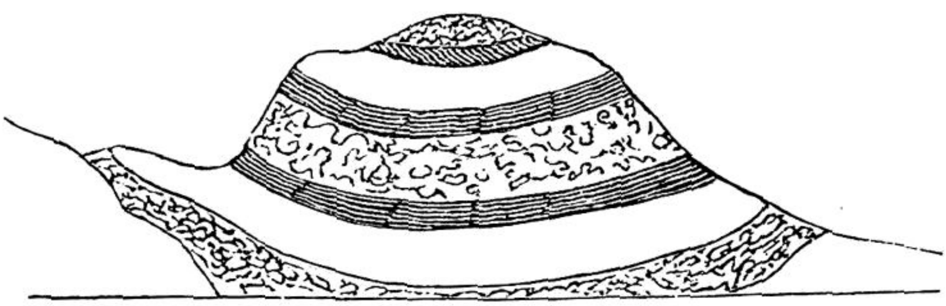
The fan-shaped stratification is the reverse of the saddle-shaped. The following figure is a section of the mountain limestone, as it occurs at Daleberry Camp, and is an example of this variety of stratification. To produce this appearance there must have existed a different condition from that which would produce a saddle-shaped stratification, which requires, as we have seen, a force acting upon the centre of a bed that



Section of fan-shaped strata.

has two ends in a fixed position. A fan-shaped stratification, on the other hand, can only be produced by the action of two forces, one at each end of the bed, while the centre is partly retained in its position. Thus a piece of card, having a weight in the middle, may be raised by the hands at each end, and be made to assume this particular form. From this it would therefore appear, that to produce the stratification observed at Daleberry Camp, the ends of the strata must have been upheaved, probably by some force similar to that which now produces volcanic action.

The basin-shaped stratification is not uncommon in coal districts. Geologists are not agreed as to the cause of this appearance, some attributing it to the elevation of the beds as described in explaining the formation of fan-shaped stratification, while others imagine it to have been produced by the sinking of the central parts. It is not impossible that both



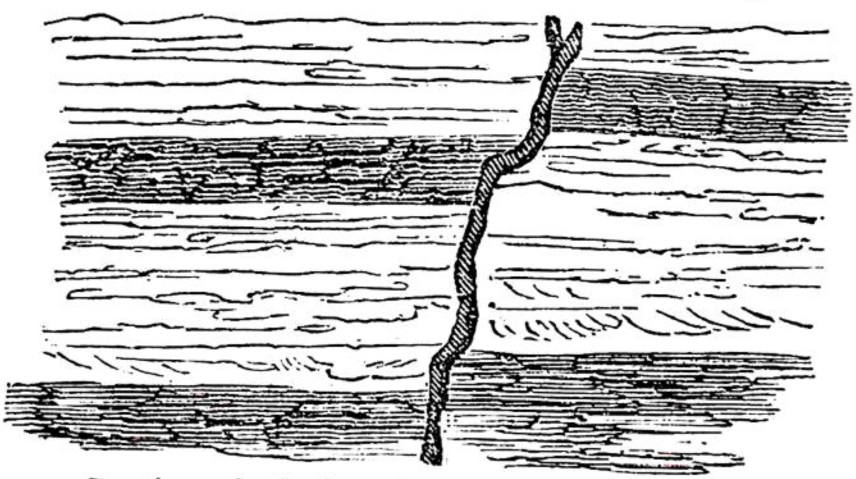
Basin-shaped stratification.

these causes have assisted in producing this peculiar disposition of strata. One thing, however, is certain, that there must have been a great degree of flexibility in the materials.

The task of determining the stratification of rocks in any district will not now perhaps appear so easy as might at first have been imagined. The art must be acquired by practice and the habit of close attention; and though there are occasional appearances which perplex the inquirer, yet the commonly occurring conditions of rocks are such as to give the practical geologist but little trouble. It cannot be too strongly impressed upon the student how necessary it is to examine for himself, if he intend to make himself a master of science, or to be useful to those who are to follow him. In geology practical studies are peculiarly necessary, for it is quite impossible that any adequate or accurate notion of the real constitution of the earth can be obtained by reading. He who would be a geologist must by constant personal exertion endeavour to form his opinions from the study of rocks in their natural situations. A life devoted to the perusal of geological papers will scarcely be sufficient to give an adequate knowledge of geology; for although a strong mind might be able to detect many errors in the theories which are proposed by geologists to account for various appearances, yet from the habit of dependance on the descriptions of others, even that mind would scarcely be in a state to propose any new explanation, or trace the origin of the error.

ELEVATION OR DEPRESSION OF STRATA.

There is another circumstance in relation to the stratification of rocks which is worthy of notice, as it may be a source of some difficulty to the beginner, and will frequently occur. Strata have been in some instances deranged by fracture,



Section of a fault at Tynemouth Castle Cliff.

and a portion of them has been depressed or elevated. In consequence of this it sometimes happens that a geological observer, after having traced a particular bed for some time, suddenly loses sight of it, and comes upon some bed above or below it, according as the strata may have been elevated or depressed. The point where this elevation or depression has occurred is called a fault. The preceding figure represents a fault in Tynemouth Castle Cliff, on the coast of Northumberland, observed by Professor Sedgwick, and, though not of great extent, affords an illustrative section. In this locality the strata have been fissured, and shifted from their natural situation. The coal-beds are peculiarly subject to this particular disturbance, to the no small inconvenience of miners; for it frequently happens that, after having worked a bed for a considerable time, it is suddenly lost, and many months or years may be expended in the effort to regain it.

CLASSIFICATION OF STRATIFIED ROCKS.

Having stated and explained the various appearances which stratified rocks present, and suggested the explanation of some difficulties that may be experienced by the beginner in the process of his inquiries, our next object must be to explain the classification which has been adopted by geologists. Plans of classification can only be considered as arbitrary arrangements, formed for the purpose of facilitating the study of the sciences, and of combining isolated facts. To form an advantageous classification requires a considerable knowledge of facts, and on this account the systems adopted in the infancy of particular sciences have been found unsuited to their maturer growth. This has been exemplified in the progress of geology. It was at first doubted whether a system formed upon the mineralogical character of rocks, or upon their position in relation to one another, would be found most advantageous. This doubt was removed by the increase of knowledge, and the latter plan has been universally adopted.

One of the first classifications of rocks was formed upon the discovery that some rocks contained animated and vegetable remains, while others were destitute of them. The rocks lowest in the series, that is, those at the greatest depth to which our researches have extended, do not contain fossils, and were therefore supposed to have been formed before the creation of things that had life, and were arranged under a class called primitive or primary; while those which possessed these relics of organization were denominated secondary rocks. But, as the science advanced, an intermediate class appeared necessary to comprehend a series of beds formed of the fragments of primary rocks, and was adopted under the name of the Transition or Fragmentary class. Another division, called the Tertiary, to comprise the upper beds of the Secondary, has since been added, so that, according to this system, the substances which form the crust of the globe may be arranged in the four following classes, beginning with the lowest :—

1. The Primary, or Crystalline.
2. The Transition, or Fragmentary.
3. The Secondary, or Sedimentary.
4. The Tertiary, or Upper Secondary.

This classification was universally adopted in this country, till the publication of "Conybeare's Geology of England and Wales." In this work a new classification was adopted, and the crust of the earth was divided into five portions, forming the following classes :—

1. The superior, containing the tertiary deposites.
2. The supermedial, containing the upper portion of the secondary class.
3. The medial, containing the coal series and the lower portion of the secondary rocks.
4. The submedial, comprising the transition rocks.
5. The inferior, containing the primitives.

The most convenient and useful classification that has been introduced, we think, is that proposed some time since by M. De la Beche, in the Annals of Philosophy, and recently adopted with great success in his Manual of Geology. But there are many objections to the introduction of new classifications; and geologists do not always adopt those suggestions which they may consider improvements. By using an established classification, the learned of different nations are able to understand each other's writings; but when new arrangements are adopted, a considerable time must elapse before a foreigner is made acquainted with the change; and even then, prejudice would, in many instances, prevent its adoption. Such alterations can only be effectu ally introduced by societies, or the combination of writers; for, generally speaking, an old nomenclature, with all its imperfections, will be preferred to a modern improvement. But the system proposed by M. De la Beche is, in our estimation, so very superior to all others, that we are willing to hope it may be an exception to the general rule, and be adopted not long hence by geologists.

All rocks may be divided into two general classes, stratified and unstratified; and this forms the first division of this system. The next general truth is, that the lower stratified beds do not contain fossils, whereas the others do; hence, we have a subdivision of the stratified rocks into fossiliferous and non-fossiliferous. It then only remains to arrange the strata in groups and formations, and we at once obtain an easy and an intelligible system.

It would be impossible to describe, in these pages, the peculiarities and relations of the beds that together constitute the crust of the earth. We shall therefore proceed to an investigation of the unstratified rocks, and then make a few remarks upon the coal measures in illustration of the statements advanced.

UNSTRATIFIED ROCKS.

The unstratified rocks are extensively distributed over the globe, but cannot be said to occupy any constant position in the series, for they are occasionally associated with nearly all the several groups. It is now generally supposed by geologists that they derived their present appearance, and were placed in their present positions, by the agency of fire; and, upon this supposition, it is easy to explain the origin of the variety of appearances they present, and of the circumstances under which they occur. Sometimes we find them as masses overlying other rocks, and presenting an appearance similar to that of the lavas which are ejected in the present day by volcanoes; while at other times they occur as vein-stones, filling fissures which, in all probability, were formed by the pressure of the vapours which arose from the boiling mass.

The unstratified rocks, as might be expected from their origin, greatly differ among themselves in mineralogical character. Even the same mass of rock will have a variety of appearances in different parts. Deriving their present condition from the agency of fire, many compounds, whatever may be the number of minerals that enter into their composition, must be formed, some containing more and others less quantities of particular substances, varying with the intensity of the heat that produced the rock. Some of the minerals that enter into the composition of the unstratified rocks being more easily fused than others, we may imagine that, under some circumstances, one difficult of fusion has not been reduced to a liquid state, while others, less resisting the action of fire, may have been ejected. To the shades of mineralogical distinction produced by this and similar adventitious causes, some writers have attached great importance, and have given names to the several varieties of rock; but it may be doubted whether science has derived much advantage from this particularity, and it is possible that the time expended in describing and naming them would, in the present state of our knowledge, have been better employed in determining their general characters and probable physical constitution.

The importance of the unstratified rocks, in relation to the extent of space they occupy on the surface of the globe, is much inferior to that of the other class. In England they do not cover one thousandth part of the surface, and the same observation might be made in reference to many other countries. Generally speaking, they occupy the highest points of the district in which they occur, and some of the loftiest peaks and ridges on the surface of the globe are composed of them. It must not, however, be understood that they always occur in such positions; for although they compose some of the points of the gigantic mountain chains of South America as well as of the Alps, yet they sometimes are found on the seashore, as in many of the Western Isles.

Another fact worthy of notice in relation to the unstratified rocks, is their great want of continuity. Stratified beds frequently extend over considerable districts, and may be traced at the surface for many miles. The unstratified rocks, on the other hand, rarely occupy any considerable extent of surface, but protrude themselves among the stratified at considerable distances from each other, and in comparatively small quantities. "In Scotland, it is not unusual," Dr. Macculloch states, "to find a portion of some one of these rocks, of a few yards in diameter, separated for many miles from any other mass of the same rock, though it is possible they may be united beneath the surface."

A few observations may be made on the two classes of unstratified rocks, the granitic and the trappean.

GRANITIC ROCKS.

The term granite is derived from the word *geranites*, and Tournefort, the celebrated naturalist, was the first modern author who employed it; but, at the time in which he wrote, it had a much wider signification than it has now, and was used to designate a granular stone.

The minerals which commonly enter into the composition of granite are quartz, feldspar, mica, and hornblende, and the combination of any two or more of these constitutes a granite. It must therefore be evident that granite differs greatly in its composition. Feldspar is generally the most abundant; but this mineral, as well as others, varies in its proportions, and is sometimes absent. A granite of Mount Blanc is composed of feldspar, quartz, and chlorite; one in Aberdeenshire consists of feldspar and hornblende; and another in Perthshire, of quartz, feldspar, and actinolite. Mr. Poulett Scrope, in his splendid work on Central France, speaks of a granite, constituting a very extensive tract in the department of Haute Loire and Ardêche, which contains so much pinite, that it is estimated to form a third part of the rock. It must then be evident that the composition of this rock is various, and its colour will depend upon that of the preponderating mineral. Granite was formerly supposed to be the primary rock, that upon which all others were formed. This opinion is now found to be erroneous; for although it frequently has its place beneath all the stratified rocks, yet it not uncommonly takes a higher position. Werner arranges the granites in three classes. First, the primitive, or that which is the basis of all other rocks; secondly, that which traverses other rocks in veins, as may be seen in Iona, Barra, Tirey, and others of the Western Isles; and thirdly, that which superposes other rocks, as at St. Gothard, where it rests on mica slate, and at Kielwig, in Norway, where it lies above clay slate.

Granite is not abundant in England, but in Scotland and Ireland it occupies a considerable extent of country. The granitic region of the eastern mountain chain of Ireland commences on the south side of Dublin Bay, and stretches continuously to Blackstairs and Brandon. Those countries which consist of granite are generally mountainous and rugged, and abound in sublime scenery. Glendalough, in Ireand, is a fine example; the lake, the precipitous sides of the jagged mountains, and the waterfall, will not fail to excite a state of mind often to be recalled with enthusiasm.

Mr. Bakewell has described a very remarkable appearance presented by a granitic spire in the valley of Chamouny, which will give an idea of the mountainous country that usually attends the appearance of this rock. "The most striking object in the valley of Chamouny," says Mr. Bakewell, "next to the glaciers, is the Aiguille de Dru, a taper spire of granite, which shoots up to the height of eleven thousand feet above the level of the sea, and is apparently detached from all the surrounding mountains. The upper part, or spire, rises nearly to a point, in one solid shaft, more than four thousand feet; it is utterly inaccessible; its sides are rounded, and are said to have a polish or glazing like that which is sometimes seen on granite rocks exposed to the action of the sea. By what means it has been shaped into its present form, is difficult to conceive. When approaching the Glacier de Bois, it is impossible to view without astonishment this isolated pinnacle of granite, shooting up into the sky to such an amazing height."

But although granite is found in some of the highest chains of mountains, as the Himalaya and the Alps, yet it sometimes occupies comparatively level countries. A skilful geologist may generally detect the presence of this rock by the singular but almost indescribable diversity of outline it gives to a district. At one time we find it constituting a ridge of mountains, or a single peak, and in others it barely makes its appearance at the surface, as though the force which ejected it had been just counterbalanced by the resisting force of the rocks with which it was covered.

TRAP-ROCKS.

A number of rocks having a resemblance to one another in mineralogical characters, have been classed together under the general term *trap*, from the Swedish word trappa, a stair, because of the stair-like appearance they often present. The individual kinds of this class of rocks greatly differ in appearance the one from the other, and are designated by different names: thus we have basalt, greenstone, clinkstone, and others. They are supposed to have been formed, like granite, by the agency of fire, and are not only found intermixed with the stratified rocks, but have also filled up the fissures which have been made in them, and produced veins.

One of the most singular circumstances in connexion with the trap rocks is the columnar structure they sometimes assume. The Giant's Causeway and Fingal's Cave are two justly celebrated examples.

The Giant's Causeway is situated on the northern coast of Antrim, in Ireland. It commences, in one direction, at the base of a cliff rising to the height of six hundred feet above the level of the Atlantic. The causeway consists of an immense number of columns, which project into the sea to a considerable distance below low-water mark. Its length at low water has been computed at about six hundred feet, and its greatest width at about two hundred and forty feet: the height of the columns varies. The majority are not more than twenty feet high, while others have been found to measure six-and-thirty. But besides the mass of columns which constitutes what is called the Giant's Causeway, there is a great number of the same kind spread over the country to a considerable distance; the causeway is in fact only a portion of a great area consisting of basaltic rock.

Fingal's Cave.

Fingal's Cave, in the Island of Staffa, one of the Hebrides, is formed of the same rock as the Giant's Causeway. The entrance to this most splendid cavern is about fifty feet broad, and one hundred high. The entire length of the cave is two hundred and fifty feet. On each side there is a series of beautifully-formed and regular columns, and the broken pillars of the roof present the appearance of the enrichments of Gothic architecture. "But if this cave," says Dr. Macculloch, "were even destitute of that order, symmetry, and richness, arising from the multiplicity of parts, combined with greatness of dimensions and simplicity of style, which it possesses, still the prolonged length, the twilight gloom, half concealing the playful and varying effects of reflected lights, the echo of the measured surge as it rises and falls, the transparent green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or in nature If to those be added that peculiar sentiment with which perhaps nature most impresses us when she allows us to draw comparisons between her works and those of art, we shall be compelled to own it is not without cause that celebrity has been conferred on the cave of Fingal."

Many other of the Western Isles exhibit beautiful examples of the trap-rocks, among which we may especially notice the picturesque Island of Egg. The Scuir, which is the most remarkable appearance, is an immense columnar mass of trap, of that variety called pitchstone porphyry, and is upwards of thirteen hundred feet above the level of the sea. "Viewed in one direction, the Scuir presents a long irregular wall, crowning the summit of the highest hill, while on the other it resembles a huge tower. The clouds may be often seen hovering on its summit, and adding ideal dimensions to the lofty face; or, when it is viewed on the extremity, conveying the impression of a tower, the height of which is such as to lie in the region of the clouds. Occasionally they sweep along the base, leaving its huge and black mass involved in additional gloom, and resembling the castle of some Arabian enchanter, built on the clouds and suspended in the air."

We have noticed these few instances of columnar structure sometimes assumed by the trap-rocks, but it must not be considered as a universal appearance. They are not unfrequently found to overlie the stratified rocks, and in this state they possess all the distinguishing characters of recent volcanic products. It is not unusual for them to form groups, or ridges of mountains, having considerable elevations and rounded forms, and at other times, the districts in which they occur present low and gentle undulations. This tameness of outline may, perhaps, in some measure, be attributed to their igneous character, and the circumstances under which they were formed; but in a still greater degree to the rapid disintegration which the rocks have suffered in consequence of the yielding nature of their material. There is, however, another form under which the unstratified rocks are presented to our notice, and that is as veins.

GRANITE AND TRAP VEINS.

It has been already stated that the unstratified rocks are frequently found to traverse other rocks in the form of veins. From the appearance which is thus presented, we gather an *evidence that they have been in a state of igneous fusion, for* it is only by this supposition that we can account for the existence of veins. If we imagine granite or trap liquefied by heat to lie beneath any stratified rock, it is evident that it may be forced into any fissure that may be made, and form a vein, when it has solidified by cooling. So, if a liquefied rock flows over another rock, it will enter into all the openings in its surface.

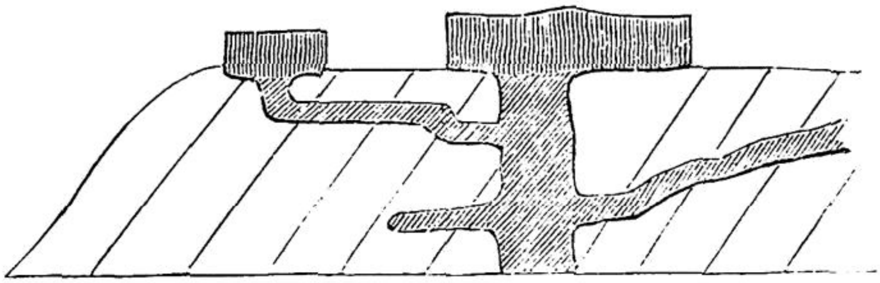
Some years since, when the Wernerian theory was in vogue, the existence of granite veins was doubted by many geologists, but we have now abundant examples. In the neighbourhood of the Land's End in Cornwall, in the Alps, and in many parts of Scotland, particularly in Glen Tilt, they have been traced by many observers.

These veins have been formed at different dates in the history of the material world. This fact is learned, not only from the character and age of the rocks which are traversed, but also from the circumstance that, in some instances, veins are traversed by other veins, that is to say, one granite vein is divided by another, and the appearance that is presented at the point where they join will enable the observer to judge of their relative ages.

Trappean rocks have also been injected among the stratified beds. There is, perhaps, no better locality for the examination of these rocks than the coast and islands of Scotland, so well described by Dr. Macculloch. It is not always possible to trace the veins of unstratified rocks to the mass from which they proceeded, but this may be done in the majority of cases, though in others, as may be readily imagined, the mass is too deeply seated beneath the surface of the earth.

The size of these veins is exceedingly various both in length and breadth. They have been seen to decrease in breadth from many yards to a few inches, while they differ in length between miles and feet; but it may be taken as a general rule that trap veins are much more extensive than the granitic, and it may also be mentioned that they are usually more vertical.

Veins also differ in another particular. Some are, as it were, immensely thick walls, and divide the strata without turning either to one side or the other. But there are others that diverge from side to side, and are characterized by extensive ramifications; this is generally the feature of granitic veins, and of the trap occasionally.



Section of Trap Veins.

METALLIC VEINS.

Other substances besides the unstratified rocks occur in veins, and particularly the metals, though they do not always appear in this form. Sometimes they are disseminated through the mass, as tin is in granite; sometimes they are found in bunches, as in the copper mines of Ecton, in Staffordshire; at other times they occur in beds, as in Thuringia; but in England they are commonly found in veins, called lodes by the miners. It must not, however, be supposed that these veins are entirely filled with metal, for, generally speaking, the ore occupies only a portion of the vein, and the other part is either entirely empty, or filled with broken earthy substances, called deads.

Veins differ considerably in thickness. Humboldt observed a vein of spar in the Alps of Switzerland, which was one hundred and forty feet thick. Metalliferous veins are generally much narrower, but the mines of Pasco, in Peru, are situated in a vein of brown iron-stone, containing silver, which is thirteen hundred yards wide. Some of the tin veins of Cornwall are not more than three inches thick, while others are thirty feet. The general thickness of the copper and tin veins in this country is from a foot to three feet, and it has been observed that the ore of these is much less intermixed with foreign ingredients than that of wider veins.

When a vein that has been productive in one rock enters another, it very rarely continues to be equally rich; and it is a remarkable fact, that veins are found to be rich or poor, according to the nature of the rock in which they happen to lie. When they pass through sandstone or slate into limestone, they enlarge and grow rich, and it is well known that all the lead mines of Northumberland and Durham are situated in this rock. In these counties, the deeper the lead veins are followed, the poorer they become, while in the copper mines of Cornwall they become richer; and it is said they are never known to come to an end, although several of them have been traced to a depth of one thousand feet from the surface, and a few for fifteen hundred feet.

There is only one ore of tin, called the native oxyde, and it is sometimes, though rarely, found with the copper ores, but it is not at all uncommon for them to follow each other. Tin will perhaps be traced for eighty or one hundred feet, and then a course of copper; but when a rich copper is found at the commencement of the vein, tin has never been known to succeed it.

The most recent veins, which run north and south, are called cross veins, and pass through those which lie east and west. This circumstance leads us to the deduction that the east and west are older than the north and south, which are usually filled with clayey substances, and contain but little ore: the metalliferous veins are those that run east and west. A cross vein frequently disturbs the direction of a vein that lies east and west so much, that it is lost sight of by the miners, and months or years may be spent in the effort to find it again. Not long ago a vein was recovered four hundred and fifty feet from the cross vein that altered its course.

The origin of metallic veins is not by any means so clear as that of the granitic. It is quite possible that many of them may have been formed by injection from below, in the same manner as the veins of unstratified rock. But this supposition will not account for the alteration in the character and thickness of veins, which has been observed when they leave one rock and enter another. The general tendency of the veins to take a north and south, or east and west direction, is another fact unexplained by this theory. It has been supposed that electricity has been an active agent in their formation, and the interesting experiments made by Mr. Fox give some probability to the opinion. Farther experiment, how ever, is necessary, before any theory can be established.

COAL MEASURES.

Having explained the general characters and appearances of the two great classes of rocks, the stratified and the unstratified, we shall now proceed to illustrate their combination by the description of a series of beds. For this purpose we have chosen that collection called the coal measures, not only because they furnish us with that most useful and im portant mineral, coal, but also because they are perhaps more adapted to our purpose than any other series of rocks.

The coal measures consist of various beds of sandstone, shale, or slate clay, and coal, irregularly interstratified. The coal does not occur as a single bed of considerable thickness, but a series of beds are met with, in some instances as many as thirty or forty, alternating with the sandstone and shale. The nature of the coal measures will be better understood by the following table of the beds which have been passed through at the coal-works of Rowley, in South Staffordshire, than by any description that could be given.

			Feet	In.
Of Coal,	11 beds,	Total thickness	81	7
Limestone,	1		30	0
Slate Clay (Shale),	30		715	8
Gravel,	1		6	0
Bituminous Shale,	2		6	7
Sandstone,	13		82	10
Shale (emitting fire-damp),	1			3
Clay,	2		9	9
Ditto (coaly),	2		1	1
Ditto (red),	1		5	6
Soil,	1		1	0
			940	3

The slate clay, or shale, called by the miners shivers and black metal, frequently forms nearly three fourths of the mass constituting the coal measures. The sandstone of this series is used, when hard, for grindstones, while the softer varieties are employed for filtering. Another bed frequently associated with the coal measures is clay iron-stone, so called because of the large quantity of iron that is obtained from it. Next to the coal, it is the most important bed of the coal measures. At the Merthyr Tydvil works, in Wales, there are sixteen strata of iron-stone intermixed with numerous strata of coal. In the years 1805 and 1806, 26,253 tons of iron were obtained from the iron-stone at this place, and nearly three times as much is produced at the present time.

The coal measures abound in vegetable remains, and the coal itself is now very generally considered to have had a vegetable origin. The great abundance of vegetable remains in the alternating beds of this formation, is a strong reason in favour of the vegetable origin of coal; and the state in which they are found, the woody parts being usually converted into coal, or a substance having nearly the same chymical composition, strengthens the argument considerably.

Another reason for this opinion may be gathered from the consecutive train of varying substances, from vegetation to perfect coal. It is well known, that in many parts of England accumulations of wood and plants are found, which, although now mingled with the mineral deposites, at no very distant period were growing on the spot where they are now buried. These vegetable deposites are found in different states; sometimes the wood is so perfect that the character and species of the tree may be readily determined, while at other times it is much decayed, and has suffered so great a chymical change from humidity and pressure, that its vegetable origin can scarcely be recognised. That substance called peat, and used as fuel by the lower classes in many parts of this and other countries, is a vegetable remain of the latter kind.

At other times we find vegetables changed into that well-known substance, jet, of which boxes and other trinkets are frequently formed. Of the vegetable origin of jet there cannot be the slightest doubt, for instances have occurred in which one half of the trunk of a tree has retained its natural character, while the other half has been converted into pure jet. The characters of this substance and an imperfect coal called cannel-coal are the same, and their external appearances have frequently a close analogy.

From these remarks it will be seen that we may trace a succession of changes from vegetation to coal, which, independent of all argument, is a sufficient proof of the origin of the coal-beds. But there is no point of resemblance between the vegetables of the coal measures and of the submarine forests, which have been formed in comparatively recent times, or are now being formed. They are in both instances mingled with mineral deposites, but the plants belonging to the recent deposites have no points of distinction from those which are now growing on the surface. The oak, beech, elm, alder, and hazel, have all been found in the submarine forests, and with them the hazel-nut, as well as common household utensils and partly obliterated coins, all which are evidences of a recent formation. But the vegetables found in the beds associated with the coal have no feature in common with those now found in England.

The remains of plants in the coal measures are, according to the opinion of the most celebrated botanists, such as could only have existed in at least tropical regions. Now if these plants grew in a country that had a temperature at least as warm as the tropics, one of two things must have happened: either they were drifted by water from some very distant place, or, if they grew on or near the place where their remains are found, the temperature of the earth must have changed since the formation of the coal measures.

The state of the vegetable remains forbids, according to the opinion of some geologists, the supposition that they were brought from any distance to their present situations by water. They are generally found lying flat, with their stems and leaves parallel to the direction of the strata, but this is not universally the case. Mr. Witham states that he has found them in a vertical position, and especially notices the occurrence of a number of fossil vegetables beneath the high main coal at Newcastle, which had their roots fixed in a seam of coal, and presented an appearance as if they had been imbedded in the spot on which they were growing, and the same fact has been observed at St. Etienne by M. Brogniart. These facts are considered to oppose the supposition that the vegetable remains were drifted from any considerable distance to the spots where they are now imbedded.

In addition to this argument against the transport of the plants of the coal measures, it is stated that they must all have been much more injured than they are if they had been thus brought to their present situations. A plant of delicate texture cannot be long in the water, unless at a depth beneath the surface, without suffering at least a mechanical decomposition, and having its characters destroyed. But the vegetables found in the coal measures have not suffered in this way; their leaves are beautifully preserved, and their markings are exceedingly distinct.

These considerations induce some persons to believe that the vegetable remains of the coal measures could not have been transported from a distance, and consequently that they grew on or near the places where they are found, and that the surface temperature of the earth has been changed.

The question that now presents itself is, what causes have decreased the surface temperature of the earth in such places? It is supposed by many geologists that the interior of the earth has, at a former period, had a much more intense heat than it now has, and that its decrease has occasioned the alteration. This opinion, maintained by Baron Humboldt and many other eminent geologists, would evidently be sufficient to account for the change that has happened since the supposed period when the tropical plants of the coal measures grew on our soil.

Mr. Lyell accounts for the change of temperature upon another principle. He considers the temperature of a place to depend upon the relative proportions of high land and sea near the poles. The higher the polar land, the greater will be the cold; the more the land at or near the equator, and the greater the quantity of sea at the poles, the higher will be the temperature, and the more equably will it be diffused. In proof of this he states that arborescent ferns are found in Van Diemen's Land, in 42° south latitude, which is a much higher latitude than they reach in the northern hemisphere, where the climate is not so equable. This is attributable, he thinks, to the circumstance that there is more and higher land towards the north than towards the south pole. Mr. Lyell's theory will therefore resolve itself into the following statement:—that the superficies of the earth has been and is still changing, by the agency of rivers, currents, earthquakes, volcanoes, and other causes; and that the variation between the proportions and situations of land and water is sufficient to account for any higher temperature of the earth at some former period than it has now.

But whatever theory may be adopted to account for the higher temperature of our earth at the time of the deposition of the coal measures, there can be no doubt that the plants grew in a warm climate, whether in our northern latitudes or in spots where they are still found. To supply the beds of coal which we find in our own country seems to have required the luxuriant vegetation of an equatorial climate, and we can scarcely imagine them to have resulted from the scanty resources of such forests as might exist in the present temperature of England. But if the reader can imagine the state of the vast forests of Brazil, almost too thickly intwined to admit of human research, or the luxuriant and extended woods on the banks of the Missouri, and if he can form an estimate of the immense quantity of vegetable matter which is there produced all the year round, and year after year, for ages, he may approach in fancy the physical condition of that country in which the vegetables of the coal measures grew; for such was the climate that nurtured, and such were the forests that produced, the plants which were designed by the Creator to become the source of comfort to his unborn creatures. And we cannot avoid remarking, that here we see a most interesting display of the kindness which designed, and the superintendence that fulfilled, the intention to make the world a suitable residence for man.

So closely are the unstratified rocks associated with the beds of the coal measures, that they have been considered almost an essential part of the formation. Although we can only consider them as occasional or frequent intruders, yet it cannot be denied that the coal measures have been greatly disturbed by their interference, and that their present condition is mainly owing to them. Immense walls or dikes of trap often intersect the coal measures, having been thrust upward in many instances a considerable time after the deposition of the stratified rocks. The Cleveland Dike is an instance in point, for it pierces through four formations that were deposited after the coal measures. These dikes, which are fissures filled with unstratified rocks, have acted as mechanical agents in contorting the strata, sometimes to a considerable extent. The dike which extends from Whitby, in Northumberland, to Greenside, in Durham, has thrown down the strata on the north side about five hundred and forty feet; but this effect is rather to be attributed to the fissure made in the beds than to the ejection of liquefied rocks, for the opening is filled with clay, and the effect produced is called by geologists a fault. The dike at Bartreeford throws down the strata four hundred and eighty feet on its west side; but a branch of the Coaly Hill Dike traverses the beds of the Walker Colliery on the Tyne without causing any alteration in their level, though it is thirty-five feet thick, and quite vertical. There is a very considerable fault near Bilston, in the South Staffordshire Dudley coal-field, and it has the effect of reversing the dip of the beds; on the south side of the fault they dip to the south, while on the north side they dip to the north, presenting an appearance not unlike that of a side section of a roof.

If any farther evidence were necessary to prove that the trap dikes were formed by the agency of heat, and at a period after the deposition of the coal measures, that evidence might be gathered from the effect which has, in many instances, been produced upon the coal-beds. The Coaly Hill Dike, which has been traced from the sea to the western side of Northumberland, has charred the beds of coal with which it is in contact. The Cockfield Dike, which underlies the coal measures of Durham, has reduced the coal in its vicinity to a cinder, and has sublimed the sulphur from the iron-stone. It once happened that the collieries of Durham caught fire, and continued to burn for many years. The heat which was thrown out was so great, that the vegetation on the land above the burning coal was accelerated, the temperature of the water was raised, and the clay that covered them was converted into a species of porcelain jasper.

From these statements it will be evident that coal is of vegetable origin, and that the unstratified rocks have been ejected among them in a heated liquefied state. It may not now be uninteresting to inquire by what means vegetables may be made to become coal. A very celebrated and highly-esteemed geologist once objected to the arguments that are usually employed to prove the vegetable origin of coal. One of the strong arguments in favour of this opinion is founded on the abundance of vegetables enclosed in the coal measures; but, says the opponent of the theory, by a parity of reasoning, we ought to ascribe the origin of those beds where large quantities of shells are found, to the destruction of shellfish. Could no other argument be used in favour of the vegetable origin of coal, we must give up the opinion altogether; but other reasons have been used for the support of the theory, and the combination of these is, we think, conclusive. The strongest individual argument is the absoute formation of coal from plants. It has been already proved that jet has a vegetable origin, and it might, therefore, be supposed that it is capable of conversion into coal. To determine the problem experimentally, Dr. Macculloch reduced a quantity of jet to powder, and placed it in a gun-barrel, covering it with clay. By exposing it to a moderately red heat, the jet was converted into a substance having precisely the same chymical and external characters as coal, while the clay was changed into a substance similar to that found in the coal measures, and called coal shale. An appearance has been observed at Meisner, in Hesse, which has a strong resemblance to the result of the experiment we have just described. A thick bed of imperfect coal is there covered by an enormous mass of basalt, from which it is separated by a thin bed of clay. The upper part of the bed of lignite is converted into coal, while the lower part still retains the fibrous woody structure.

Gathering together the variety of evidence that has been alluded to, we seem to be led to the conclusion that vegetable substances may be converted into coal by the united action of moisture, pressure, heat, and exclusion of air. The heat has, in many instances, resulted from the actual ejection of volcanic rocks among the beds; and where this has not occurred, the heat has been sufficiently intense, from the peculiar activity of volcanic causes at the time, to produce the change.

This brief account of the evidence which has been collected in reference to the origin of coal, may serve as an example of the manner in which the geologist pursues his inquiries into the origin of rocks, and to prove that his opinions are not mere speculative conjectures.

ORGANIC REMAINS.

It has been already stated that many stratified rocks contain the remains of organized bodies, some of which are of the most remarkable character, and lead us to very important deductions. The wonder of thinking men has long been excited by the discovery of these in the solid strata of the globe, and that at great depths below the surface. There is evidence that they were objects of attention among the learned long before the science of geology had a name; and some of the speculations which have reached us are little to be preferred to the notions of the most ignorant peasants of our own day. But since men have been engaged in geological investigations, the study of fossils has risen to great importance, and has conferred many advantages upon geology itself.

By the character of the organic remains found in a bed, the relative position and age of a deposite may, as we have already shown, be frequently determined, for every series of beds contains some which are peculiar to itself. It is not always possible to assign to a deposite its proper position in the geological series, by its mineralogical characters; but if a collection of its fossils can be formed, the difficulty vanishes, and its relative age may be determined. Every series of beds, therefore, possessing fossils peculiar to itself, contains an index to its own mysterious history; for not only can its position in the series be read, but also the circumstances under which it was formed.

The fact that every series of rocks contains fossils peculiar to itself, was first discovered by Lister, more than one hundred and fifty years ago, but the honour of demonstrating it by extensive observation is due to Mr. William Smith: and thus he has placed the naturalist, as well as the geologist, in a new position,—inducing him to extend his observations into the bowels of the earth, where the remains of a race of beings before entirely unknown have been discovered.

The fossilized bones of animals are among the most singu ar organic remains. Baron Cuvier, the celebrated French geologist, was the first who commenced the study of these fossils. As an antiquary of a new order, to use his own words, he was obliged at once to learn the art of restoring these monuments of past revolutions to their original forms, and to discover their nature and relations. He had to collect, in their original order, the fragments of which they consisted, to reproduce the ancient beings to which they belonged, with all their proportions and characters, as well as to compare them with those which now live on the surface of the globe. In effecting these objects he was assisted by naturalists and geologists in various countries, and the characters of many singular animals have been determined.

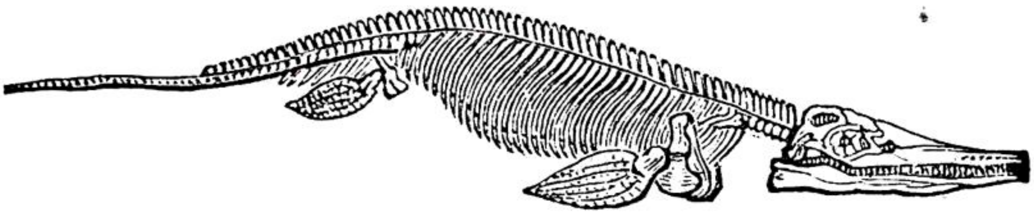
REPTILES.

None of the results of modern geology have attracted so much of public attention as the discovery of the remains of many gigantic reptiles. There has been a time in the history of our world when these animals attained an appalling magnitude, and, rioting in the wide expanse of water, swayed the sceptre of uncontroverted power over all other created beings. The descriptions of the fabled monsters of antiquity, which have so often delighted our childhood, lose all their character of exaggeration when compared with those that have been given of the reptiles whose bones are entombed in the solid strata of the globe. Some of these have evidently been fitted to live in the deep waters of the sea, while others in all probability inhabited lakes and rivers; but they all appear to have existed at a period when our earth enjoyed a much higher temperature than it now possesses. Judging from the antiquity of the rocks in which the bones of reptiles are found, they appear to have been created a long period before the viviparous animals, and at a time when the earth was unfit for creatures of a higher organization.

The first appearance of the bones of reptiles is in the beds lying immediately above the coal measures, and they are found more or less abundant as high as the chalk deposite, but above this they entirely disappear. During some part of the time that intervened between the formation of these two deposites the reptiles must have existed in immense numbers, if we may calculate from the quantity of bones that are found. They are most abundant in a limestone rock, called the lias, in which the bones of two extinct marine genera, the ichthyosaurus and plesiosaurus, are very numerous.

THE ICHTHYOSAURUS.

The ichthyosaurus, whose remains were discovered by Sir Everard Home, had a large head, enormous eyes, a short neck, and a very long tail. It was evidently destined to live in the sea, being furnished with four broad and flat paddles, which it used to force its way through the water, and to di rect its course. This animal attained a length of from twen-

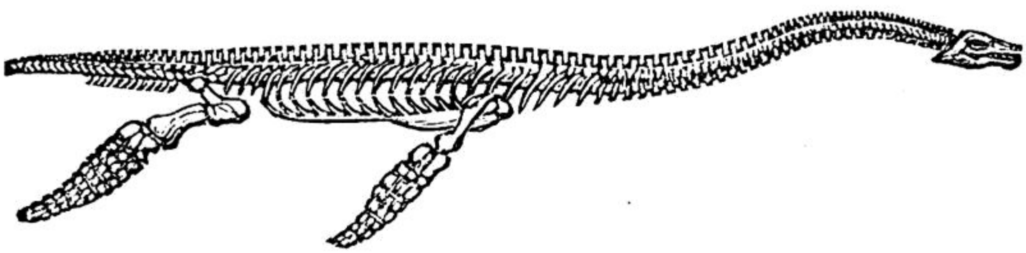


The skeleton of the Ichthyosaurus.

ty to thirty feet. It has the head and sternum of a lizard, the muzzle of a dolphin, and the teeth of a crocodile; its eyes are immense, and its teeth conical and pointed.

THE PLESIOSAURUS.

The plesiosaurus resembled the ichthyosaurus in some particulars, and had four paddles of a similar structure, but differed from all other animals in the extreme length of the neck, and the number of vertebræ of which it was composed. The neck of birds consists of more vertebræ than any other organized creatures, and contains from nine to twenty-three; and reptiles have from three to eight; but one species of the

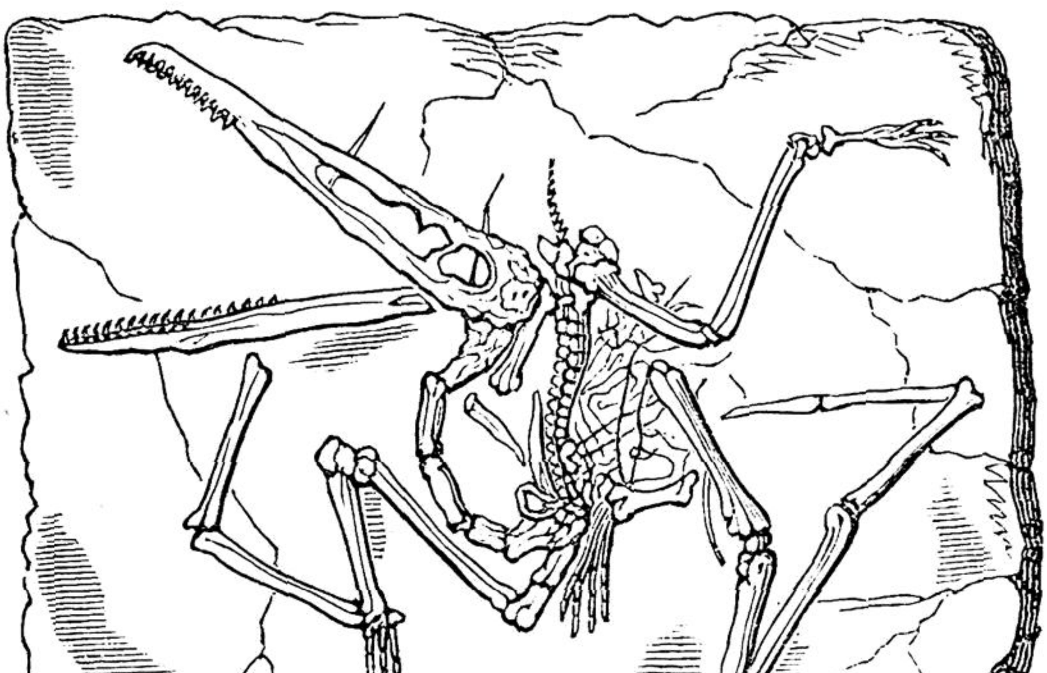


The skeleton of the Plesiosaurus.

plesiosaurus has thirty. This singular animal is supposed to have swum on or near the surface of the water, carrying its head like a swan, and darting upon the fish on which it lived. For our knowledge of this interesting animal, we are entire ly indebted to that very able geologist, Mr. Conybeare When examining some vertebræ of the crocodile and ichthy osaurus, found in the neighbourhood of Bristol, he detected some remains among them which appeared to differ from those of both genera. This supposition was strengthened by finding, in the collection of Colonel Birch, a considerable portion of the skeleton of the animal, and he immediately commenced his researches, hoping to obtain other bones of the newly-discovered genus, and in 1821 published a memoir conjointly with M. De la Beche, describing its characters. At this time the head was wanting, but in the following year he obtained one that was tolerably perfect. In the year 1824, Miss Anning, of Lyme Regis, found a skeleton, nearly entire, by which Mr. Conybeare was able to complete his inquiries: such is the history of the circumstances by which we were made acquainted with the plesiosaurus.

THE PTERODACTYLUS.

The pterodactylus was a flying animal, which had the wings of a bat, and the structure of a reptile; jaws with sharp teeth, and claws with long hooked nails. The power which

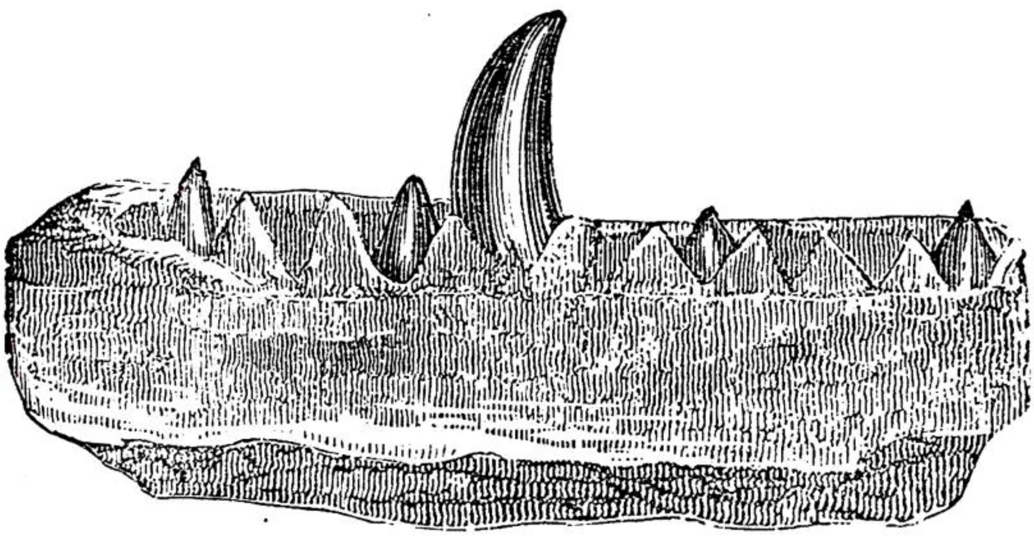


The skeleton of the Pterodactylus.

it had of flying was not by means of its ribs, nor by wings without fingers, as in birds, but by wings supported by one very elongated toe, the others being short and furnished with claws. The remains of this animal were brought under examination by M. Collini, Director of the Museum of the Elector Palatine at Manheim. There was at first some discussion as to the actual character of the animal. M. Blumenbach supposed it to be a bird, and M. de Soemmering classed it among the bats. M. Cuvier, however, maintained that it was a reptile, and showed that all its bones, from the teeth to the claws, possessed the characters which distinguish that class of animals. But still it differed from all other reptiles in the capability of flying. It is probable that it could at pleasure fold up its wings in the same manner as birds, and might suspend itself on branches of trees by its fore toes, though it possessed the power of sitting upright on its hind feet. This is the most anomalous of all the fossil reptiles.

THE MEGALOSAURUS.

This monstrous animal must have been thirty or forty feet in length, and seven or more in height. It was probably a terrestrial animal, and from the form of its teeth, the structure of its jaws, and the bones of the extremities, we discover

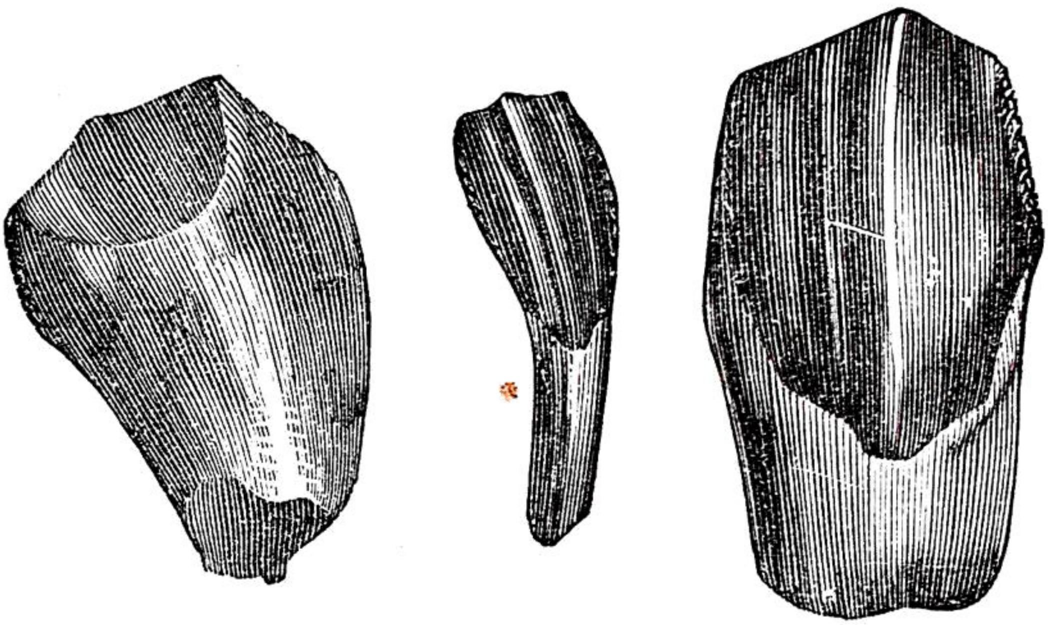


Jaw of the Megalosaurus.

that it was allied to the recent monitor. The remains of this animal were discovered at Stonesfield, by our very eminent countryman Dr. Buckland.

THE IGUANODON.

The iguanodon was an herbivorous reptile, which differed from all the animals we have mentioned, and surpassed them in size. A thigh-bone of one specimen of this animal measured twenty-three inches in circumference. Other bones that were found were equally gigantic, and its teeth were as large as the incisors of the rhinoceros. It derives its name from the resemblance between its teeth and the teeth of the Iguana; and it is a remarkable circumstance that they are more or less worn by the operation of grinding its food, which

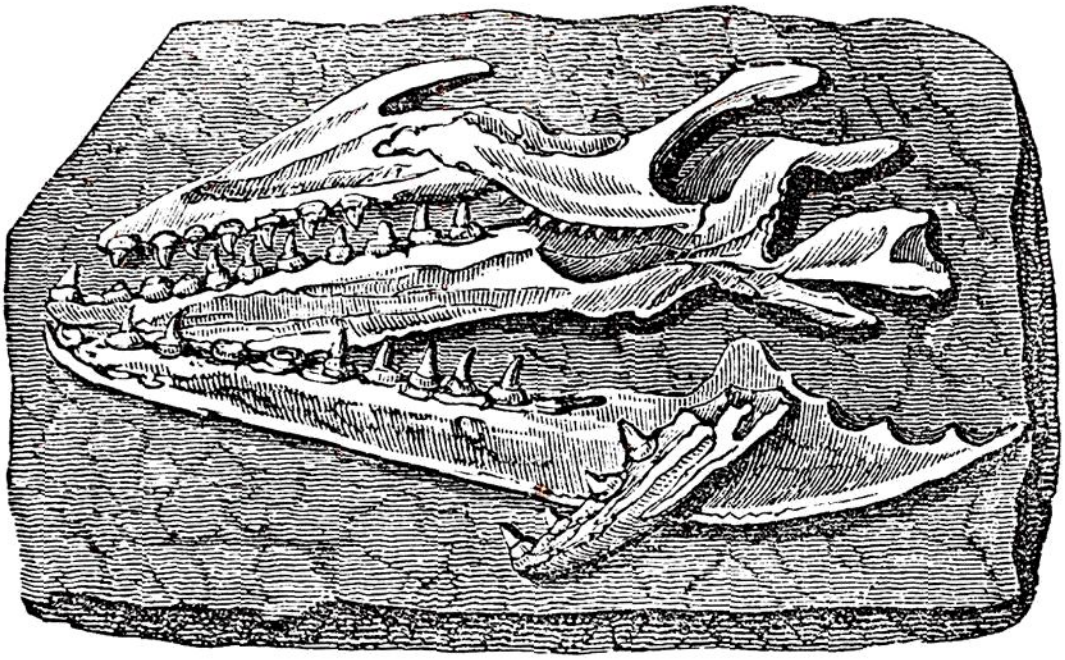


Teeth of Iguanodon.

shows that it performed mastication in the same manner as the herbivorous quadrupeds of the present day. It is generally supposed that this animal was shorter in proportion to its bulk than the recent lizards, to which it is nearly allied; but even with this supposition, it appears to have been fifty or more feet in length, and eight or nine in height.

THE MOSOSAURUS.

The remains of this animal were discovered by Hoffman. It appears to have formed a link between the monitors and the common lizards. A jaw of this animal measured three feet nine inches, and hence it was deduced that the entire length of the animal was about four-and-twenty feet. Its tail was much shorter in proportion to the length of its body than the crocodile, but very broad, so that by its means it could force its way through the most stormy waters. It has no relation to the crocodile except in some partial characters, and the bones of the hand and feet have led to the supposition that it possessed a contracted fin, not much unlike that of the *Plesiosaurus.*



Scull of the Mososaurus.

FOSSIL BIRDS.

The bones of birds are less frequently found in a fossil state than those of other classes of animals, so seldom indeed that some persons have absolutely denied their existence in that condition. Baron Cuvier, to whom the science of fossil organic remains is so much indebted, has detected and described at least eleven species of birds found in the gypsum of Paris, and among them a bone which greatly resembled that belonging to a preserved specimen of the celebrated Egyptian Ibis. The information, however, that has been collected concerning fossil birds, is at best but very confined, if not uncertain.

FOSSILIZED REMAINS OF MAMMALIA

The remains of mammalia have never been found in any bed below the chalk, and hence it is supposed that they did not exist until the period immediately preceding the deposition of that rock. The existence of organic remains in rocks indisputably proves that every bed in which they occur has been at some period the superficial rock; for, whether the remains were brought from a distance, or the animals to which they belonged existed on the spot, it is certain they could not have been disseminated through the bed if it had not at that time been uppermost. When, therefore, the remains of any animals, or class of animals, are found in particular beds and not in others, we have evidence that the animal or class only existed during the period in which the beds themselves were deposited. It is by the admission of these principles that we deduce the non-existence of mammiferous animals previous to the formation of chalk.

Some few bones of individuals of the human race have been found in beds containing fossils, but in all instances there is reason to believe that they have been casually introduced at a very recent period. In turf bogs, in alluvial deposites, in fissures of rocks, and in caves, the bony structure of man is sometimes found, but in no instance in such a position as would lead us to suppose that our species was the contemporary of the palæotheria, or even of the mammoth and rhinoceros. It is true that human bones were found in some of the caves in France, and old pottery in some of those in Germany, but their situation and circumstances clearly proved that they were of recent date, and could not claim the same antiquity as we are compelled to give to the animal remains usually found in such situations. And yet there is nothing in the composition of the human bone to prevent its preservation; there is no principle of premature decomposition in its construction. The bones of men are equally well preserved in ancient sites of combat as those of the horse, and yet the latter are found in a fossil state. From these facts we deduce that the human race did not exist at the same time with these animals in places which the geologist has had an opportunity of examining. It is nevertheless possible that future inquiries in other countries may detect the presence of fossilized relics of man, associated with the animals whose bones are found in the gravels and caves of Europe. It may also be mentioned that no remains of monkeys, the race which ranks next to man in anatomical construction, have hitherto been discovered, although the bones of animals which now inhabit the same woods with them are found in abundance.

For the knowledge that has been collected in reference to the nature of the mammiferous quadrupeds, we are chiefly indebted to the laborious researches of the late Baron Cuvier. There is a series of recent beds of gypsum, which occur in detached hills along the course of the rivers Marne and Seine, in which a great number of bones are found. The greater part of these belong to that order of animals which Cuvier has called the Pachydermata, or thick-skinned non-ruminant animals; but all the species, and many of the genera, are extinct; there is one in particular, called the palæotherium, that has some points of resemblance to the rhinoceros, the hippopotamus, the horse, the camel, and the pig. Eleven or twelve species of this animal have been found, the largest being about the size of a horse, the smallest not larger than a hare, but they all had fleshy trunks, like the tapirs, and lived on vegetables.

The anoplotherium is another extinct animal, and has two remarkable characters; the feet have only two toes, and the teeth are a continued series, without any intervening gap, which, except in this instance, is only observed in man.

In the superficial gravel-beds, and in some caves, a large number of the bones of mammiferous quadrupeds have been found, belonging to both existing and recent genera; but in nearly all those instances where recent genera are found, the species are observed to be distinct from those now existing. A large number of the bones of hyænas, for example, have been found in some of the caves of Germany, as well as in the cave of Kirkdale; but Cuvier, after examining them very carefully, could not detect the existing species, though the animal had evidently all the habits which it is known to possess in the present day.

The fossil elephant, or mammoth, was a most remarkable herbivorous quadruped, on account of its immense size. Judging from the number of bones which have been found in Europe and in America, it must have existed in herds of thousands. In very many of the gravel-beds found in the valleys of our own country, the bones of the mammoth have been discovered. It has, however, fortunately happened, that an entire specimen of one of these animals has been preserved in the ice of the northern regions. "In 1799, a Tongoose fisherman observed, on the borders of the icy sea, near the mouth of the Neva, in the midst of the fragments of ice, a shapeless mass of something, the nature of which he could not conjecture. The next year he observed that this mass was a little more disengaged. Towards the end of the following summer, the entire side of the animal and one of the tusks became distinctly visible. In the fifth year, the ice being melted earlier than usual, this enormous mass was cast on the coast. The fisherman possessed himself of the tusks, which he sold for fifty rubles. Two years afterward, Mr. Adams, associate of the academy of St. Petersburgh, who was travelling with Count Gobovkin on an embassy to China, having heard of this discovery at Yakutsk, repaired immediately to the spot. He found the animal greatly mutilated, but the skeleton was entire with the exception of a fore-leg. The neck was furnished with a long mane. The skin was covered with black hairs, and with a reddish sort of wool. The remains were so heavy, that ten persons had much difficulty in removing them. More than thirty pounds of hair and bristles were carried away, which had been sunk into the humid soil by the white bears when devouring the flesh. The tusks were nine feet long, and the head, without the tusks, weighed four hundred pounds."

The mammoth bears a close resemblance to the Indian elephant, but Cuvier considered it a distinct species. The height of the animal was from fifteen to eighteen feet, and it must at one period have existed in Europe, with the hippopotamus, rhinoceros, tapir, and other gigantic animals, whose bones are found in the same deposites.

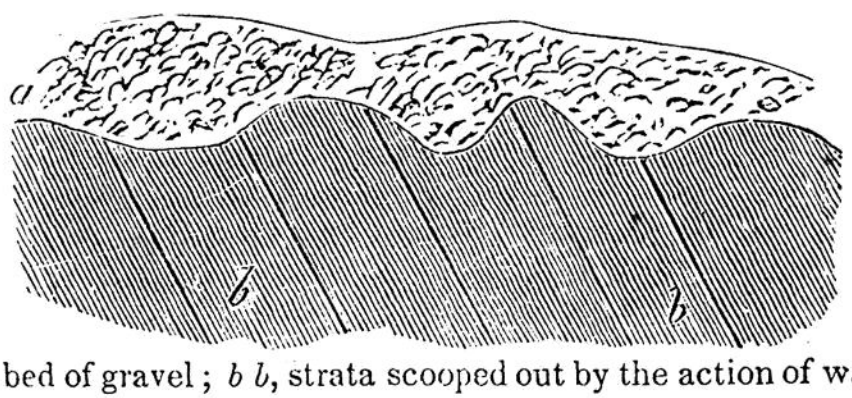
DILUVIAN ACTION.

It is a common opinion among all those who have not studied the physical constitution of the globe, that the deposition of organic remains in the solid strata is attributable to a universal deluge; but this opinion is exceedingly erroneous, for the various beds which together form the crust of the globe have been produced at different times, and under different circumstances. But, after the formation of all these beds, the earth suffered under a general catastrophe, and was overflown by water, or, according to some, suffered under a succession of these deluges. It is not necessary for us to stop and inquire whether it was a single action or a succession of causes; we have only to attend to the results. The effects which are now to be observed may be considered under the following heads:—the destruction of pre-existing rocks and deposition of gravel: the transport of large stones from their parent beds: the formation of caves, and the scooping out of valleys.

SUPERFICIAL GRAVELS

It is well known that many districts in England are covered by beds of gravel, which consist of fragments of rock and rounded pebbles. These fragments and pebbles will be found, if examined, to consist in many places of rocks which are not to be obtained in the neighbourhood where the gravel is deposited. In many districts of the midland counties in England, a nearly complete suite of rocks might be collected from the gravel, and must therefore have been carried from various, and some from very considerable distances. Mr. Phillips, speaking of the superficial gravel in Holderness, on the coast of Yorkshire, says—" The rocks from which the fragments appear to have been transported, are found, some in Norway, in the Highlands of Scotland, and in the mountains of Cumberland; others in the western and northwestern parts of Yorkshire, and no inconsiderable portion appears to have come from the seacoast of Durham, and neighbourhood of Whitby. In proportion to the distance they have travelled is the degree of roundness they have acquired."

The distribution of these fragments of rocks could only have been effected by a vast body of water. From the facts that have been gathered by geologists, it appears that it has taken a direction from north to south over the British Isles, and, according to Mr. Phillips's statement, has even transported fragments from Norway. In this course it has been modified by hills and mountain ranges, which may have divided



a a, bed of gravel; *b b*, strata scooped out by the action of wa .

the body of water, and caused the many irregularities which are to be observed in the deposition of the gravel-beds. In passing over the surface of rocks, it has scooped out cavities, and in nearly all places where the transported gravel occurs this furrowed appearance may be observed, particularly in the chalk districts of Kent.

BOULDERS.

The action of the diluvian current has not been confined to the transport of the small fragments which constitute beds of gravel, but in many places we find large masses of rolled stones, or boulders, which, having been torn away from their parent rocks, have been carried to a distance by the force of the overwhelming waters. Near Hayton Castle, in Cumberland, there is a spheroidal mass of granite, ten feet and a half in diameter, and more than four feet high; and at High Peak, in Derbyshire, there is another which is twenty-one feet long, ten feet high, and nine feet wide. The granite boulder, near Hayton Castle, is supposed to have been brought from the Criffel mountain, in Dumfriesshire. As early as the year 1740, Ehrhart had traced to the Tyrol the granite blocks found in the country situated between the Alps and the Danube, and Von Buch ascribed those found in the north of Germany to Norway. Throughout the whole of Staffordshire, Cheshire, and Shropshire, these blocks are distributed, many of which are supposed to have been brought from the Cambrian hills.

We have already stated that there is evidence of the passage of a body of water from north to south over the British Isles, and that evidence is strengthened by the positions of the transported masses. "But if," says M. De la Beche, "the supposition of a mass of waters having passed over Britain be founded on probability, the evidence of such a passage or passages should be found in the neighbouring continents of Europe, and the general direction of the transported masses should be the same. Now, this is precisely what we do find. In Sweden and Russia, large blocks of rock occur in great numbers, and no doubt can be entertained that they have been transported southward from the north."

BONE CAVERNS.

It is exceedingly difficult to determine when the bone caves which are so frequently found in rocks, and particularly in limestones, were formed; but the probability is, that they have been excavated at various times, and by different causes. It is not, however, so much our object to speak of the caves themselves, as of the bones which are so frequently found in them, though it must at the same time be acknowledged that the bones were in all probability deposited at different periods, and in many instances were accumulating for a long space of time.

The existence of bones in caverns has been long known, and has always attracted a considerable degree of curiosity. The limestone caves of Germany, and Hungary in particular, have been celebrated for the quantity of bones and teeth of carnivorous animals they contain. The bones which are most numerous are those of the bear and the hyæna, the former being a species as large as a horse, and the hyæna often one third larger than any recent species. There are, however, mingled with these the bones of tigers, wolves, foxes, and other animals, none of which are petrified or rounded by rolling.

Some of the early accounts given of these caves and their contents are very singular. Dr. Ebrœus describes one situated in the Lower Hartz, in the county of Holinstein, called by the country people Dwarf's Hole. "Here," he says, "are found the sculls, jaw-bones, shoulder-blades, back-bones, ribs, teeth, thigh-bones, and all other bones of men and beasts; and there are some like an unshapen mass or lump of stone, having no resemblance to any bone at all." Such is the indefinite and absurd character of the accounts given by early writers of the bones found in limestone caves. Professor Buckland commenced the philosophical investigation of the organic remains of bone caverns by the examination of that of Kirkdale in Yorkshire. Since the publication of his large work, "Reliquæ Diluvianæ," the subject has acquired a new interest; many geologists have been actively engaged in the investigation, and, although the information that has been acquired cannot be considered satisfactory, it may be hoped that the time is not very distant when the efforts that have been made will be attended with entire success.

Kirkdale cave is situated between Helmsley and Kirby Moorside, about twenty-five miles from York. It was discovered in the summer of 1821, while cutting a quarry, and was visited by Professor Buckland in December of the same year. Its greatest length is about two hundred and forty-five feet, but it is so low that there are only a few places where a man can stand erect. A bed of soft mud entirely covers the floor of the cave, and upon removing this the bones were found. The whole of the bottom of the cave, from one end to the other, was strewed over with hundreds of teeth and bones, presenting an appearance like that of a dog's kennel. The greatest quantity were found at the mouth of the cavern, but in all places the bones of both large and small animals were mingled together.

The remains of twenty-three species of animals were found in the Kirkdale cavern; the hyæna, tiger, bear, wolf, fox, and weasel; the elephant, rhinoceros, hippopotamus, and horse; the ox, and three species of deer; the hare, rabbit, water-rat, and mouse; the raven, pigeon, lark, snipe, and a small species of duck. Nearly all these bones presented a fractured and gnawed appearance; and, except teeth, and some hard and solid bones, none were found perfect; but there were some fragments of jaw-bones belonging to the deer, hyæna, and water-rat, which contained their teeth, and were in a state of good preservation.

From the gnawed and fractured state of the bones, the manner in which they were strewed over the floor of the cave, and the great abundance of hyænas' teeth over all others, Dr. Buckland infers that the cavern was the den of hyænas for a long succession of years, and that the bones of other animals are the remains of those bodies which they dragged into the cave for food. During this time there was, as the doctor supposes, an irruption of muddy water, which deposited the bed that now covers the floor of the cavern, and preserved the bones from that destruction which would have resulted from their exposure to the air. Many of the bones were found to be polished on one side, while the other remained rough, which is attributed to the friction produced by the animals walking or rubbing themselves upon the exposed surface. How many hyænas have existed in this cavern cannot be very readily determined; but there is evidence, it is said, of at least two or three hundred. The supposition that the Kirkdale cave was the den of hyænas, is, according to the opinion of the professor, favoured by the certainty that these animals died at various periods of life; for, while some of their teeth bear marks of extreme old age, being abraded to their very sockets by continual gnawing, there are others which have belonged to exceedingly young animals.

The German caves of Gailenruth, Kühloch, Scharzfeld, and Baumanns Höhle, contain abundance of bones, but the greater number of these belong to two extinct species of bear. Sir Philip Egerton, who has recently visited these places, states, in a letter to Professor Buckland, that bones of pigs, birds, dogs, foxes, and ruminantia were found in all the caves he visited, and, what is still more remarkable, old coins and iron household implements of most ancient and uncouth forms in that of Rabenstein. This discovery seems to throw an additional interest over the existence of bones in caves, and especially when connected with the fact that the remains of man have been found in the South of France, mingled with the bones of the extinct rhinoceros and other animals. It may, even in the present state of our knowledge, be deduced, that the bones of all caves have not been carried to their present situation at the same period, or by a common cause; but we cannot expect to gain much additional information until travellers pay some attention to the condition of the country around the caves they visit, as well as to the collection of bones. If we possessed as full and accurate accounts of the many bone caverns, whose names we know, as M. De la Beche has given of that of Plymouth, there would be little difficulty in determining their eras. "At Oreston quarries, Plymouth, clefts and caverns in limestone rocks have afforded numerous remains of the elephant, rhinoceros, bear, ox, horse, deer, and other animals, buried, more particularly in the case of clefts, beneath considerable angular masses and smaller fragments of limestone. In one instance which I noticed, the animal remains occurred beneath ninety feet of such accumulations, the bones and teeth being confined to a black clay under the fragments. The remains of bears, rhinoceroses, hyænas, and other animals contained in the celebrated Kent's Hole, near Torquay, belong to the same district. In the superficial gravel of this part of the country, the remains of animals of the same kind as those detected in the caverns have not yet been discovered; but, if we continue our researches eastward, we shall find them in the valleys of Charmouth and Lyme; thus, apparently, giving these remains of elephants and rhinoceroses the same relative antiquity as those beneath fragments in the clefts of rocks near Plymouth, and probably also as those contained in the caverns at the same place, and at Kent's Hole. It will be remarked, that the animal remains which seem to imply a warmer climate existing at that time than at present, occur in low grounds, fissures, and caves. Upon the former they have lived, and into the two latter they may may have either fallen or been dragged by beasts of prey. The elephants probably browsing on branches and herbage, the rhinoceros preferring low grounds, the bears and hyænas inhabiting caves, and the deer, the ox, and the horse ranging through the forest and the plain; all which supposes land fitted for them, and therefore hill and dale. Consequently valleys were scooped out previous to the existence of the elephants; and if a mass of water acted on the land destroying these animals, it must have been influenced in its direction by the previously existing inequalities of surface." This remark leads us at once to make a few observations on the formation of valleys, as a fourth result of diluvian action.

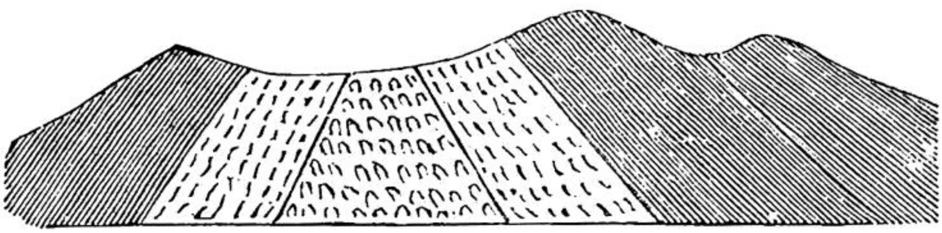
FORMATION OF VALLEYS.

All valleys have not been formed in the same way: some are due to the elevation and some to the depression of the strata which compose the adjacent hills, and others to partial slips or dislocations of rocks. To these we need not refer in the following remarks, for the statements already made in relation to stratification and its disturbance, must have suggested the thought that some valleys may have been occasioned by the elevations and depressions which rocks have suffered.

There is another class of valleys produced by water; but there is a difference of opinion as to the manner in which water acted upon the surface of rocks, and formed valleys. Some suppose that they were caused by the action of rivers and the bursting of lakes, while others attribute them to the irresistible force of a vast diluvian current, which, sweeping over the surface, has scooped out for itself as channels these depressions. The dispute between the advocates of the two theories was once very violent, but they have now probably seen that both theories may be in part true. We cannot understand how either the action of a river or the bursting of a lake could have produced many of the valleys in our own country, but it is probable that the ravines and gorges, that is, the narrow defiles which, bounded by perpendicular walls of rock, communicate between more open spaces, may have been produced by these causes.

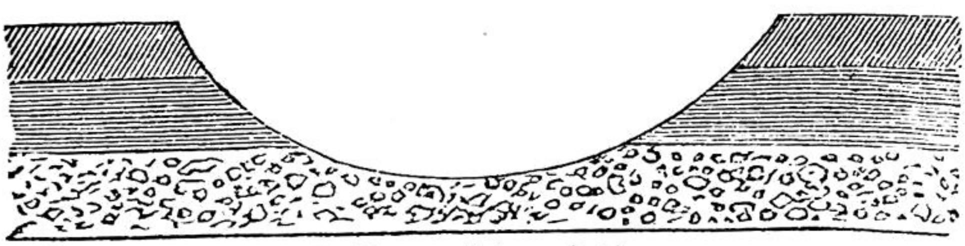
The valleys that are owing to the action of water have been divided into two classes, valleys of elevation and valleys of denudation, the one resulting from the combined action of subterranean and aqueous causes, the other from the action of water only.

The valleys of elevation are depressions made in high lands that have been formed by the fracture and upheaving of strata, the fractured parts being afterward carried away by the force of water. In all valleys of this description it may be observed that the strata, though once continuous, have been upheaved, and that the removal of the point where the strata met, after elevation, has produced the valley.



Valleys of elevation.

Valleys of denudation are those which have been produced by the action of vast bodies of water at a time after the deposition of the most recent of the ancient rocks. This fact is proved by the undisturbed position of the beds on each side of the valley. The rock found at the mouth of the Seine is covered by green sand, to the exclusion of many beds which usually intervene between them, and the same irregularity occurs in the opposite coast of Lyme, from



Valleys of denudation.

which it may be deduced that these two places were once united. So on a smaller scale it will be observed that many of the valleys so numerous in Devon, Dorset, and Kent, and more or less found in all counties and in all districts, have the same beds on each side, and generally in such a direction that a line carried from one side to another would be in a right line with the direction of the stratification. "If a person were to see," says Mr. Calcott, "the broken walls of a palace or a castle that had been in part demolished, he would trace the lines in which the walls had been carried, and in thought fill up the breaches and re-unite the whole. In the same manner, when we view the naked ends and broken edges of strata on one side of a valley, and compare them with their corresponding ends on the other, we cannot but perceive that the intermediate space was once filled up, and the strata continued from mountain to mountain." Such effects, we think, can only be attributed to the action of moving floods of water, and these of the most impetuous character; and it may be remarked, that while they acted upon the surface of rocks, breaking down every impediment, they accumulated the components of the superficial gravel and transported boulders.

It will appear, then, if the statements and deductions advanced in the preceding pages be admitted, that the crust of the earth has been formed by a succession of causes, differing from each other in character as well as in intensity. The condition of the earth when it proceeded from the hand of the Creator, and was thrown into space to perform its ceaseless revolution round the orb of day, geology does not pretend to determine; nor does it assert that any of the rocks which now compose its crust formed, in their present condition, a part of the primordial mass. But there is abundant evidence to prove that the present arrangement of rocks is not that which they had at the beginning. The agents of destruction and recomposition are everywhere active, and from the very constitution of matter it may be deduced that their agency must have been influential from that instant when the particles of matter were united together; and, consequently, we may expect to find the effects of these causes on the surface of the earth itself. Observation proves that the expectation founded on the consideration of present causes is not fallacious, for the rocks which compose the crust of the earth bear evidence of the variety of causes which acted upon them. But this evidence is not confined to the constitution of the beds themselves, for we may deduce many facts as to the condition of the earth at distinct periods, from the nature and condition of the organic remains which are found in the several deposites.

The effect of water in abrading and destroying rocks will be best understood by an examination of the vast deposites of clay, sand, and gravel, found in rivers, seas, and oceans, differing in no respect from the beds of the same nature known to constitute in part the crust of the earth. The aqueous causes which now act upon the surface of the earth differ from those which produced rocks in no other circumstance than in their want of intensity, the greater energy of the destroying agents at former periods depending upon the peculiar physical constitution of the earth.

The relative positions and superficial extent of land and water have been constantly changing; not slowly and imperceptibly, as in the present day, but by the activity of causes the effects of which have been almost instantaneous, upheaving the bed of the ocean and deluging the dry lands. In some instances the cause, and consequently the effect, have been local; but at certain periods there was probably a universal convulsive movement of the entire crust of the earth, when element warring with element involved all nature in one general ruin. The distorted and shattered condition of some series of rocks assures us of the truth of this statement; the hardest minerals have been melted by the intensity of the heat, while the vapours which have been generated have torn asunder the mightiest masses, and afforded an exit to the melted rocks.

It must never be forgotten that the ultimate object of geology is to gain some information concerning the formation of the earth, the causes employed, the circumstances under which these causes acted, and the physical condition of districts at each successive period of its existence. To gain this knowledge we trace the superposition of rocks, the disturbances they have suffered, and the organic remains they contain. The facts which geologists have discovered are, therefore, only the rudiments of their science, the principles to which the process of induction must be applied.

TEMPERATURE OF THE INTERIOR OF THE EARTH.

There are many circumstances which induce us to believe that the interior of the earth has a much higher temperature than its surface. From the experiments of Professor Mitcherlitch and others, we learn that mineral substances may be made to assume a crystalline form when cooled from a state of fusion; and this result, connected with other facts, proves that many of the crystalline rocks were produced by the agency of fire. The existence of more than two hundred active volcanoes affords evidence that there is an intense internal heat; and the lavas they eject are so analogous in appearance and composition to certain of the trap-rocks, that it is not possible to deny them an identity of origin. These observations have compelled geologists, in spite of early prejudices, to admit the agency of fire in the production of some rocks, and in modifying, if not in producing, the present state of the earth's crust. We should not, perhaps, greatly err from the truth, were we to state that all the causes which are now instrumental in producing a change in the relations of land and water have always been active, and at former periods produced much more violent effects than they do at the present time. However disastrous and sudden may be the changes which occasionally affect certain districts, their effects are, doubtless, but trifling, when compared with those which were not of unfrequent occurrence during the formation of the earth's crust. This remark is as true in relation to the agency of fire as to that of water. The causes of disturbance are now placed under a control which they themselves were made instrumental in producing,—a circumstance that gives us a high sense of the arrangements which the Creator adopted in the first constitution of the earth.

The exhibitions of Tomboro, Teneriffe, and other large volcanic mountains, are not worthy to be compared with the energy of the same force, when it upheaved continents, formed mountain chains, and covered the face of countries and continents with lavas. All nature is now in a comparative state of repose; the forces that once devastated the earth with an internal and superficial war have almost ceased to act; and the earth being thus prepared for the residence of man, he is permitted to enjoy the patrimony that God has given, with little disturbance from those numerous enemies by which he is surrounded.

The appearances that are presented by rocks in almost all countries strongly support the supposition that the interior of the earth has a much higher temperature than its superficies, though it may have been long and is still decreasing. We are not yet able to assert this as the result of experiment; but from the observations that have been made upon the temperature of mines, it is, we think, quite certain, that the heat increases from the surface downward. There are, however, many difficulties connected with the investigation of this subject, and the sources of error which affect the results of all the experiments that have been made, lead many persons to believe that the comparatively high temperature of mines and other excavations may be traced to local causes, independent of any increase of internal heat. It is true that the breath of the miners, and the heat given out by their lamps, as well as by the explosion of gunpowder, are calculated to raise the temperature of mines, and to vitiate the results obtained by experiment. But the errors thus produced are in some measure corrected by the circulation of cold air through the galleries of the mine; for, as one mass of air becomes heated, it expands, and escaping, is replaced by cold air which rushes in. Now, whether experiment be made upon the temperature of the air or of the water in the mine, or of the rocks themselves, some allowance must be made for the effects of the disturbing causes to which allusion has been made. Some geologists, however, attribute the increased temperature of mines and other excavations entirely to these local causes. There is something like an unwarrantable skepticism in this opinion; for, admitting and allowing for the influence of these deranging causes, there is evidently a resultant which increases with the depth, and can be only attributed to an increasing interior temperature. About three hundred observations had been made in various countries previous to the year 1827, at depths varying from 127 to 1700 feet, the results of which have been combined by M. Cordier, and they severally lead to the same conclusion—a subterranean temperature increasing with the depth. M. Cordier has endeavoured to allow for the errors to which these experiments were liable, and has probably approximated to the truth, although the difficulties connected with the investigation are undeniably greater than might at first be imagined. If the temperature of the water found in mines be taken as a criterion of the temperature of the depth at which it is found, it will be necessary for the observer to consider whether it came from above or below its present situation, and to allow for the heat it received or gave out in passing through rocks. If the temperature of the rock itself be taken into account, an allowance should be made for the contact of the air, and of the water that percolates through it. After estimating as nearly as possible, M. Cordier deduces from the experiments generally, and from his own in particular, a series of interesting and important principles.

It appears, then, that there is an increase of temperature according to the depth from the surface of the earth; an increase which is not at all dependant on the solar rays, but belongs essentially to the condition of the mineral components of the earth's body. This increase of subterranean heat in proportion to the depth does not follow the same law in all places; for, in some countries, the ratio between the depth and the increase of temperature is much greater than in others. From experiments made beneath the Observatory of Paris, it was deduced, that at that place a depth of fifty-one feet corresponds with an increase of one degree of heat, from which it would follow, admitting a similar continued increase, that the temperature of rocks, at a depth under the city of Paris of about a mile and a half, is equal to that of boiling water. But the same results are not obtained in all places, for we have a variety of depths as the index of an increase of one degree in temperature, varying from twenty-four to one hundred and four feet. It is probable that the difference between the increase of temperature in relation to the depth at different places, may be in some measure attributable to the imperfection of the experiments from which the results are deduced; but it is not wholly referrible to this cause, and we must concede, after making every allowance, that there is a certain irregularity in the distribution of subterranean heat, which has no constant relation to the latitudes and longitudes of places. The mean increase of temperature is calculated to be a degree for every forty-six feet; but this result cannot be considered as perfectly accurate, nor is it possible to determine whether there be any lines upon which the depth and the increase of temperature would have a constant ratio to one another. Many other experiments are necessary; and they should be made not only with the intention of ascertaining the ratio between the increase of temperature and the depth at particular places, but also to fix those lines, if there be such, upon which the ratio is the same. We may hope to accomplish this desirable object, and it will be the duty of succeeding ages to repeat the experiments, to ascertain whether these ratios are constant, or whether they are influenced by duration, to fix their relation to the isodynamic zones, and to the line of no variation. With the most industrious exertion it will require a considerable time to solve these interesting problems, for we have as yet taken but the first step towards the investigation of the subject. Two things, however, are certainly determined, the increased subterranean temperature, and its variation of amount in different places.

A simple reliance upon these facts, without an allusion to theory, could scarcely be expected of the most cautious philosopher. Let it be admitted, that the temperature continues to increase from the surface to the centre of the earth at the rate of one degree for forty-six feet, and it follows that at the centre there is a temperature equal to 450,000° of Fahrenheit's scale; and at the depth of about sixty miles, there is a temperature sufficient to fuse all known rocks. These deductions are believed by some philosophers, while others are unwilling to admit them; for though they may allow that subterranean temperature does increase within the depths to which examination has extended, yet they assign a limit to this increase, such as may suit their own theoretical notions. It is perhaps unwise to press the facts to which we have alluded into the service of any particular theory; but, at the same time, if it be true that the interior temperature increases proportionally with the depth in all those places in which experiments have been made, it will be difficult to assign any depth at which the temperature ceases to increase. It is this, in all probability, that has led M. Cordier and others to believe that the temperature continues to increase even to the centre of the earth, though at every depth it is gradually becoming less, from the radiation at the surface.

It is no new doctrine that the centre of the earth is in a state of igneous liquidity, though it has but recently been proved by experiment. Some of the ancient philosophers, imagining the principle we call heat to have a material existence, supposed the interior of the earth to have received and retained a portion of the solar rays, and thus to have stored up a laboratory of calorific matter suited to produce those phenomena acknowledged on all hands to result from a greatly increased temperature. Other persons imagine the earth to have been originally in a state of igneous fluidity; but, in proportion to the decrease of surface temperature, there must have been a condensation of aqueous vapour on its surface, and oceans, seas, rivers, and lakes, were consequently produced, with all those results which are now known to proceed from the motion of the aqueous fluid. To account for the primitive intumescent state of the earth, some have supposed it to be a part of a comet that was by some misfortune brought in the course of its wandering within the attractive influence of the sun, by whom it was enchained, and compelled to perform an undeviating attendance around him. Others have fancied that it must be a fragment from the body of the sun itself, ejected in a liquid and ignited state. La Place, the celebrated French astronomer, calculates its history from a period when it was floating in space as nebulous matter, having no greater consistence than the morning cloud. With these hypotheses we have nothing to do; they are monuments of record to the folly of great minds; but as they are without foundation, they cannot long exist, even to serve as warnings to future adventurous theorists.

Having shown the results to which we may be brought by deductions from well-authenticated experiments, and by imagination unrestrained by philosophy, it may not be undesirable to ascertain what may be gathered from some of those principles which philosophers universally admit as true. Whatever opinion may be entertained concerning the igneous liquidity of the interior of the earth, there can be no reasonable doubt, admitting the truth of the laws of gravitation, that there is an increasing subterranean temperature. Now, it has been proved in a former chapter, that atmospheric air has different densities, dependant on the pressure it undergoes, and the force of gravitation; and as air has a greater density at the level of the sea than on a high mountain, so its density must be greater in a deep mine than on the surface of the earth. But it is well known that heat is given out by bodies when they suffer condensation, and this, in part, accounts for the fact, that temperature increases as the elevation above the sea decreases. The very increase of atmospheric density would, therefore, raise the temperature of the air in deep mines: and although it may not be sufficient in itself to account for all the results that have been obtained by experiment, it is worthy attention. Mr. Ivory has calculated that one degree of heat will be evolved from air when under a condensation equal to 1-180; and if a volume of air be suddenly reduced to half its bulk, the heat given out would be equal to 180°.

But solids as well as vapours give out heat when they suffer compression. A piece of iron, by frequent hammering, may be raised to a red heat. Now it may be easily deduced that the mineral constituents of the earth undergo compression in proportion to their nearness to the centre, and consequently their temperatures will be in the same proportion. There are two antagonist forces acting upon the body of the earth, centrifugal force and gravitation. The rapid revolution of the earth on its axis generates a force which urges every particle to leave its combination, and to fly off into space as an independent mass of matter—this is the centrifugal force; but its influence is restrained by the force of gravitation, which gives each particle a tendency to fall to the centre, and entirely prevents the separation which would follow from the unrestrained activity of the centrifugal force. But the effects of the two forces are not less distinct than the laws by which they are governed. The centrifugal force increases with the distance from the centre; the force of gravity increases as the distance diminishes. It will therefore follow, that the density of the earth increases in proportion to the depth from the surface; and as heat is given out by compression, the subterranean temperature must increase with the depth.

Admitting the truth of the arguments that have been employed, and the deductions that may be drawn from them, it is not difficult to account for the various results that have been obtained by experiments on the internal heat at different places. It is well known that the earth consists of a great variety of substances, having distinct physical properties. There are some that have a great capacity for heat; there are others that are good conductors; while a third class may be altogether devoid of both these properties. If we could suppose all the mineral compounds that compose the earth's body to be perfect conductors of heat, there would be a constant current towards the surface, and a radiation from it. There is such a current; but all the mineral masses are not conductors, and when a heated stratum is surrounded with a substance which cannot conduct heat, the temperature must be retained. We need not, therefore, be surprised, that different results should be obtained at the same relative depths in distant places, a circumstance necessarily resulting from the peculiarities of bodies in regard to the principle of heat. It may, perhaps, be supposed by some, that this variation in the temperature at equal depths may be aided, in certain places, by a local chymical action. Within certain limits, this may possibly occur, and produce casual variations in the general law; but we do not believe that chymical action can be exerted under the enormous pressure that exists at comparatively small depths.

In this way the existence of an increasing interior heat may be deduced without adopting the supposition that the whole globe was originally in a state of fusion, and that by the radiation of heat, and the consequent cooling of the upper portion of the mass, beds of primitive rock were formed. Nor do we perceive any necessity for supposing the interior of the earth, either at a former or at the present time, to be in a state of igneous fluidity, though the reasons adduced are sufficient to prove that there is a considerable increase of heat in the interior of the earth, and possibly in some places an absolute liquidity.

M. Cordier, who admits the igneous liquidity of a large portion of the earth's body, has applied the supposition to the explanation of volcanic action, in a very ingenious manner. He supposes volcanic phenomena to result from the gradual cooling and consequent contraction of the interior of the earth. The contraction of the refrigerating crust is said to produce an enormous pressure upon the interior fluid matter, in many cases equal to 28,000 atmospheres, and to force a portion of the fused rocks through a vent already formed, or to produce a new aperture for emission, by breaking away the solid crust in those places where it has least power of resistance. In support of this opinion, he adduces the following singular calculations. From the measurement of the matter ejected by different volcanoes, he calculates that the extreme limit of the product of an eruption is less than one cubic kilometre, or 1,308,044,971 cubic yards. Now, if the mean thickness of the crust of the earth be 62.1 miles, its contraction, producing a decrease of the radius of the central mass equal to the 12,694th of an inch, would be sufficient to produce a violent eruption. M. Cordier then proceeds to state that, allowing five eruptions every year, the difference between the contraction of the solid crust and that of the internal mass would not shorten the radius of that mass more than ·03937 of an inch in a century.*

That volcanic eruptions are the effects of a high interior temperature we have no doubt, but many valid objections might be urged against M. Cordier's theory.

From the short analysis we have given of the facts and reasonings by which a high interior temperature may be proved, it will be evident that it is not easy to determine the general laws by which it is governed. If the central portion of the earth be in a condition of igneous liquidity, the solid crust which envelops it may be supposed to be of various thickness, as all mineral substances have not the same power of conducting heat. Hence there must be a considerable difference in the amount of radiated heat, unconnected with the situation of the place on the surface of the globe. This view of the subject connects it with the question of climates, the diversity of which has long attracted the attention of philosophers. But at present we cannot even guess the influence which the determination of this question may have upon the solution of many problems that have long perplexed the philosopher. In the present condition of our knowledge, the details that have been given may be somewhat uninteresting to the general reader; but we anticipate that, when those principles are determined which are within the reach of experiment and physico-mathematical reasoning, the subject will be second to none in importance or interest.

If it be true that temperature increases with the depth, there will be little difficulty in explaining many phenomena, the causes of which are now matters of conjecture. The disturbances suffered by the ancient rocks, and the ejection of volcanic products among them, as well as the existence of modern volcanoes, earthquakes, and thermal springs, are easily accounted for, should the statements we have advanced be true. We have no doubt of their accuracy, and shall consequently proceed to an explanation of the appearances which we suppose to result from them, and review the

* See page 107.

opinions which some other persons have entertained as to the origin of the same phenomena.

VOLCANOES.

Geology was for a long time a combination of hypotheses, but for many years past it has been advancing to the rank of a practical science. Although it has gained much by the industry and zeal of those who have devoted themselves to its improvement, yet it is still necessary that some care should be exercised in the admission of statements as facts, and all hypotheses should be examined with a jealous regard to the advantage of science. So long as Stahl and Beccher haunted chymistry with their phlogistic phantom, every phenomenon was wrapped in the mist which it generated; and so the random conjectures of cosmogonists have enveloped the facts recorded upon the page of material existence. In describing the geological constitution of the earth, we are accustomed to speak of the agencies which we suppose to act upon it as though it could not exist unless it preserved the character with which it has been invested by our imagination, and could not have existed at all unless it had been formed according to our own plan. Now geologists are cured of the mania by which their predecessors were afflicted, and direct their energies to the discovery of truth, our knowledge of volcanic forces, and the phenomena which attend volcanic activity, will soon, it is hoped, be so much increased as to enable us to determine, with much more certainty than we now do, the extent and relations of the volcanic cause. There was a time, and it is almost within the remembrance of some of our readers, when the Mounts Etna and Vesuvius were universally considered the types of volcanic activity, and the existence of the igneous cause was determined by a comparison of phenomena with those which attended the eruption of those celebrated mountains. The extensive observations made by those who have recently engaged in the study of rocks, have already given us a more accurate conception of volcanic action, have exposed to view many facts probably connected with the cause, and made us tolerably acquainted with the geographical position of mountains and their periods of activity.

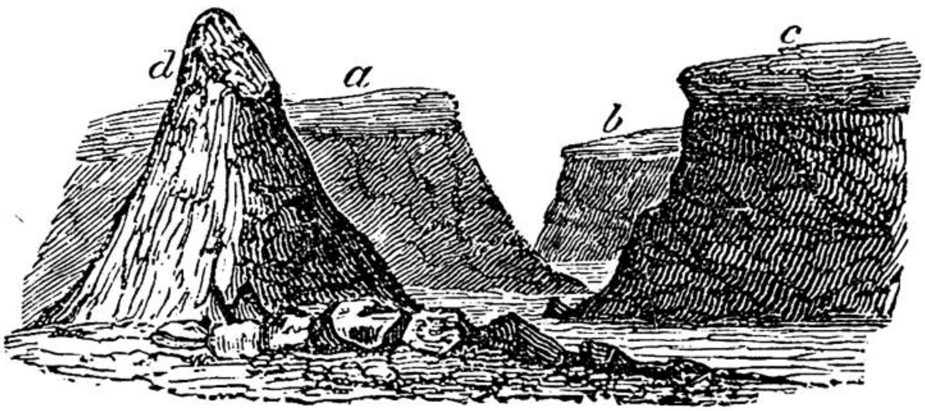
There is a great want of definite application in the use of the words volcano and volcanic cause. Sometimes they are used as synonymous with the terms igneous effects and igneous agencies, while at other times they are only employed in relation to elevations which eject from their summits or cones fused rocks, and the cause which gives them birth. Some writers include in the expression, volcanic action, the phenomenon of hot springs; others add to this the ejection of mud, as at Turbaco, in South America, while others confine it to the positive projection of liquefied mineral matter from the interior of the earth. Now, however certain it may be that many phenomena derive their origin from the energy of the same cause, yet some difference should be made in descriptive language; and therefore, instead of applying the term volcano to all those appearances in which heated substances are ejected from below the surface of the earth, we shall confine its application to those spots where liquefied rocks, having proofs of calorific agency, are ejected.

Volcanoes, according to our definition of them, may be divided into two classes, active and extinct. There is some difficulty in determining whether a volcano is extinct or not; for craters which have not suffered eruption for ages, have suddenly assumed all their activity, and spread their liquefied contents over the adjacent districts. We must then consider all volcanoes to be extinct which have not been active during the historic period; but should any of these hereafter exhibit any proof of a continued existence of the agent, they may then be classed among the active cones.

The most interesting series of extinct volcanoes with which we are personally acquainted, is that of Auvergne, in France. The most recent of these had certainly no relic of activity at the time when Julius Cesar invaded Gaul; for although he encamped upon them, he has not in his commentaries alluded to their volcanic origin. How long before this they ceased to present those phenomena which attend eruption must be a matter of speculation, as the most ancient historical records of the country do not in any way refer to them.

The most recent part of this district is that to the west of Claremont. This fact is determined by the position of the lavas, and not by any distinctive characters in their composition; for it is well known that all deductions formed upon the differences of chymical constitution in the ejected materials, are exceedingly erroneous. But when the geologist traces a bed of lava down a contiguous valley, he is justified in supposing that the lava was ejected after the valley was excavated, and, on the other hand, when it occurs as an outlier, and caps the hills which surround the valleys, he may then conclude that the valley was formed after the ejection of the lava, as its excavation has destroyed the continuity of the bed. Now, it is generally acknowledged that these valleys were formed by the last diluvian forces; we have, therefore, a convenient and natural division of extinct volcanoes, into ante and post diluvian.

Let us suppose, for the sake of illustration, that the outliers, *a b c*, are composed of a volcanic rock, having the



characters necessary to identify them as parts of the same mass. It is evident, from their situation and dip, that they were once continuous, and that the catastrophe which excavated the valley destroyed the intermediate portion of the bed; the volcanic rock is therefore antediluvian. But if the cone *d*, and a contiguous valley should be covered with a bed of lava, it would be spoken of as a postdiluvian formation.

There is one district which, above all others, would repay investigation, and probably lead to some important results: we refer to the country around the Dead Sea. From the Sacred Writings we learn, that the spot now called the Dead Sea was the well-watered and fertile plain of Jordan, in which Lot resided when the cities were overthrown. From the character and distribution of the ancient lavas, pumice, and other volcanic productions found in this district, we may deduce that the overthrow of the cities, and the formation of the sea or lake, were produced by a now extinct volcano situated to the southeast of the lake. The wells of naptha, and the hills of sulphur, are spoken of by all travellers who have visited this desolate country, and in some places, it is said, the soil is so impregnated with these inflammable materials, that it may be easily set on fire. Pumice, obsidian, and ashes, are scattered over the face of the country; and craters have been discovered in various parts among rocks of sienite and porphyry.

Dr. Daubeny has given a very interesting account of this district, in his work on Volcanoes, but in some particulars we differ from him as to the origin of the Dead Sea. "I should suppose," he says, "that the same volcano which destroyed the cities of the plain, threw out at the same time a current of lava sufficiently considerable to stop the course of the Jordan, the waters of which, unable to overcome the barrier, accumulated in the plain Siddim, until they converted it into the present lake." The natural termination of the river was thus altered; its estuary, which the doctor supposes to have before opened into the Elemitic branch of the Red Sea by Ahaba, was entirely destroyed; and the waters which it brought down from the mountains of Antilibanus, were dissipated by evaporation from the Dead Sea, which is a mere accumulation of them, its extent being determined by the temperature, which induces evaporation from its surface in proportion to the quantity brought into that sea by the Jordan and other streams.

Although we admit the accuracy of the general outline of the geological picture which Dr. Daubeny has drawn of the Holy Land before the catastrophe which destroyed the cities of the plain, there is one feature which appears to us inaccurate—the southerly direction of the Jordan. He speaks of a great longitudinal valley, discovered by Burckhardt, as the channel through which its waters were once discharged. But the probability is, that this river was either lost before it reached Ahaba, or it turned to the west after passing through the Vale of Siddim, and fell into the Mediterranean Sea; for we cannot imagine that so small a river as the Jordan, fed by so few auxiliary streams, could find its way through the broad gorges of El Araba and El Ghor, the stream itself being constantly decreased by evaporation. This question, however, can only be solved by a careful examination of the district. Nor do we believe that the Dead Sea is an accumulation of water brought into the Vale of Siddim by the Jordan; for it appears to us far more probable that the earth on which the devoted cities stood, sank at the time of their destruction, and that the lake was then immediately formed, as in the case of Euphemia. But, whatever may have been the manner in which the volcanic agent acted to produce the effect, it would be exceedingly interesting to know something of the present appearance of the district, and the distribution of the lava over the neighbouring valleys.

It has been already stated that it is not uncommon to find volcanic rocks, or at least rocks which so much resemble those now ejected by volcanoes, that few geologists doubt their igneous origin, alternating with, or enclosed by, stratified deposites. The rocks of this class are known by the generic term trap, and are specifically designated green-stones, basalts, and porphyries. The rocks of the Pic du Midi de Bigorre, for instance, and the limestones especially, are generally superposed by trap. At Christiana, in Norway, slate and the rock called grauwacke are covered by a bed of porphyry, not less than sixteen hundred feet in thickness; and at Holmestrand, the same mass passes into a fine-grained basalt. In the Island of Skye, red sandstone is traversed by a great number of trap veins, and is sometimes superposed by the same rock. At Lamlash, in the Western Isles, sandstone, conglomerate, and clinkstone, are traversed by a vein of spheroidal trap.

ACTIVE VOLCANOES.

Active volcanoes may be divided into two classes, the aerial and the subaqueous; that is to say, those which have their craters exposed to the action of the air, and those which are under the water. It will be readily supposed that there must be a considerable difference in the character of the phenomena which attend the activity under these two circumstances; a difference which has in fact some relation to the density of the medium by which the agency is restrained. Our knowledge of the phenomena which precede and attend subaqueous eruption is exceedingly limited; but still it will be necessary to consider the appearances which result from the activity of volcanoes under both circumstances.

THE PHENOMENA WHICH GENERALLY PRECEDE VOLCANIC ACTIVITY.

In every age of the world there have been some who, separating themselves in part from the common pursuits of mankind, have devoted a portion of their time to the investigation of natural phenomena. These men have attempted to explain those things which others have considered as the secrets of Almighty Intelligence, and have delighted themselves with the contemplation of the beauty of created existence, and the wisdom displayed in its formation. But those who have been unimpressed by nature in her periods of repose, have been attracted by her appearance in the moment of sublime excitement. The accuracy of this remark will be admitted by those who have never beheld a more violent convulsion than that produced by a passing thunder-storm, and still more by those who have seen mountains themselves shaken and rent by the impetuous action of subterranean fires. The importance which men attribute to uncommon appearances, and particularly to those of a fearful character has been the means of supplying us with an ample fund of information concerning the states and effects of those volcanic mountains which exist in countries inhabited by, or known to, those whom we designate the ancients.

The phenomena which precede volcanic eruptions always present, wherever they may occur, a great similarity of character, though they may vary in their intensity. The energy chiefly depends upon the force required to open a passage for the liquefied mass, and the attendant gaseous fluids. If the vent of an habitual volcano be much obstructed by the accumulation of lava in the fissure through which ejection has taken place, a greater power will be required than would be otherwise necessary, as the fissure must be re-opened and the lava elevated; and if it be necessary to form an entirely new vent, a still greater force must be brought into action, and that in proportion to the solidity, position, and weight of the superposed mass. There is not, we believe, a single instance within the range of historical records, in which a new vent has been formed in a country never before the seat of volcanic action. It is not uncommon to hear of the eruption of volcanoes that have been for centuries inactive, nor is it improbable that entirely new vents are sometimes formed in those situations where the same power has been before exerted. In both these cases, the great obstruction presented to the volcanic agent by superposed rocks has been removed by former eruptions, and therefore but little increase of power is required to force a passage for the melted materials.

Volcanic eruptions are generally preceded by earthquake, and the phenomena which are known to attend that terrible disturbance of the earth's stability. Loud rumbling sounds are heard, the air has a mournful stillness, as though conscious of the coming darkness, the electric fluid bursts in broad flashes over the smoking summit of the mountain, and nature itself seems to be dressed in mourning habiliments. These appearances may last for hours or for days, and sometimes the fears which they excite are not realized, but after a brief convulsion natural objects resume their accustomed appearance. It must not then be supposed that earthquake is always followed by volcanic eruption, for there are some countries so insecurely based, that the inhabitants might live in the momentary expectation of being covered by the ground on which they tread, though a volcano does not actually exist within hundreds of miles. Captain Bagnold states that in twelve months, during his residence at Coquimbo, on the coast of Chili, he felt no less than sixty-one shocks of earthquake, not calculating the slighter movements to which the surface is still more frequently subject.

PHENOMENA RESULTING FROM VOLCANIC ACTIVITY.

The period and intensity of volcanic eruptions are in nearly all cases irregular, and we have consequently no means of arranging the several mountains in class s, for the sake of a more accurate comparison of their effects. Sometimes a mountain will be in a state of violent paroxysmal eruption; and when this has passed away, it may be for years agitated with partial throes of but little intensity, or fall at once into a state of prolonged slumber. These variations are common to nearly all volcanic mountains; and consequently we cannot arrange them permanently by the character of their activity, though we may, in considering the phenomena they produce, form a general division, founded on the period and intensity of eruption, that will considerably guide us in the study of the phenomena. There are, in fact, three classes of volcanic activity—permanent eruption, moderate activity, and pro longed intermittences.

VOLCANOES IN PERMANENT ERUPTION.

It is said that there are not more than three volcanoes which are in a state of permanent activity: that of Stromboli, one of the Lipari Isles; the Devil's Mouth, in the Lake of Nicaragua; and that in the Isle of Bourbon.

Stromboli has been in a state of constant activity for more than two thousand years, and is a good type of this class. Lava seldom overflows its crater, but large masses of burning rocks and scoriæ are incessantly ejected in a perpendicular direction. This phenomenon, accompanied by a loud explosion, occurs every seven or eight minutes, of which fact we are informed by Pliny, as well as by modern travellers.

Dolomieu examined this interesting mountain, and has given the following description of its eruptions:—"The inflamed crater is on the northwestern part of the isle, on the side of the mountain. I saw it dart during the night, at regular intervals of seven or eight minutes, ignited stones, which rose to the height of more than a hundred feet, forming rays a little divergent, but of which the greater quantity fell back into the crater, while others rolled even to the sea."

On the following day he ascended an eminence above the crater, from which he obtained a still more interesting view. "The crater," he says, "is very small; I do not think it exceeds fifty paces in diameter, having the form of a funnel terminating in a point. During all the time I observed it, the eruptions succeeded with the same regularity as during the preceding night. The approach of the eruption is not announced by any noise or dull murmur in the interior of the mountain, and it is always with surprise that one sees the stones darted into the air. There are times when the eruption is more precipitate and violent, and stones describing more divergent rays are thrown into the sea at a considerable distance."

It has been stated by Dolomieu, Hamilton, and Scropè, on the authority of the islanders, that during the winter seasons the eruptions are far more violent than in summer, and that atmospheric changes may be generally predicted from the appearance of the crater. Sometimes during the storms of winter the cone is split, and large currents of lava are discharged.

In the Island of Volcano there is a crater which at some former period must have been active, and still emits gaseous vapours, which prove the continued existence of the volcanic cause. "The operations of this volcano," says Dr. Daubeny, "exhibit perhaps the nearest approximation to a state of activity during which descent into the crater would have been practicable.

"Nor can I imagine a spectacle of more solemn grandeur than that presented in its interior, or conceive a spot better calculated to excite, in a superstitious age, that religious awe which caused the island to be considered sacred to Vulcan, and the various caverns below as the peculiar residence of the gods."

VOLCANOES IN MODERATE ACTION.

Volcanoes are in the phase of moderate activity when they are in a state of prolonged but inconsiderable excitement. Under this class we may place the volcano of Popocatepetl, in Mexico, which was found in this phase by the discoverers of the country. Such also was the condition of Vesuvius from the commencement of this century to the year 1822.

Signior Maria Gemmellario has given, from a meteorological journal kept at Catania, a very interesting view of the successive changes of Mount Etna, at a period in which it was in the phase of moderate activity; and no description could give so accurate a conception of the ever-changing phenomena.

On the 9th of February, 1804, there was a sensible earthquake. Etna smoked ninety-seven days, but there was no eruption nor any thunder.

On the 3d of July, 1805, there was an earthquake. Etna smoked forty-seven days, and emitted flame twenty-eight days. There was an eruption in June, but no thunder.

There were earthquakes on the 27th of May and 10th of October, 1806. The mountain smoked forty-seven days, flamed seven, and detonated twenty-eight; little thunder.

On the 24th of February and 25th of November, 1807, there were earthquakes. Etna smoked fifty-nine days; little thunder.

In August, September, and December, 1808, earthquakes were frequent. Etna smoked twelve days, flamed 102, and often detonated. Thunder-storms were frequent.

From January to May, and during September and December, 1809, there were thirty-seven earthquakes. The most sensible shock was on the 27th of March, when the mountain ejected lava on the western side. This eruption lasted thirteen days, and part of the Bosco di Castiglione was injured. The mountain smoked one hundred and fifty-two days, flamed three, and detonated eleven. Little thunder.

On the 16th and 17th of February, 1810, there were four earthquakes. On the 27th of October, Etna suffered an eruption on the eastern side, and the lava flowed into the Valle del Bue. There were about twenty thunder-storms.

1811, no earthquakes; but the mountain continued, until the 24th of April, to eject lava from the east. At this time the Mount St. Simon was formed. No thunder.

Earthquake on the 3d and 13th of March, 1813. The mountain smoked twenty-eight days. On the 30th of June and on the 5th of August St. Simon smoked. There were twenty-one thunder-storms.

On the 3d of November, 1814, there was an earthquake, preceded by a discharge of sand from that part of the mountain called Zoccolaro. There were twelve thunder-storms.

On the 6th of September, 1815, there was an earthquake The mountain smoked forty-two days, and there were eleven thunder-storms. On the 6th, 7th, and 11th of January, the lightning was tremendous.

1816, no earthquakes. On the 13th of August a part of the interior side of the crater fell in. Ten thunder-storms.

There was an earthquake on the 18th of October, 1817. The mountain smoked twenty-two days. There were eight thunder-storms.

During 1818, there were twenty-five earthquakes. The most violent was in the neighbourhood of Catania, on the 20th of February. The mountain smoked twenty-four days No thunder.

The phase of moderate activity is not very common, and the instances which have been adduced will be sufficient to acquaint the reader with its general character. The effects of the volcanic cause, even when it assumes the moderate characters we have described, would be sufficient to excite fear and surprise in the mind of any man who had not been accustomed to behold volcanic disturbances; but those who have seen a paroxysmal eruption from an elevated cone after a period of long quiescence, would not much regard these comparatively puny efforts.

THE PHASE OF PAROXYSMAL VIOLENCE.

The phase of paroxysmal violence, or, as it is usually called, long intermittences, is characterized by lengthened periods of repose, followed by violent, though transient eruptions. Baron Humboldt has stated that lofty volcanoes are always in this state. The volcanic mountains of the Andes have not, generally speaking, an eruption more than once in a century; and the Peak of Teneriffe, which was active in 1798, had not at that time been disturbed for ninety-two years. It must not, however, be supposed, that this volcanic condition is confined to elevated craters, for the histories of other mountains give abundant instances to the contrary.

The phenomena which accompany eruption are nearly the same in all cases; varying in intensity, and consequently in the violence of their effects. In some cases the phenomena and the effects are confined to the immediate neighbourhood of the excited mountain; while in other instances, and it is generally the case when the mountain is in the phase of paroxysmal intensity, the effects are felt for many miles round the active cone. The explosions of Cotopaxi have been heard at a distance of 600 miles.

The activity of a volcano generally commences with a loud detonation, which is succeeded by others less loud, and the escape of aeriform fluids. Large fragments of rock and masses of lava are usually projected by these discharges, some of which fall back into the crater and are redischarged, until they are reduced to powder, and mingle with the surrounding atmosphere of heated vapour. The accumulation of these particles produces the appearance of dense clouds of smoke, which are almost invariably seen to surround the summit of the crater.

The lava then rises to the vent of the mountain, and finds an egress from the crater, or from some lateral opening. In some cases, however, scoriæ alone are projected. During the day, the lava is generally hidden by the aqueous vapours which arise from it, but at night it appears of a glowing heat. While the lava continues to flow, the detonations are frequently less violent; but there is no proof of the diminution of the paroxysm until the mountain ceases to eject; and even then peace is not immediately restored, for scoriæ and masses of rock are often thrown out for some time after the dreadful crisis is past.

When the detonations become less frequent, rumbling sounds are heard, as the retreat of mighty waters; and the mountain seems gradually to yield to exhaustion, or sinks into a state of partial rest, occasionally disturbed by explosions, and the ejection of scoriæ. Towards the conclusion of an eruption, that is, after the lava has ceased to flow, the surrounding country is frequently enveloped in dark clouds of black-coloured sand, or a white comminuted pumice.

The lofty mountains seldom eject lava from their summits, but from lateral openings; for it requires far less power to open a passage in the side of the mountain than to elevate the intumescent mass to the summit. In the last eruption of Teneriffe a lateral opening was formed; and, according to a calculation by M. Daubuisson, it would have required a force equivalent to a thousand atmospheres to raise a mass of lava to the elevated crater of the mountain.

We may now adduce a few examples of activity in the phase of paroxysmal violence; and the difficulty is not to find a characteristic type, but to choose from the many authenticated and interesting details that are to be found in the page of philosophical records.

Vesuvius was in this phase in the year 1794. The first proof of the approach of the dreadful eruption which happened at this time, was during the night of the 12th of June, when a severe shock of earthquake was felt at Naples, and over the surrounding country. Nothing more occurred to rouse the fears of the inhabitants till the evening of the 15th, when the earth was again violently agitated. Shortly after this an opening was formed on the western base of the mountain cone, which, on after examination, was found to be 2375 feet in length, and 237 feet in breadth, and a stream of lava was ejected. Not long after the volcanic action had commenced, four distinct hills were formed, composed of lava, from each of which stones and other ignited substances were thrown in such quick succession, that it appeared as if they were each ejecting a vast flame of fire. At this time the lava flowed in great abundance, taking its course towards Portici and Resina. The inhabitants of Torre del Greco, rejoiced to see a prospect of their escape from the destroying fluid, were assembled together to return thanks for their deliverance, and to supplicate for their unfortunate neighbours, when they received the melancholy tidings that the lava had changed its direction, and was approaching their town

In flowing down a declivity, it had divided itself into three streams; one directing its course towards St. Maria del Pagliano, another towards Resina, and a third towards La Torre.

During the whole of this time the mountain was greatly convulsed, and deep hollow sounds were heard, which, together with the impetuous ejection of the lava, shook the mountain itself to the very base. When the oscillatory motion of the mountain ceased, the sounds became less frequent, but more distinct; the lava flowed more abundantly, and the action seemed as though it were suffering under the last paroxysm of its dying energies. This was about four o'clock in the morning of the 16th, and at that time the intumescent mass had spread itself through all the streets of Torre del Greco, and from thence had flowed into the sea, covering its bed 362 feet beyond the margin of the water, the current having a breadth of 1127 feet. The distance from the point of ejection to the place where its progress was arrested was 12,961 feet.

During the progress of the eruption the summit of Vesuvius was perfectly quiescent, and no remarkable phenomenon was observed round the crater. But towards the dawn of day, the heights of the mountain were hidden by a dense cloud of comminuted sand, which, spreading itself, in a short time covered the whole country, and the sun was darkened by an impenetrable mantle of clouds.

It is impossible to describe the horrors of that night, in which Vesuvius poured out its terrible fury on the beautiful valley beneath it. The fiery ejections, and the inexpressible groans of the mountain, the death-like stillness of the atmosphere, and the cries of the thousands who had been driven from their homes and all the pleasures of life, must together have presented a combination of terrors which no imagination can realize.

But, it was not on the western side only that lava was ejected; there was an active crater on the eastern; and the stream which flowed from it filled the valley of Torienta, which was 65 feet wide, 120 feet deep, and 1627 feet long. From this valley it took its way into the plain of Forte, where, like the western stream, it divided into three branches, which severally took their courses towards Bosco, Mauro, and the plains of Mulara. This current was not above half so large as that which flowed from the western side.

When the lava ceased to flow, the crater was covered by a dense cloud of comminuted pumice, which enveloped it the four following days, during which time the summit of the mountain fell into the internal cavity. The surrounding country, to the distance of ten or twelve miles, was wrapped in a midnight darkness, and thunder-storms were awfully frequent. The average depth of the sand which fell during this period, for a distance of three miles round Vesuvius, is said to have been fourteen inches and a half.

But although this eruption was attended with phenomena of a most awful character, yet its effects are not to be compared with those which attended the activity of Tomboro, in Sumbawa, in the year 1815. The convulsions of Tomboro commenced on the 5th of April with loud rumbling sounds, which continued till the 7th of that month, when three columns of flame burst forth from near the top of the mountain. A short time after the lava began to flow, the mountain appeared as though it were a solid body of fire; but at eight o'clock, about an hour after the ejection of lava, it was obscured by a thick cloud of sand. Between nine and ten o'clock ashes fell, and a whirlwind arose which struck to the ground almost every house in the village of Sangar, and carried, with tremendous force, the lighter parts, uprooted the trees, and swept away both men and cattle in its fury. About midnight the explosions commenced, and continued with intense violence till the evening of the 11th instant without intermission. After this they moderated, but did not entirely cease till the 25th of July. Of all the villages round Tomboro, only one, Tempo, escaped destruction; and out of twelve thousand inhabitants, only twenty-six were saved.

But the effects of this eruption were not confined to a limited district. The fall of the ashes forty miles distant was so heavy, that the houses were considerably damaged, and in many instances rendered uninhabitable. In Java, three hundred miles distant, the detonations were so distinct, and so much resembled the discharge of artillery, that a detachment of soldiers were marched from Djocjocarta, under the supposition that there was an attack upon a neighbouring military post; and on the seashore the reports were mistaken for the guns of a vessel in distress, and boats were in two instances sent to give relief.

On the 6th the sun was, even at this distance, obscured, and there was every appearance of an approaching earthquake. On the 10th the noises were louder, and at Sumanap and Banynwangi the earth was violently shaken. Gresie and other districts more eastward were enveloped during the greater part of the 12th of April in indescribable darkness, but, as the clouds of ashes passed over and discharged themselves, light returned; but it was not till the 17th, when a shower of rain fell, that the atmosphere was cleared of its clouds of heated vapour and sand. The ashes were nine inches deep at Banynwangi.

The detonations of Tomboro were heard in Sumatra, 970 miles distant, and indeed in all the Molucca Islands; but so dreadful were its effects along the north and west of the peninsula, that but one solitary vestige of vegetable life was preserved.

We may take Etna as another example of volcanic activity in the phase of paroxysmal violence. This mountain is entirely composed of volcanic rocks, and rises in imposing grandeur to the height of 10,000 feet above the level of the sea. It is about one hundred and eighty miles in circumference, and is surrounded on every side by apparently small volcanic cones, though of no inconsiderable size. The earliest historical notice of this mountain is by Thucydides, who states that there were three eruptions previous to the Peloponnesian war, to one of which Pindar alludes in his first Pythian Ode. In the year 396 B. C., the volcano was again active; and, according to Diodorus Siculus, the Carthaginian army was stopped by the flowing lava when marching against Syracuse.

One of the most remarkable eruptions suffered by this mountain was that which occurred in the year 1669, which was so violent that fifteen towns and villages were destroyed, and the stream was so deep that the lava flowed over the walls of Catania, sixty feet in height, and destroyed a part of the city. But the most singular circumstance connected with this eruption was the formation of a number of extensive fissures, which appeared as though filled with intumescent rock. At the very commencement of the eruption one was formed in the plain of St. Lio, twelve miles in length and six feet broad, ejecting a vivid flame, and shortly after five others were opened. The town of Nicolosi, situated twenty miles from the summit of Etna, was destroyed by earthquake, and near the place where it stood two gulfs were formed, from which so large a quantity of sand and scoriæ was thrown, that a cone called Mount Rossi, four hundred and fifty feet high, was produced in about three months.

We may, perhaps, introduce one other example of the effects produced by volcanoes in the condition of paroxysmal violence. Hecla has been long celebrated for the intensity and continuance of its eruptions. The island in which it is situated is not unfrequently shaken from its centre to its shores with violent earthquakes, and new islands are often formed upon its coasts, some of them sinking beneath the level of the water as quickly as they were formed, and others continuing for so many years as to give expectation of their permanence. Hecla has been more than twenty times in a state of eruption during the last eight hundred years, and, when excited, its devastating fury is not easily appeased. But Iceland is, as it were, the covering of one of the principal Plutonian workshops, and its mountains are the chimneys of ever active forges.

If we could mention one year as being more distinguished than any other for the violence of the volcanic force in Iceland, we might direct the attention of the reader to the year 1783. In the month of May a submarine volcano was formed in latitude 63° 25′ north, and longitude 23° 44′ west, about thirty miles southwest of Reykianas. From the crater of this island, so large a quantity of pumice was ejected, that the ocean was completely covered with it for a distance of more than one hundred and thirty miles; but, after a short time, the island sank beneath the level of the ocean, and only a rocky reef, from five to thirty fathoms beneath the water, was left as the evidence of the prior existence of the island, and the activity of the volcanic force. On the 11th of June, Skaptár Jokul, a volcanic mountain that has often spread desolation over the surrounding country, ejected a considerable torrent of lava, which, flowing into the river Skapta, dried it up, and overflowed the fields beyond it, although in some places the bed was more than six hundred feet deep and nearly two hundred feet wide. A deep lake between Skaptardal and Aa was filled with the lava, and a subsequent current "was precipitated down a tremendous cataract called Stapafos, where it filled a profound abyss which that great waterfall had been hollowing out for ages, and after this the fiery current again continued its course."

The remarks of Professor Lyell upon the effects of this eruption are so explanatory and true, that we may be permitted to quote them. "These Icelandic lavas, like the ancient streams which are met with in Auvergne and other provinces of central France, are stated by Stephenson to have accumulated to a prodigious depth in narrow rocky gorges; but, when they came to wide alluvial plains, they spread themselves out into broad burning lakes, sometimes from twelve to fifteen miles wide and one hundred feet deep. When the 'fiery lake' which filled up the lower portion of the valley of Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills, whence the Skaptâ takes its rise. This affords a parallel case to one which can be shown to have happened at a remote era in the volcanic region of the Vivarais, in France, where lava issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up the channel of the river Ardêche.

"The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont d'Or, in Auvergne, where more modern lava-currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterward, in 1794, he found columns of smoke still rising from parts of the lava, and several rents filled with hot water."

This explanation of the effects of a volcanic eruption may suggest the origin of those extensive masses of igneous rocks which are found to overlie those of aqueous origin, while at the same time it accounts for many of the veins which are occasionally found to intersect horizontal deposites. Veins have been formed by injection, and by the admission of igneous rocks from above; in the former case the rocks must have been almost necessarily disturbed, and they will consequently give evidence of that disturbance; but veins may have been formed by intermission without any disturbance of the parallelism of the beds they intersect. When lava is ejected into a fissure from below, the probability is, that the fissure was formed by either the same cause that pro pelled the liquefied rocks, or by one similar to it in intensity and character; but, when filled from above, the aperture may have been produced by an aqueous as well as by an igneous cause, and hence it is that in these instances we sometimes find that the beds which surround the basalt or trap vein give no evidence of having suffered under a disturbing force. We are taught the cause of ancient phenomena by studying those agents which are now active.

The observations and statements which have been made are sufficient to show the activity and agency of the volcanic force, when its effects are exhibited on islands and continents. But we have spoken of subaqueous volcanoes; and in order to compare the variety of effects produced by the two classes of active cones, it may be necessary to state a few examples of subaqueous eruption.

We have not authentic records of many subaqueous volcanoes. When it is considered that much the greater portion of the surface of the globe is covered by water, this fact may appear to intimate a much less active condition of the volcanic agent beneath the level of the sea than on dry land; but the elevation of the volcanic cones above the water is the real cause of this ascertained result. An eruption of any considerable violence must, of necessity, form an elevation that will come under the class of aerial volcanoes, and hence it is that so many active cones are situated in islands.

There is much difficulty in obtaining detailed information concerning the phenomena resulting from the activity of subaqueous volcanoes. That the eruptions are as numerous as from aerial craters, there can be no doubt; but there is less probability of their being observed. It is a singular fact, that we are acquainted with scarcely an instance of subaqueous eruption that has not produced an island; and yet it may be reasonably supposed that many do occur which have not sufficient energy to elevate the mineral masses above the level of the sea. This fact may be accounted for in two ways: the volcanic vent may be superposed by so great a depth of water, that no effect is produced on the surface by the eruption; or the energy which is exerted may be sufficient to occasion many phenomena on the surface of the water, though no observer is present; and therefore, in this instance, as well as in the former, we are prevented from gaining any information concerning the appearances exhibited

Some of the most remarkable subaqueous eruptions with which we are acquainted, are those that troubled the Sea of Azof, the Azores, and the Island of Santorino, in the Grecian Archipelago. We may select one or two examples to illustrate the usual class of phenomena.

The Island of Santorino, in the Grecian Archipelago, was formerly known by the name Hiera, but this name is now given to another island. Pliny, speaking of it, says, "There is a tradition, that it rose out of the sea;" and supposes it to have occurred about 237 B.C.

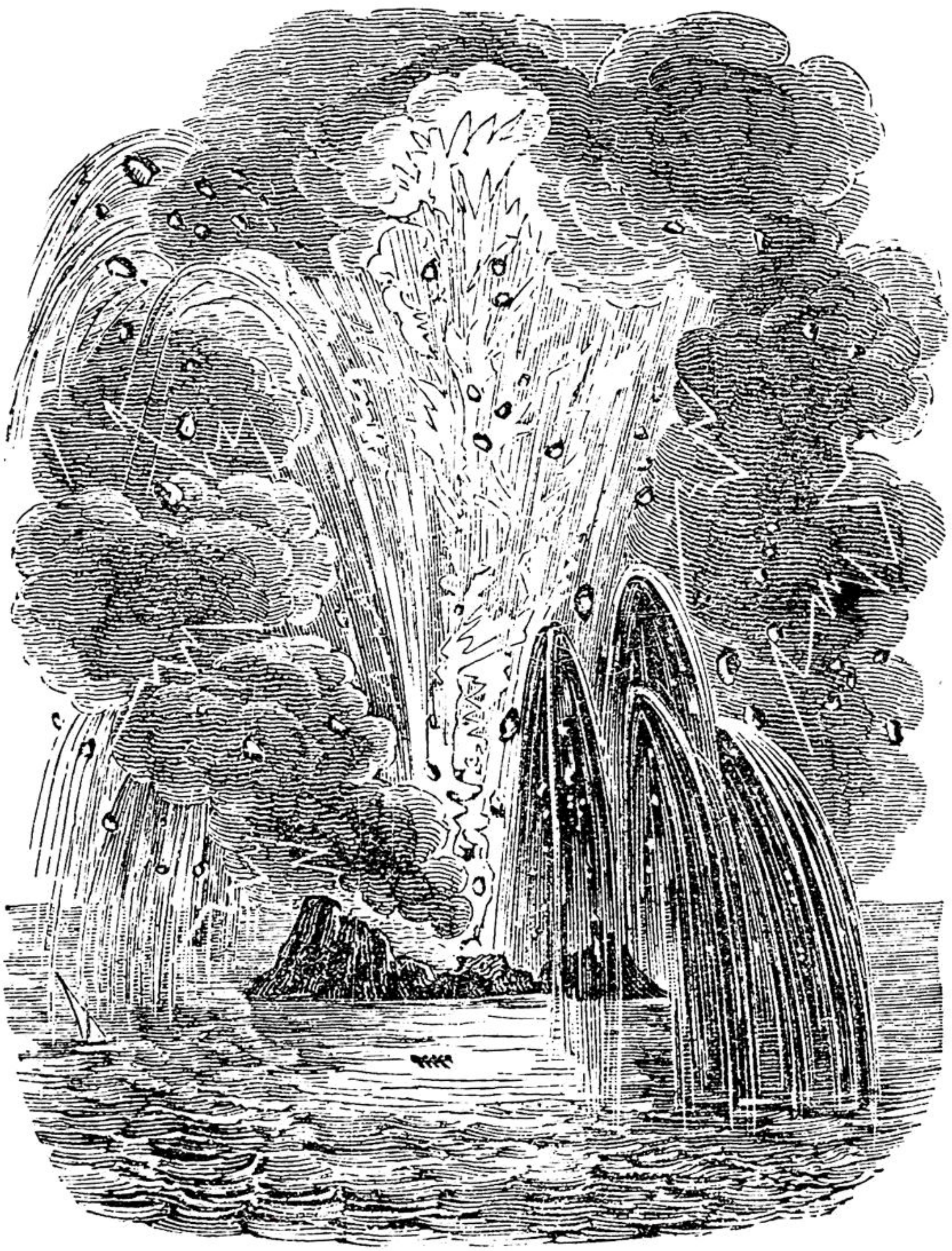
By the activity of, in all probability, the same volcanic force, several islands have at various times been formed—

Hiera rose from the sea in the year	197 B.C.
Thia - - - - -	40 A.D.
Thia and Hiera were united -	726 A.D.
Little Kamenoi was formed -	1573 A.D.

On the 22d of May, 1707, the volcanic agent was again active, and the islands were violently shaken by an earthquake. On the following morning a new island, Isola Nuova, was observed, and a few days after, several persons ventured to visit it; but during their stay it shook so much, that they hastily left the treacherous ground on which they had trespassed.

In July, there arose, at a distance of about sixty paces from the new island, a ridge of black rocks, from which torrents of smoke issued. The inhabitants of Santorino were greatly alarmed at this new exhibition of volcanic activity, and the vapour projected was so prejudicial that many of the inhabitants were killed by inhaling it, and all of them more or less suffered from its effects. On the 31st, the sea seemed as though ready to boil, and in two places revolved in circular eddies. For ten years the volcanic agent continued in a state of partial excitement, and the inhabitants of the neighbouring islands were frequently alarmed by subterranean noises and earthquakes.

The most recent instance of subaqueous eruption with which we are acquainted, is that which produced Hotham or Graham Island, in the year 1831. This island was thrown up in the Mediterranean, between the southwest coast of Sicily and the African coast, in latitude 37° 8′ 30″ north, and longitude 12° 42′ 15″ east. The eruption seems to have been first observed by John Corrao, the captain of a Sicilian vessel, who, passing near to the spot on the 10th of July, observed an immense column of water ejected from the sea to the height of sixty feet, and about eight hundred yards in circumference.

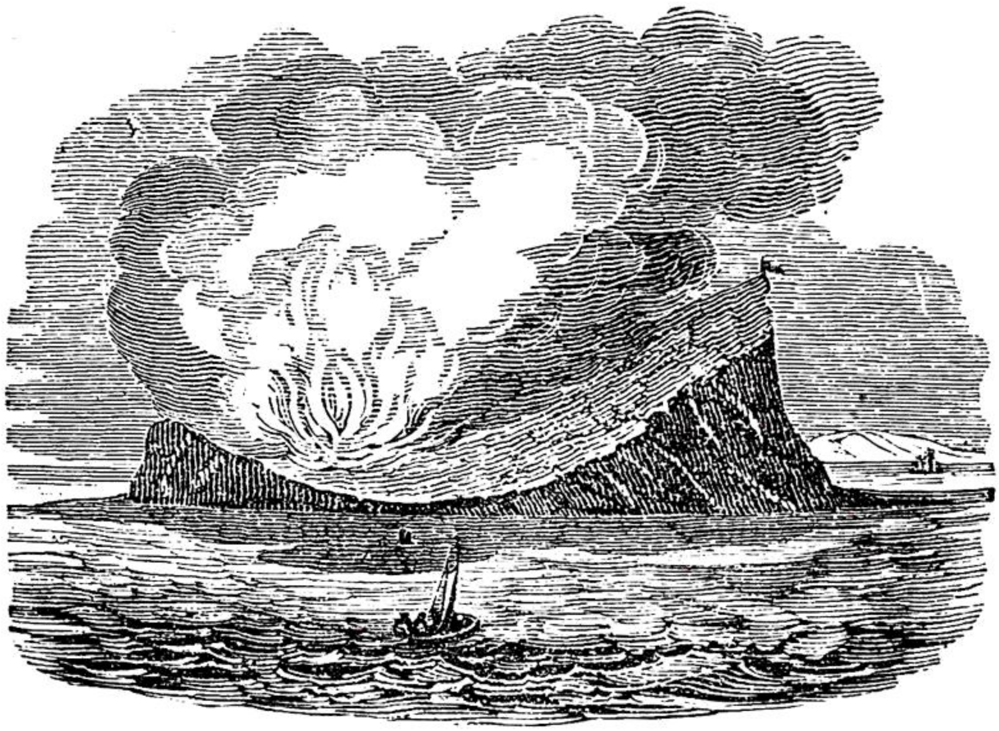


Graham Island, as seen by Corrao on the 18th of July.

On the 18th of July, Corrao again passed the same spot.

and he found that a small island had been formed, twelve feet high, with a crater in the centre, from which immense columns of vapour were ejected, and masses of volcanic matter.

The island was afterward visited by several scientific gentlemen, and is said to have been two hundred feet high, and three miles in circumference, on the 4th of August. But



from this time the island decreased in size; for, being composed of loose scoriæ and pumice, it was rapidly acted upon by the water, and on the 3d of September, when carefully measured by Captain Wodehouse, was only three fifths of a mile in circumference, and one hundred and seven feet high. At the end of October the island had entirely disappeared, except one small point composed of sand and scoriæ. Captain Swinburne examined the spot in the beginning of the year 1832, and found an extensive shoal to occupy the place where the island had been, and in 1833 there was a dangerous reef, of an oval form, three fifths of a mile in circumference.

We may now close our remarks upon active volcanoes, by the mention of one or two facts deduced from the consideration of the geographical arrangement, relative position, and attendant phenomena of active cones

1. Nearly all the active volcanic cones are either situated

in the immediate neighbourhood of the sea, or near some saltwater lake. A great number are found in islands, and many of the islands themselves have been produced by the volcanic cause. Some few exceptions, however, must be made to this rule, and we may particularly mention the American volcanoes, some of which are situated in the interior of the continent, but from their relative position there is some reason to suppose that they are all ranged over the same general line of communication with the sea. The volcano of Jorullo is more distant from the sea than any other; yet on one side it is connected with the Atlantic by Tuxtla, and on the other with the Pacific by Colima.

2. Another observation, deduced from the geographical position of volcanoes, is, that they are generally arranged in lines. It is true that we may here and there find a solitary cone apparently unconnected with any other mountain, as is the case with Etna, and the Peak of Teneriffe; and, at other times, we may observe a small group of volcanoes, as in South America; but their most common position is in lines. The volcanoes of South America are arranged in this manner; and the fact suggested to Humboldt the supposition that they might be ranged over an immense chasm of intumescent matter.

3. Volcanoes are not confined to situations of any particular geological formation. They are found among primitive and secondary rocks; and the only restraint upon the formation of a volcanic cone, is the existence of an opposing force in the constitution of the mineral crust greater than the projecting force of the volcanic agent.

4. Earthquakes and thermal springs have their origin in the same agency as volcanoes. This statement leads us at once to a consideration of the circumstances under which these two classes of phenomena are exhibited.

EARTHQUAKES.

The constancy with which volcanoes and earthquakes attend each other, is the best proof that can be given of the identity of their origin. We may select one or two examples in illustration.

The same night that Lima was destroyed by earthquake, four new volcanic vents were formed in the Andes. In the year 447, the earth was convulsed almost without intermission, from the Black to the Red Sea; and on the 20th of May, 520, Antioch was destroyed, and 250,000 persons were buried in the ruins; at both these periods, several volcanic cones were active. Soon after the earthquake at Lisbon, in 1755, various parts of the world suffered under the effect of a similar cause; and within the few succeeding years there happened some of the most violent eruptions that ever afflicted the world. In 1759, the American continent was dreadfully agitated, and Jorulla was in a condition of violent eruption, attended with some most remarkable phenomena. In 1760, fifteen fissures were opened at once, and from each immense volumes of lava were vomited; and, during the same year, Katlagiaa, in Iceland, broke out with intense paroxysmal violence, attended with such awful volcanic phenomena as were never before seen. Thirty days after the destruction of the city of Caraccas, the volcano of St. Vincent became active; and at the moment when it broke forth, a subterranean noise was heard, and the earth was shaken over an extent of nearly 2,200 square leagues. From these and numerous similar facts which might be mentioned, it will be evident that earthquakes frequently attend volcanic eruption, and the intensity of the one is generally in proportion to that of the other. Earthquakes, however, have been frequently unattended by eruption, a circumstance that may be explained by the supposition that there was not sufficient energy to form a vent, or that the gases generated by subterranean heat made their escape by some previously existing fissure.

Earthquakes differ greatly in intensity. The agitation produced is sometimes so weak, that it is only sensible to those who are accustomed to such phenomena; or it may have no other effect than that of shaking the bells and the loose articles of furniture: but at other times, the earth reels like a drunkard, as though moved from the balance which had been assigned to it by its Creator—cities are overturned, districts are laid waste, and the entire aspect of a country is instantly changed—mountains are overthrown, rivers are turned from their courses, and lakes are swallowed by the greedy earth—

"Diseased Nature oftentimes breaks forth
In strange eruptions: oft the teeming earth
Is with a kind of colic pinched and vexed
By the imprisonment of unruly winds

Within her womb; which, for enlargement striving,
Shake the old beldam Earth, and topple down
Steeples and moss-grown towers."

The violence of an earthquake seldom lasts more than a minute; but successive shocks are sometimes felt at very short intervals. During the agitation, immense chasms are frequently formed, through which flames, torrents of water, or dense volumes of gaseous fluid, are thrown. The effects produced by earthquakes are, therefore, in some instances, most extensive, and of a dreadful character. A more appalling description of the consequences of an earthquake cannot be given, than that account of the catastrophe of 1638, recorded by Kircher. The narrator was on his way to Euphemia, but the sea was tossed about by so unnatural an agitation, and such dreadful noises proceeded from it, that it was found impossible to proceed; and Kircher, with his companions, landed at Lopizicum. "Here," he says, "scenes of ruin appeared everywhere around me; but my attention was quickly turned from more remote to contiguous danger, by a deep rumbling sound, which every moment grew louder. The place where we stood shook dreadfully. After some time, the violent paroxysm ceased. I stood up, and turning my eyes to Euphemia, saw only a frightful black cloud. We waited till it passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

Humboldt has described, with his characteristic energy, the feelings which are experienced by an individual on the coast of Peru when he feels the shock of an earthquake. "From our infancy," he says, "the idea of certain contrasts fixes itself in our mind; water appears to us an element that moves—earth a motionless and inert mass. These ideas are the effects of daily experience; they are connected with every thing that is transmitted to us by the senses. When a shock is felt, when the earth is shaken on its old foundations, which we had deemed so stable, one instant is sufficient to destroy long illusions. It is like awakening from a dream; but a painful awakening. We feel that we have been deceived by the apparent calm of nature—we become attentive to the least noise—we distrust, for the first time, a soil on which we had so long placed our feet with confidence. If the shocks be repeated, if they become frequent during succeeding days, the uncertainty quickly disappears. In 1784, the inhabitants of Mexico were as accustomed to hear the thunders roll beneath their feet, as we are to witness the vivid flash in the region of the clouds. Confidence easily springs up in the human mind; and we end by accustoming ourselves, on the coast of Peru, to the undulations of the ground, like the sailor to the tossing of the ship caused by the motion of the waves."

Some idea of the frequency of earthquakes in some parts of South America may be formed from the fact stated by Captain Bagnold, that during his residence at Coquimbo, on the coast of Chili, there were, during one year, not less than sixty-one earthquakes, not calculating the slighter ones, which were even more numerous.

The effects of earthquakes are sometimes felt over a great extent of country. During the earthquake at Lisbon, in 1755, the seas in every part of Europe were agitated, and in some places became thick and turbid. Lake Ontario also felt the shock, and the sea round the Eastern Antilles. But the shocks are invariably most violent in volcanic countries, though not generally in those parts which are nearest to the seat of active volcanoes, and are seldom felt in countries which have not been, at some period, the scenes of volcanic activity. In Morocco, and on the coast of Barbary, earthquakes are frequently felt; and although there is no active cone in either of these countries, or near them, yet there is geological evidence that the volcanic force has been active at some past period. It has consequently been supposed by many persons, that there is a subterranean connexion between many distant places, and that a country once the scene of volcanic influence is liable to a repetition of its effects. Earthquakes are not always most violent in countries where active cones exist, for in such places every crater may act as a safety valve, and thus prevent the destructive effects produced in other countries by the vast expansive force of the confined vapours which struggle to escape from their prison.

It is difficult to imagine the character, much more the influence, of the phenomena which attend earthquakes, from any abstract description that could be given. We are most likely to approach to an accurate estimate of this terrible convulsion of nature from the perusal of the accounts which have been given of the phenomena by which they are attended, and the effects they have produced upon the districts in which they have occurred. We shall therefore select one or two examples.

The earthquake that destroyed Lisbon, in the year 1755, was the most violent that ever occurred in Europe, at least within the record of authentic history. On the 1st of November, at forty minutes past nine o'clock in the morning, a violent shock of earthquake was felt, which, although it did not last more than a tenth of a minute, threw down one fourth of the dwelling-houses in Lisbon, and all the large public buildings. This shock, though short, probably produced all the mischief, but was instantly followed by two others, and they all succeeded each other so rapidly that they are frequently spoken of as one shock. About twelve o'clock the earth was again shaken. A gentleman who was present, and escaped the destruction by which the great mass of the people were overtaken, states, that at this time, standing in the Terra de Pasco, he saw the walls of several houses open from top to bottom more than a quarter of a yard, and close again so exactly as to leave no sign of injury.

During the first shocks, the Tagus receded five furlongs from its usual boundary, but afterward advanced in an enormous wave fifty feet above the ordinary level of the tides, and then instantly retired. At Cascais, Setuval, Penische, and in Algarves, many persons were drowned by the sudden advance of the sea; for the effects of this terrible earthquake were felt all over Portugal, and also in other countries. The mountains of Arebeda, Estretta, Julio, Marvau, and Cintra, were shaken to their foundations; the summits of some of them were split, and huge masses were thrown down into the valleys.

The destructive effects of this earthquake cannot be adequately described. At least 30,000 persons were destroyed in Lisbon by the first fall of houses. Such scenes can be painted only by an eyewitness. "The sight of the dead," says Mr. Wolfall, "far exceeds all description; for the fear and consternation were so great, that the most resolute person durst not stay a moment to remove a few stones off the friend he most loved, though many might have been saved by so doing: but nothing was thought of but self-preservation; getting into open places, and into the middle of the streets, was the most probable security. Those lost in houses and streets were very unequal to those that were buried in the ruins of churches; for as it was a day of great devotion, and the time of celebrating mass, all the churches in the city were vastly crowded, and the number of churches here exceeds that of both London and Westminster; and as the steeples are built high, they mostly fell with the roof of the church, and the stones are so large that few escaped.

"I lodged," says the writer of this account, "in a house where there were thirty-eight inhabitants, and only four were saved. In the city prison eight hundred were lost, twelve hundred in the general hospital, and a great number of convents of four hundred each. The palace tumbled the first shock, but the natives insist that the inquisition was the first building that fell down."

This earthquake was not only felt in Portugal and the peninsula of which it forms a part, but throughout Europe, on the north of Africa, and even in the West Indies. The Jewish quarter, Mequinez, in Barbary, was swallowed up on the same day, and about ten thousand of the inhabitants perished. A town in Morocco, with about the same number of inhabitants, and all they possessed, was destroyed in the same manner, the earth closing over its victims. The city of Tasso had the same fate. In Scotland, a remarkable elevation of the waters of Loch Lomond was observed; the Thames rose and fell; and in Antigua and Barbadoes several slight shocks were felt.

It would be easy to fill a volume with the mournful accounts which have been given by observers of the effects of earthquakes in different places; but we shall refer to only two others. A severe earthquake occurred at Lima, on the 30th of March, in the year 1828, by which a part of the town was destroyed, and a number of lives were lost. The pier was cracked three parts across, and an aperture eighteen inches wide was left in the line of fissure. A large mass of rock, thirty feet thick, was separated from a cliff at the north of the Island of Lorenzo, and thrown into the sea. The chronometers and clocks were stopped by the swing or vibration of the earth, and its effects were observed on the sea as well as on the land. Captain Bagnold has given (in the Philosophical Journal) a very interesting account of this earthquake, as observed by an officer of a vessel moored in the Bay of Callao. The ship was violently tossed, and the water was in a state of apparent ebullition, the whole of its surface being covered with bubbles of gas, probably the sulphuretted hydrogen, which emitted an offensive smell resembling that of putrid pond-mud. One of the chain cables of the vessel suffered a partial fusion; and dead fish floated upon the surface of the turbid water.

Lima has often suffered from earthquakes. That of 1566 was felt over an extent of one hundred and sixty-six leagues; and that of 1746 destroyed three fourths of the city, and one hundred and twenty thousand persons.*

On the 13th of August, 1822, an earthquake destroyed the greater part of Aleppo, and about thirty thousand inhabitants. Mr. Baker has given an account of this catastrophe, in a letter to the British and Foreign Bible Society; and as it also contains an expression of the feelings which were produced by the awful phenomenon, we may quote the letter itself.

"On the night of the 13th of August, about half past nine o'clock, Aleppo, the third city of the Ottoman empire, built entirely of stone, was, in the space of a few seconds, brought down to its foundation.

"I was, at that time, asleep on the terrace of my particular friend, Mr. Meseyk, who, by the help of the Almighty, was mercifully saved, with all his family. About half an hour previous to the great shock, a light one was felt, when I took the precaution to draw my bed from under a very high wall, where it was placed. I was soon awakened by the fall of that wall, on the very spot where my bed had stood. I sprang from my couch, and without waiting to dress myself, I fled into the house, which I found falling on all sides. To remain in the house, or to take flight through the streets, appeared at first equally dangerous: at length, I embraced the latter resolution. In consequence, I descended the back stairs of Mr. Meseyk's house, for the great staircase fell at the same time. The darkness of the night, and the clouds of dust that covered the atmosphere, prevented me from perceiving the stones and rubbish on the stairs which had fallen from part of the house, and consequently I was precipitated into the courtyard, and on a dead body. How can I express

* A very dreadful earthquake occurred in that country in 1835, by which the city of Conception and a great number of villages were destroyed.

my feelings at that moment, ignorant on what body I had fallen?—I was half dead with fright and horror. I afterward learned that it was a faithful servant, who had a second before descended those stairs, when some stones from an adjoining Turkish house fell on him and killed him.

"I quitted that melancholy spot, and, like a man deprived of his senses, ran amid the fallen walls to the gate of the town, which is situated at some distance from my friend's house. It was on my road, among narrow streets, that I was destined to witness the most horrible of all scenes. The sight of the houses whose sides had fallen, exposed to my view men and women clinging to the ruined walls of their houses, holding their children in their trembling arms; mangled bodies lying under my feet; and piercing cries of half-buried people assailing my ears—Christians, Jews, and Turks.

"After a great deal of trouble and fatigue, running among the ruins, I arrived, exhausted, at the gate of the city, called Babelfarnige, the earthquake still continuing. But the gate of the city was shut, and no one dared to risk his life under its arch to open it. I threw myself on the gate. I felt in the dark, and perceived it was not locked, but the great iron bars that went across the folding-doors were bent by the earthquake, and the little strength I retained was not sufficient to force them. I went in quest of the guards, but they were no more. I fell again on my knees before the Almighty, and while in that attitude four or five Turks came near me, and joined hands to pray in their accustomed way, calling out, 'Alla! Alla!' Having in sight my safety, and that of thousands of individuals who crowded to the gate to escape, I made no more reflections, but began to entreat them to help me to open the gate in order to save our lives. Providing themselves with large stones, in a little time they forced the bars and opened the gate. No sooner had I quitted it, than a strong shock of an earthquake crumbled it to pieces, and several Jews were killed by its fall. When I recovered a little my senses, I began to feel new sufferings in the thoughts of what had happened to my brother and his family at Antioch, and the cruel fate of my friends in the city; besides, the melancholy objects around me—people wounded, others lamenting the death of their relations, others having before them their dying children taken from under the ruins—

preyed so strongly on my mind, that not the pen of the ablest writer could give an adequate idea of my feelings."

By the same convulsion, Antioch, Lattakia, Gisser, Shogre, Idlib Mendun Killis, Scanderoon, and all the other towns and villages in the pachalic of Aleppo, were destroyed.

A multitude of painful reflections rush into the mind when we consider the influence of some phenomena in the destruction of human life, and we turn with fear from the picture of the past, mistrusting the condition of the physical agents by which we are surrounded. In the bright morning of expectation we fancied that all without, as well as within us, could have no other influence than the production of pleasing emotions and happy associations. We first learn that there are as many sources of misery as of pleasure in our own minds, and man and nature then assure us there is no real dependance on them. The morning may be placid, and the unclouded sun may deck in its chastening hue the face of nature, but it may set enveloped in clouds, amid the strife and the discords of nature. Curiosity and dissatisfaction might prompt the inquiry, why has the Creator of all things permitted the existence of causes calculated to destroy animal life? but if religion and reason reply, they answer, that man may feel his dependance upon Him who has all agents under his control, and has so ordered them as to secure, consistent with the nature of his terrestrial government, the accomplishment of his own will, and the greatest happiness of the greater number of his creatures.

From the facts mentioned in the preceding remarks, it will be quite evident that earthquakes owe their origin to the internal force that produces volcanic eruption. This deduction does not depend upon any one circumstance, but is supported by various analogies. All the countries liable to earthquake are either enclosed by active volcanic cones, or have been, at some past period, the seat of volcanic eruption. Earthquakes usually precede volcanic activity, and cease with the eruption; and to these facts we may add, that volcanoes and earthquakes resemble each other in all the circumstances of activity, so far, at least, as relates to their period and intensity.

THERMAL SPRINGS.

It is almost universally admitted by geologists, that thermal springs derive their origin from the volcanic agent. This opinion is deduced from the positions of these springs, and the influence of volcanic eruptions upon them. It has been noticed by writers, that there are three places in which thermal springs may be found: in the vicinity of acti e volcanoes, in mountain chains formed by volcanic activity, and in rocks which have suffered intense physical convulsions from igneous causes. It cannot be said that thermal springs are never found in situations which do not present any external evidence of violent disturbance; but if they do occur in such situations, the circumstance cannot be urged as a proof that thermal springs are not produced by the volcanic cause.

In the vicinity of Etna, Vesuvius, and Hecla, hot springs are abundant, and in Iceland they are so numerous and active that they may be spoken of as the characteristic phenomena of the island. But they attend extinct cones, as well as those which are active; for there are many in the ancient volcanic districts of the south of France, Hungary, and Bohemia. In the Pyrenees, and in other lofty chains which owe their elevation to a great subterranean movement, they are also found, and are especially frequent in those places which have suffered from intense physical convulsions.

These facts are sufficient to prove that thermal springs are produced by the volcanic cause; and it is singular that, in proportion to the extension of geological knowledge, observers have been convinced of the universality of the volcanic force. There are some writers who seem to rest the proof of the volcanic origin of hot springs upon the effects which are produced on them by eruption; but this appears to us much less conclusive than that deduced from their position, since it often happens that cold springs, not supposed to be connected with the subterranean agent, are equally affected.

There has been some dispute among geologists as to the origin of the hot springs in England. It is true that we have no burning mountains, nor are we spectators of those scenes of devastation which equally prevail in tropical and in polar climes, amid the frozen recesses of Iceland and in the pleasant places of Italy. But it must not on this account be said that the volcanic agent does not exist beneath the rocks of our own as well as other countries, for there may be in one place causes tending to excite activity, and in another causes which restrain it. so that in one district it may spread destruction and the elements of change, and in another waste its energies upon the streams which bubble from the bowels of the earth to heal the diseases and minister to the infirmities of man.

Admitting that volcanoes, earthquakes, and thermal springs, and, we might add, gaseous exhalations, derive their being from the same cause, we must next inquire into the nature of that cause, and endeavour to show the influence which it has had in the arrangement of rocks.

THEORIES OF VOLCANIC ACTIVITY.

All persons agree that great internal heat is the principal cause of volcanic activity, but there is a difference of opinion as to the means by which that heat is produced. It is a matter of doubt whether we have sufficient data to give an appearance of certainty to any particular theory, and this has given the student liberty to form a theory for himself, or to modify that which pleases him best. The pages of our scientific journals and works on volcanoes are therefore crowded with new theories of volcanic action, all of which have found some defenders. We might have passed over a subject upon which there is so great a difference of opinion; but as there is no probability of ascertaining truth while the mind indulges error, there may be some advantage in exposing false opinions, and in breaking the fetters which prevent the intellect from healthy and vigorous activity. We shall therefore enumerate a few of the theories which have, at various times, engaged the attention of the learned, and state some of our objections to those which may appear the most plausible.

There is reason to believe that much of ancient fable derived its origin from an erroneous estimate of natural phenomena. The history of astronomy affords abundant evidence of this statement; and we believe that in every country where an idolatrous or superstitious population have been accustomed to the sight of volcanic phenomena, they have invariably ascribed them to occult deified agency. The Egyptians attributed all physical evil to the demon Typhon, and the Greeks, who adopted the science and superstitions of the Egyptians, have evidently symbolized the volcanic phenomena in their description of this personage. Typhon, they tell us, was a giant more powerful than all the children of Earth; his head reached to the stars, and his arms embraced the rising and the setting sun. With his hands he hurled the rocks to the highest heavens; fire gleamed from his eyes, and liquid fire boiled in his mouth. He is said to have been born in Cilicia, which is known to be a volcanic district; and having, shortly after his birth, frightened the gods from heaven, he was pursued by Jupiter to the borders of the lake Serbonis, another volcanic district, and was at last imprisoned in the Island of Sicily, where he still continues to rave, shaking the earth with his groans, and ejecting liquid fire.

The philosophical opinion of the ancient Greeks and Romans, if such we may call it, as standing in opposition to the fable by which the uninitiated were imposed upon, is stated by the Roman poet Lucretius, in his *De Rerum Naturâ*. Volcanoes were supposed to derive their origin from the conversion of the air confined in the cavities of the earth into violent winds by heat, which, generating an increased temperature, inflamed the combustible bodies contained in the bowels of the earth.

This theory is nothing more philosophical than the popular fable, and far less poetical. But it is not surprising that such a theory as this obtained currency among the ancients, for they were almost entirely ignorant of those facts upon which an explanation must be founded, and indeed of many of the effects of the causes they sought. The phenomena which accompany eruption preventing a direct examination of the cause, opinions must be formed from the circumstances under which the effect is produced, the extent of the influence, and the character of the ejected mass. With all these the ancients were unacquainted, and even our own knowledge is inferior to our opportunities.

Werner was among the first of the geologists who ventured to propose a theory of volcanic action. He attributed eruption to the ignition of coal and other inflammable substances; and, in support of this hypothesis, Pallas states, that the ejection of mud by the cones near the Cimmerian Bosphorus was occasioned by the combustion of the coal measures. Brieslak proposed to improve the theory, by attributing volcanic phenomena to the ignition of petrolium by sulphuric and phosphoric acids; and, in support of his theory, adduces the presence of these substances in lava. As it would be difficult in the present day to find an advocate for either of these theories, we shall not attempt to show how inadequate they are for the explanation of volcanic phenomena.

A singular theory, and one which has a much greater appearance of probability than either of those we have mentioned, was proposed by Sir Humphrey Davy. After the discovery of the metallic bases of the earths and alkalis, he was induced to imagine that the earth itself might perhaps have been originally a globe of metallic alloy. Now, if this had been the primitive condition of our world, the combination of the oxygen of the atmosphere with the metals would, he says, have formed a crust of earthy matter as a superficial covering, the interior still remaining a deoxydised metallic mass. If water should, by penetrating through the crust, reach this metallic mass, a chymical action would be immediately produced: the oxygen of the water, having a great affinity for the metal, would be disengaged from the hydrogen, and a metallic oxyde would be formed. This chymical action would cause the disengagement of caloric sufficient to melt the surrounding rocks, while the disengaged hydrogen gas would, exerting its influence as a confined elastic fluid, rend the rocks, and burst into a flame upon exposure to the air. There is certainly a great degree of plausibility about this hypothesis, and it is not altogether unphilosophical; but Davy was, from some cause, induced to renounce it, and give preference to an explanation founded on the doctrine of central heat. Dr. Daubeny, who has adopted Davy's discarded child, suggests that it is not inconsistent with what we know of Davy's character, to suppose that he acquired a distaste for the theory in question, when he found it an object of admiration among an humbler class of inquirers. This observation may be correct; but perhaps a better reason may be given for Davy's want of confidence in his own theory.

We have already expressed, through another channel, ou objections to the theory in question, and we cannot now dc more than repeat those objections, and quote the answer which Dr. Daubeny has given; but, at the same time, we would take an opportunity of stating, that our remarks are made with a consciousness of the high pretensions of the doctor, both as a scholar and an observer.

Two admissions are required by this theory, and to us they appear to draw largely upon the faith of the reader. We must first admit the existence of a deoxydised metallic nucleus, and its inflammability, or at once give up the theory. It is possible that the interior of the earth consists of metallic alloys, though there is as much reason to believe that it is composed of almost any other substance; but we will grant, for the sake of the argument, that the earth beneath its superficial covering consists of metals, for it is only a matter of opinion, and we may imagine it one substance as well as another. We are next required to admit that this metallic nucleus is of such a character as to suffer oxydisation by the presence of water, the hydrogen being liberated and ignited. To determine the nature of the metallic nucleus, we must examine the character of the lava that is ejected, or the earths composing the crust of our globe, which are supposed by the theory to have been, at some former period, a part of the metallic nucleus. Dr. Daubeny accurately states that silica, alumina, lime, and iron, are the chief ingredients of volcanic products. The metallic alloy, therefore, must be composed of silicon, aluminium, calcium, and iron. Now, of all electro-positive substances, silicon is the most incombustible; it may be made white-hot in the open air, without evincing any tendency to burn; and, so far from decomposing water at common temperatures, it may be boiled in that fluid. There is every reason to believe that silicon is not a metal, but has a closer resemblance to carbon, a non-metallic substance; but, however this may be, it is so far from alloying with the metals, that it has no tendency to unite with other bodies, except when in a nascent state, or when double affinities are exerted. We cannot help remarking, that it was only a short time after Berzelius had discovered the properties of silicon, that Davy renounced his theory. A consideration of the properties of aluminium is equally fatal to the theory; for it sustains no visible alteration by long boiling in water, even when in the state of fine powder, and oxydises only when raised to a red heat. Of calcium and iron we need not speak; the former is only an imaginary substance, and the properties of iron are too well known to require a remark.

That any compound of these substances should fulfil the conditions required in the theory, is, we think, utterly impossible. It is true that metallic alloys are more oxydisable than pure metals; but we have given a reason for the supposition that, if the substances of which we have spoken were existent in a deoxydised state, it would not be in union with each other. If it could be imagined that the earth was originally a ball of potassium, the theory might then be supported; for the decomposition of water and the burning of potassuretted hydrogen might be supposed to mimic the exhibitions of Etna, if not of Tomboro. But, as the constituent elements of lava evince no tendency to act agreeably to our requisitions, we must renounce the theory, unless we can give the substances imaginary properties. No one would be led to think of a volcanic eruption from the effect of water on a cold cannon-shot; yet the chymical action is as strong in this experiment as it would be if the water were acting upon the deoxydised nucleus of the earth. Iron is much more readily oxydised than the bases of silica and alumina; for in a spongy state it will decompose water, and become redhot on being exposed to the air at common temperatures. We are therefore justified in stating, that we should as soon receive Southey's assertion, that the atmosphere of Elysium and the Fortunate Islands consists of the protoxyde of nitrogen, as this theory for an explanation of volcanic phenomena.

It is but just to those who may support the theory we have attempted to disprove, that we should insert Dr. Daubeny's reply to our objections; but we shall take another opportunity of expressing those opinions which this reply has suggested.

"It has been alleged," says the doctor, "that the two principal constituents of lava, namely, the bases of silica and alumina, are not highly inflammable. Silicon, when perfectly pure, resists a white heat without uniting with oxygen, and aluminium may be boiled in water without decomposing it. But, in the first place, it is rare to meet with these oxydes, without finding them accompanied either with lime or an alkali, and the basis of the former, we have reason, from Davy's experiments, to believe, is highly inflammable; the latter we know to be so.

"Secondly, silicon kindles readily if united with a little hydrogen, or with carbonate of soda: and aluminium, even by itself, burns brilliantly when heated to redness, and dissolves with the evolution of hydrogen, in very dilute solutions of potass.

"There is, therefore, no difficulty in imagining the combustion to be kept up by means of silicon and aluminium, when once it has commenced, by the action of water upon the potassium, sodium, or calcium present."

If this answer to our objections were as conclusive as it is undecided, imperfect, and objectionable, we might add, as a farther reason for our dissent, that many arguments might be gathered from the invasion it makes upon the laws which would govern the arrangement of a metallic nucleus; the improbability of water reaching it; the uncertainty whether atmospheric air could reach it; and the doubt whether any chymical action would be developed under great pressures;—each of these might, and the sum of them would, lead us to the conclusion that the theory is doubtful, if not visionary.

Dr. Daubeny makes an admirable and comprehensive classification of the theories of volcanic action, when he says, "the theories which have been propounded with the view of accounting for the existence of volcanic action, may be divided into two classes—those which assume some chymical process, of which the heat is merely an effect; and those which, assuming the existence of the heat, deduce the other phenomena from its presence." We have explained the only theory worthy our attention, belonging to that class which assumes the existence of heat as an effect of the volcanic cause, and must now refer to the arguments by which those who maintain the primordial agency of heat defend their opinions.

That the earth's interior has a much higher temperature than its surface, has long been a prominent feature in geological hypotheses. But cosmogonists and theorists have not been satisfied with assuming a present condition, but have stoutly asserted the igneous fluidity of the primitive earth. It has been sometimes stated that the earth is a fragment of a body that was, at the time of partition, in a state of fusion; and this being assumed, its form may be readily traced to the diurnal revolution it is known to have. Sir William Herschel seems to have been enticed from his practical studies by a theory not less fascinating. This celebrated astronomer believed the earth to have been, at some past period, a mass of vapour, and attributes its present form to the condensation of the elastic fluid, an intense heat being given out during the process of reconstruction. It is not, however, easy to comprehend either the philosophy of, or the necessity for, these theories, as there can be no reason why the Almighty fiat should not have called the earth into existence as an independent solid body, without the cumbersome machinery with which some philosophers seem to be so much delighted. But with such speculations we do not at present concern ourselves, as they cannot guide to an acquaintance with the cause of the phenomena already explained. It is sufficient to know that the interior heat does increase with the depth, a fact proved by a variety of experiments, and doubted only by those who wish to disbelieve it.

The earth is a reservoir of heat; and this agent exists with an intensity sufficient to produce the phenomena ever attending volcanoes, earthquakes, and thermal springs. From the known effects of condensation, an increasing internal heat may be deduced, so that theory in this instance is confirmed by facts. There may be a modification beyond a certain depth in the ratio of increased temperature; but should future experiments establish the authenticity of this supposition, many objections now made to the theory, with what show of truth and honesty we do not say, will be effectually answered.

Those who differ in theoretical opinions too often imagine their theories to be diametrically opposed; but, when truth shall be discovered, it may be found that none of the causes zealously advocated by parties could of themselves produce the effects they are now supposed to explain. It is more than possible that neither internal heat, chymical action, nor electrical currents, could alone produce the volcanic phenomena; but, acting together, and they are known to be in some degree dependant on each other, they may give birth to all the violent disturbances that agitate the surface of the earth

We have now attempted to explain the most important facts and theories in relation to the interior of the earth. It is not to be denied that there is much uncertainty and error in many of the speculations indulged and defended by the geologists of the present day, or that more extensive investigations will disabuse their minds of the fallacies resulting from an imperfect view of nature. The human mind may be admirably adapted to deduce principles from the information communicated by the senses, but if that information be inaccurate or partial, it will produce erroneous principles. A variety of circumstances may prevent the accurate perception of truth, but especially prejudice, and a partial view of facts. These are even in the present day sources of error, for they still govern to some extent the reasoning of scientific men. We would not, therefore, force our opinions upon the reader, as though they were capable of the same rigid demonstration as a geometrical problem; we would rather have them considered as elements of thought than as dogmatical conclusions.

In the examination of the facts advanced in this chapter, there are two things which appear to us particularly evident, written, as it were, upon the face of every stratum that forms a part of the earth's crust; first, that a series of causes have acted in the production of rocks, differing from each other either in character, extent, or intensity; and secondly, that the condition of these rocks gives evidence of the existence of more violent igneous agents than are now in operation.

1. The beds forming the crust of the earth being distinguished from each other by mechanical and chymical composition, and each bed or suite of beds being remarkable for some organic remain peculiar to itself, there is evidence of the existence of secondary causes from the period when these rocks were formed; and the variety of agents supposes an interval of time between their successive operations. To imagine that a bed of sand and a bed of gravel could have resulted from the same physical force, or that there was not a perceptible interval of time between the deposition of a limestone, its disturbance by internal forces, and the formation of another bed upon the dislocated stratum, would effect as great an alteration in deductive reasoning as the volcanic force produced upon rocks. Great minds may be guilty of excessive folly in their effort to support a favourite hypothesis, and do sometimes resort to arguments they would condemn if employed by others. It has been maintained by some writers, who have had ample opportunities of examination as well as of reading, that a continuous series of causes, acting within a very short period of time, if not a single cause, produced all rocks, and occasioned all the disturbances under which they have suffered. The Mosaic deluge has been considered sufficient, both in intensity and period, to account for all the varied phenomena to which we have referred. But this supposition is opposed by facts too evident to be denied.

2. If the interior of the earth has a higher temperature than its surface, there is a probability that the ratio was greater when the ancient rocks were in the process of formation than at the present moment; and this is deduced from the abundance of igneous rocks, and the fact that heat is dissipated by radiation. In every age the volcanic force has been active, distorting strata, and ejecting among them *igneous products; but it appears to have been most violent* during the formation of the older rocks, a deduction that coincides with the supposition of a decreasing superficial temperature as the result of radiation.

But whatever opinions may be entertained after an examination of the earth's crust, it will be universally admitted that the arrangement of the mineral masses is not fortuitous, but the consequence of the same preordaining power that adapted all natural agents to aid in supporting life under pleasurable conditions. The sun may shine upon some worlds with an energy equal or superior to that with which it falls upon the earth, and it may diffuse over them the same vivifying rays; but if they are so constituted as to present a surface inapt to the reception of the life-supporting agency, then the solar rays, so far as these worlds are thus concerned, are useless. The earth is so formed, that it is suited to receive such influence from surrounding causes as is calculated to maintain life. It should ever be remembered that man acknowledges the display of Divine wisdom in the creation, because he perceives that in all parts of the mundane system there is an exact proportion between agents and the substances upon which they act.

CHAPTER IX.

LAND AND WATER.

The superficies of the earth is estimated at two hundred million British square miles, and consists of land and water Seven tenths of this surface are occupied by water, and a portion of the remaining three tenths is actually beneath the level of the ocean. A large proportion of the dry land is situated in the northern hemisphere, the southern hemisphere presenting a broad and almost uninterrupted surface of water, the Pacific Ocean itself being of greater extent than all the dry land on the surface of the earth. Humboldt estimates the dry land between the tropics in the northern and southern hemispheres as being in the ratio of five to four, and without the tropics as thirteen to one, the northern hemisphere being the greater in both instances.

This relation between land and water has not, in all probability, constantly existed. The loftiest elevation upon the surface of the globe may have been at some past period beneath the level of the ocean, and the agent which elevated it may act, at some future period, upon the bed of the present ocean, and, raising it to the same elevation, entirely change the relative distribution of land and water. If it be denied that the dry land has been once beneath the water, how can the presence of organic remains in rocks be accounted for? It must not be supposed that the ancient shells found in rocks are merely distributed over their surface, for they form an integral portion of the beds, and are so disseminated through them that the rocks and the shells must have been deposited at the same time But that which was the bed of the sea is now dry land, and consequently one of two things must have happened: either the dry land that then was sank beneath the level of the ancient basins and received their contents, or the bed of the sea was raised, and the waters rushed into the newly-formed valleys. There can be no doubt as to which of these two causes produced the present relative condition of land and water. Rocks hav been violently tilted from a horizontal to a highly inclined or vertical position; immense masses of igneous rocks have been ejected from the interior of the earth, and form, as it were, immoveable walls, against which the disturbed strata are piled in succession. Some local results may be due to depression, but all the great movements to which the earth's crust has been subject may be traced to elevation.

We need not refer to a very distant era, geologically considered, to find evidence of an alteration in the relations of land and water. The ancient beaches are among the most recent geological formations, and give evidence of at least a partial, though by no means limited elevation, after the deposition of the most recent tertiary deposites. On the English coast there are not many examples; but they are sufficiently numerous to prove that it was in many places upheaved with the beaches that had been formed by the washing up of shells, pebbles, and other marine productions. There is a good example at Plymouth, and another on the Devonshire coast, near Babbacombe, and also one on the opposite coast, in the Island of Portland. We know that some geologists are unwilling to admit that these ancient beaches were produced by elevation, but it is really no objection to the theory that they only occur in small masses here and there; for it may be easily admitted that the fractures produced by the elevation would tend to destroy the continuity of beds, and that the destroying agents which have for ages since that event been acting upon our coasts, have, in all probability, destroyed the greater portion of the masses that remained as evidences of the event. There is reason to believe that these beaches were formed after the deposition of the crag, if we may attempt to determine the relative ages of rocks by the organic remains they contain, and that the force which elevated them was one of the last dying throes of that intense volcanic power which had been long before rapidly expending its energy, and is now so weakened as to produce comparatively small and always local effects.

But although the changes in the distribution of land and water have, since the period when the beaches were raised, been effected by moderated agents, yet we know that causes do exist by which districts once covered with water are delivered up to man, while, on the other hand, the sea makes rapid encroachments upon that which has been for centuries his patrimony. The effects of these causes are produced so slowly that they frequently pass unnoticed from generation to generation, and yet they are effecting mighty changes in the distribution of land and water; and, if sufficient time be allowed, will ultimately give a new character to the physical appearance of the earth's surface.

The subjects embraced in this chapter are too extensive, and the space for discussion is too narrow, to admit a detailed description of the causes which are now effecting an alteration in the distribution of land and water; and it is the less necessary, because we have examined the subject with some particularity in our "Alphabet of Theoretical Geology." It may not, however, be improper to state the nature of those causes, and to attempt an estimate of their effects.

There is no physical agent too weak to assist in altering the relative distribution of land and water. The soft breezes which blow at evening from the boundless ocean, the gentle shower which refreshes the thirsty earth, and even the heat and light which emanate from the great orb of day, have some influence in carrying on that constant series of changes observed on every hand by the man who devotes himself to the investigation. It is a common error that the most violent causes are the most destructive, and it would be scarcely admitted that rivers do more to change the superficial appearance of the earth than the devastating volcano. Time and persevering activity effect more than casual impetuosity; this is true in relation to mind, and it is equally true when used in reference to those agents which act upon matter. The volcano whose periods of activity may be years or centuries apart, does, when roused, produce terrible effects upon the district in which it is situated, but the river ripples along its course day after day, and is every hour bearing to some distant sea a portion of the material it has collected.

There are four agents remarkably active in the destruction and recomposition of rocks,—heat, air, water, and chymical action; and there are but two conservative principles,—vegetation and cohesion. The agents of destruction frequently act in concert, and in many instances, by continuance, effect the decomposition of rocks capable of resisting an instantaneous effort of much more energetic activity. Water will cut a path through the hardest rock, and heat will reduce its materials to a state of fusion; or the two agents may act together upon a bed whose particles have very slight cohesion, but are bound by a luxuriant vegetation. A cliff composed of clay, for instance, may be periodically attacked by the water of the ocean, and in the interval dried by solar heat. This constant change of condition soon breaks away mass after mass, in spite of the binding influence of vegetation. But, in order to trace the changes which are in progress, it is necessary to examine the subject under two aspects,—the destruction and the recomposition of rocks.

Air and water act chymically and mechanically upon rocks. Both these elements, as they were called by the ancients, occasionally contain carbonic acid, which, together with the substances of which they consist, has an effect in the destruction of rocks, producing such compounds as have little or no cohesion, or are readily dissolved in water.

Air has a mechanical action upon rocks, especially when it contains a large quantity of water. The weathering of rocks, as this effect has been called, may be observed more or less in all districts. Air, when in violent motion, as in hurricanes, is a destroying agent of no common power, and even the mineral masses suffer under its terrific influence.

Water is a more active agent; for whether it passes over the surface of, or percolates through, strata, it carries away a portion of the bed itself. Wherever water is found, it is blended with mineral substances, some of which it holds in chymical and some in mechanical solution. The amount of detritus formed by rivers will depend upon the velocity of the stream, and the character of the deposite through which it passes. It has been frequently mentioned that rivers containing a large body of water do always carry down their courses an immense quantity of argillaceous matter, or deposite it in their beds. But, to estimate the effects produced by water when in the condition of violent motion, the inquirer must examine the influence of impetuous mountain torrents and occasional floods.

Heat is an important agent in the production of change in the superficial appearance of the earth, or, at least, of districts. That volcanoes, earthquakes, and thermal springs are due to internal heat, is admitted by all persons, though there is a difference of opinion as to the cause of that heat. Volcanoes have their effect in the ejection of liquefied rocks over districts of greater or less extent, and in the still wider distribution of pumice and scoriæ. Earthquakes act variously upon the surface, sometimes raising and sometimes depressing an island, a coast, or a country, and not unfrequently producing enormous fissures; diverting rivers from their courses, and leaving stagnant lakes on the sites of fertile districts and noble cities. Thermal springs deposite large quantities of lime and other minerals. This cause, however inadequate it may appear for the production of extensive effects, has probably in past ages given birth to deposites of immense thickness and extent, and is not an unimportant agent in the present day.

In whatever district we make our inquiries, we discover that some or all of these agents are acting upon rocks, de stroying the continuity of their particles, and accumulating them in heaps, or distributing them over districts. But it will be necessary to inquire, what is the ultimate destination of this detritus? is it suffered to remain upon the spots in which it is formed, or is it carried from these to some distant regions to form new compounds, and again to assist in the composition of mineral masses?

Water is the principal agent in the decomposition of the superficial earthy materials, and it has also the most important influence in the recomposition of the parts which are removed. Atmospheric causes, acting upon elevated districts and mountain chains, separate from rocks a portion of their mass in large fragments, and in minute decomposed particles; but all these must remain upon the spots where they are produced, if they were not subject to the action of moving water. By the melting of snow and the fall of rain a considerable body of water is provided, and streams of larger or smaller extent rush down the sides of mountains, occasionally uniting together and forming torrents which have a tremendous momentum. The loose and detached fragments are consequently carried down the mountains into the valleys, or rather into the rivers of which the mountain streams are the source. But the quantity is constantly increasing; for not only does every auxiliary stream add something to the amount, but the water is everywhere acting upon the banks of the course it has made for itself, and extending its influence over the land. Rivers frequently form for themselves new beds, gradually cutting their way through districts in which the water they contain can be equably distributed. We must, therefore, look for this detritus in the beds of rivers, and in the basins to which they flow. Lakes which receive the waters of rivers are nearly all becoming less and less deep, in consequence of the earthy matter carried into them; and, if the ocean be examined, immense banks of clay and sand will be discovered in it. Should any volcanic force, similar in intensity to those which have been, elevate these deposites, they would in a few years present an appearance in every way resembling some of those which now constitute the dry land. But, admitting that no such agent can ever act upon the crust of the earth, the gradual accumulation of these deposites must ultimately affect the distribution of land and water, by causing the ocean to advance upon districts once distant from it, and the banks and shoals of the ocean to appear as islands. It is evident, then, that there is no stability in the relative amount or position of land and water; the present distribution has resulted from a combination of causes that have acted from the beginning; and it is constantly changing, though so slowly, that the period of a man's life is in many instances too short to produce an effect sufficiently extensive to be detected by an acute observer. But causes do exist calculated to limit the destruction of rocks, and, more especially, to prevent the casual distribution of the masses formed by the process of recomposition. There is, in fact, reason to believe that, how rapidly soever the decomposition may go on, the position of masses in relation to the globe itself cannot greatly change, though the materials may enter into new combinations, or form parts of masses of smaller or larger dimensions.

We may now proceed to examine, with a little more particularity, the features which distinguish the present distribution of land and water. The greater portion of the land is included in two masses of considerable extent, called continents, and these are separated by basins or valleys containing water, called seas. Here and there, smaller and detached portions of land are found, having a greater or less elevation above the level of the water, and these are denominated islands; and so, also, small bodies of water are in some places surrounded by land, and these are called lakes. Some geographers have considered Australia as a continent, while others have described it as an island; if magnitude be the distinction between continents and islands, it is difficult to say whether it ought to be considered as belonging to one or the other; for it may be esteemed, with equal propriety, the smallest of the continents or the largest of the islands. On account of its evident connexion with the islands by which it is surrounded, it may, we think, be classed with that group which together form an archipelago.

If the outline of the continents and islands were perfectly even, few other terms of distinction would be necessary in physical geography; but this is not the case; for the land is everywhere more or less indented, the indentations being either permanently or occasionally occupied by water. When the ocean extends for a considerable distance into the interior of an island or continent, and has, in proportion to othe internal bodies of water, a considerable extent, it is called an inland sea; such is the Adriatic, the White Sea, or the Mediterranean. When the surface of an inland body of water is less, and the opening by which it is connected with the ocean wider, it is called a gulf or bay; and when still smaller, and nearly surrounded by land, it is called a port, creek, or road, according to its extent. It will be evident that the names given to these masses of water depend upon their proportions in relation to each other, and the definitions must consequently appear exceedingly vague; but it would be difficult to give them a more accurate character, and they are generally adequate for practical purposes. The same remark applies to those small masses of land which project into the ocean. A peninsula is a neck of land which enters the sea, and is connected with a continent or island by only a narrow surface. The smaller projections are called capes, promontories, or points, according to their size.

The surface of the land varies in elevation as well as in its horizontal form, and this circumstance produces the necessity of adopting other distinctive terms, and we have consequently mountains, hills, plains, and valleys, as descriptive of the various elevations of the solid portions of the earth's surface. There are also terms to distinguish the circumstances under which water is sometimes found, such as springs, rivers, and cataracts.

CONTINENTS.

The old continent, or world, as it is usually called, which comprehends the three great divisions, Europe, Asia, and Africa, has a general direction from southwest to northeast; but, excluding Africa, is nearly parallel to the equator. The new world, which lies in the western hemisphere, and includes North and South America, lies in a nearly north and south direction. The longest line that can be drawn across the old world would commence on the western coast of Africa, near Cape Verde, and terminate on the shore of Behring's Strait, on the northeast coast of Asia, and would measure about eleven thousand miles. A similar line over the new world would have its direction from the Strait of Terra del Fuego to the arctic shore of North America; its length would be about nine thousand miles.

The continents have several features in common, a fact which seems to indicate that some universal agent was active in their formation. All the peninsulas, with the exception of two, one in each world, have a southerly direction. The exceptions are the peninsula of Yucatan, in Mexico, and Jutland, in northwestern Europe. There is also a similarity between the two great divisions, in the union of continents, and the manner in which that union is completed. North and South America, forming the new world, are connected by the Isthmus of Darien. The old world may be considered as though divided into two parts; the western, including Europe and Africa, the eastern, Asia and Australia; the former are united by the Isthmus of Suez, and the latter by the islands of Java, Sumatra, and others, which form, as it were, a broken isthmus. In these particulars there is a great resemblance between the old and new worlds; but there are many points in which they greatly differ from each other, and particularly in the form of their coasts. The coasts of the old world, excepting Africa, which is singularly even, are deeply indented; gulfs, bays, and inland seas, giving a constant character to every shore; but, on the western side of the new world, there is only one considerable inlet, the Gulf of California.

MOUNTAINS.

The elevations upon the surface of the earth are known as mountains or hills. The distinction between these two classes is not so definite as might be desired; for if we were to attempt an explanation of what is meant by a hill, we could only say an elevation less than a mountain. There is, in fact, no height at which the elevation ceases to be a hill and becomes a mountain; the terms are relative, and every observer must decide for himself whether the one or the other should be employed. It is necessary to observe that a distinction must be made between a plateau and a mountain. A plateau is an upland plain, and is generally situated in the centre of a continent or island. In South America these plains are exceedingly numerous, and have a considerable elevation; but as they are often quite level, the inhabitants have not the slightest idea of their height. The plain which surrounds the mountain Antisana occupies a surface of twelve leagues, and is 13,451 feet above the level of the sea.

Mountains present a great variety of forms: some are bold and rugged, with vast precipitous projections that assume a highly romantic appearance; others are marked by a smoothness or tameness of outline. Some appear as though they had been formed by the heaping up of immense crystals confusedly upon each other, and others as though they had been produced by the ejection of igneous rocks in a liquid state. These and other forms may be traced to the existence and operation of geological causes. Mountains consisting of granite are generally lofty and rugged; of gneiss, projecting, but less precipitous. Some of the highest summits in the new world consist of old volcanic rocks;—Chimborazo and Antisana are capped with vast masses of porphyry; but the highest mountains of the old continent are composed of granite. A geologist, accustomed to examine the primitive rocks, may often detect the presence of one or another by the appearance of a district, in the same manner as a less experienced observer would, by the form of the hills, convince himself, even at a distance, of the presence of chalk.

Mountains have always a greater declivity on one side than on others, and generally that which is nearest to the sea is the steepest. The Alps has a much more abrupt descent on the Italian than on the Swiss side; the Himalaya mountains are steepest on the southwest, and the Elboors on that side nearest the Caspian Sea; and Mount Taurus, in Armenia, has its greatest descent on the north side, but near to the Mediterranean on the south. Almost every other mountain of considerable elevation will give evidence to the same fact. It is also worthy remark, that mountains are commonly most elevated in the interior of the countries in which they occur, and gradually decrease in height as they approach the sea. There are, however, some exceptions, and there is a very remarkable one in the mountains of Spain, which, as they approach the Bay of Biscay, increase in height; so that Bilboa, a seaport, is actually surrounded by mountains.

A series of mountains, having the same base, is called a chain; thus we speak of the Uralian, Alpine, or Caucasian chain. But when these chains are united together, they are called a system; the American mountains, for instance, are spoken of generally as the system of the Andes. But some mountains are insulated, as are many of those in China and in Iceland, and also the rock of Gibraltar. Terms do not always have the same confined acceptation in science as they would if employed in common use, and this frequently leads the student into error. A chain of mountains does not necessarily mean a series of elevations situated in the same line; some chains have this arrangement, as the Cordilleras des Andes; but the term is applied to a number of mountains thrown off from a common centre in different directions, or to the inferior ranges which often branch in great numbers from an elevated central district.

We must now close our remarks upon mountains, with a short and general outline of the important discoveries made by M. Elie de Beaumont. In the last chapter an attemp was made to explain the manner in which geologists determine the age of rocks, and the periods when they suffered disturbance. M. Beaumont has adopted the same means to discover the periods when mountains were elevated; and from his observations he has deduced some principles which are worthy the closest examination of the geographer and geologist. It may require a considerable period of time to determine how far we may receive some of his deductions, but there are others which are now susceptible of a demonstration as rigid as many acknowledged geological principles. There are four statements upon which all M. de Beaumont's theoretical opinions are founded. The statements themselves may be considered theoretical by some writers; but, if they are so, they are supported by evidence much stronger than that upon which theories are usually built.

1. There have been, from the earliest geological era, long periods of comparitive repose, during which rocks have been formed by aqueous causes, in the same manner as they are in the present day.

2. These periods have been disturbed by intervals of violent paroxysmal action, and at such times mountains have been elevated.

3. All the mountains formed during the same interval, in whatever part of the world they may be situated, have the same direction—that is to say, they are parallel to each other within a few degrees of the compass.

4. Chains produced at different times have different directions.

There are few if any geologists in the present day who will deny the first proposition, that the aqueous rocks of the earth's crust were produced by causes resembling those which are now instrumental in forming similar deposites. But there is not so great a unanimity of opinion concerning the second statement, for it has been maintained that no such intervals have occurred; but that strata have been occasionally disturbed by forces equal and similar to the volcanic force of the present day, and that a series of these produced mountains.

Mr. Lyell is one of those who differ from M. Beaumont on this subject, but the terms of his objection do not appear to us so sound as might be expected from a geologist of so much acuteness and research. "The geologist," he says, "who assumes that continents and mountain chains have been heaved up suddenly by paroxysmal violence, may be considered as pledging himself to the opinion that the accumulated effects of ordinary volcanic forces could never, in any series of years, produce appearances such as we witness in the earth's crust. Time, and the progress of science, can only decide whether such an assumption is warranted, or whether, on the contrary, it does not spring from two sources of prejudice; first, the difficulty of conceiving the aggregate results of a great number of minor convulsions; secondly, the habit of viewing geological phenomena without any desire to explain them as the effects of moderate forces, such as we know to act, instead of that intense degree of energy, the occasional development of which, however possible, is entirely conjectural."

There are many geologists who have confessed their conviction that the volcanic force, as exhibited in its effects at the present time, could not have produced such appearances as we discover in the earth's crust; and by so doing they pledge themselves to hold that opinion until they are convinced that it is erroneous. If their opinion be founded on an assumption, it cannot be more violent than that admitted by Mr. Lyell, and those who agree with him. But Mr. Lyell attempts to account for the opinions of those who have upon this subject arrived at a conclusion opposed to his own. As one reason, he states, that we have "the habit of viewing geological phenomena, without any *desire* to explain them as the effects of moderate forces, such as we know to act." If this be the cause of our peculiar opinions in this matter, it is a better evidence of their accuracy than of their falsehood; and if Mr. Lyell and his followers desired to come to the conclusion they hold, we are not surprised that they have obtained their wish. The other reason assigned for our conclusions is the difficulty we have found "of conceiving the aggregate results of a great number of minor revolutions." In this there may be a slight mistake, for we may have rightly conceived the effects that would be produced by a number of minor revolutions, but that conception may not agree with the one formed by our opponents. To defend the supposition that the mountain chains were elevated by a paroxysmal force rather than a series of minor convulsions, would lead us to a series of arguments which must be extended to a much greater length than our now limited space would admit; and it would be necessary for those who maintain an opposite opinion, to state, first of all, whether the series of forces mentioned by them had at all times the same degree of intensity, or were in this particular as variable as at the present moment.

Mr. Lyell, however, gives, in another part of his "Principles of Geology," a more definite view of his objections to Beaumont's theory. In determining the period of a disturbance or an elevation, it is of course only possible to state that it happened during an interval anterior to one event, and posterior to another, and that interval may have been an instant or a protracted period of time. Mr. Lyell assumes, that the periods of revolution were of considerable duration, and that successive operations of the volcanic force produced the mountain chains. This opinion is evidently maintained as consistent with his theoretical opinions in general; for, in another place, he says—"before we can reasonably attribute extraordinary energy to any known cause, we must be sure that its usual force would be inadequate, though exerted for indefinite ages, to produce the effects required." This might be done, we think, by comparing the present condition of rocks forming mountains with what might be supposed to result from a long-continued operation of a cause not more violent than that which is now active. But this is more than can be required of those who believe continents and mountain chains to have been produced by a sudden paroxysmal force. It is sufficient to know that the volcanic cause has not, within the period of history, produced any effect that bears an analogy to those of which we have been speaking; for it has only produced a few isolated cones, and in one or two instances raised a district to an insignificant height. Com pare all that has been effected by volcanic forces since the commencement of this era, or what they may be expected to do if that era be extended for thousands of ages to come, with the meanest mountain chain, and then say whether the ordinary volcanic forces, acting for any series of years, could have produced them.

The other statements made by M. de Beaumont, that chains elevated at the same period have the same direction, and that chains of different ages are not parallel, must be submitted to the test of very extensive and accurate observations.

We may close these remarks with an extract from M. de Beaumont's own paper on the subject. "The fact of a general uniformity in the direction of all the beds upheaved at the same epoch, and consequently in the crests formed by these beds, is perhaps as important in the study of mountains as the independence of successive formations is in the study of superimposed beds. The sudden change of direction in passing from one group to another, has permitted European mountains to be divided into a certain number of distinct systems, which penetrate and sometimes cross each other without becoming confounded. I have recognised from various examples, of which the number now amounts to twelve, that there is a coincidence between the sudden changes established by the lines of demarcation observed in certain consecutive stages of the sedimentary rocks, and the elevation of the beds of the same number of mountain systems.

"Pursuing the subject as far as my means of observation and induction will permit, it has appeared to me that the different systems, at least those which are at the same time the most striking and recent, are composed of a certain number of small chains, ranged parallel to the demi-circumference of the surface of the globe, and occupying a zone of much greater length and breadth, and of which the length embraces a considerable fraction of one of the great circles of the terrestrial sphere. It may be observed respecting the hypothesis of each of these mountain-systems being the product of a single epoch of dislocation, that it is easier geometrically to conceive the manner in which the solid crust of the globe may be elevated into ridges along a considerable portion of one of its great circles, than that a similar effect may have been produced in a more restricted space.

"How well soever it may be established by facts, the assemblage of which constitutes positive geology, that the surface of the globe has presented a long series of tranquil periods, each separated from that which followed it by a sudden and violent convulsion, in which a portion of the earth's crust was dislocated—that, in a word, this surface was ridged at intervals in different directions—the mind would not rest satisfied, if it did not perceive, among those causes now in action, an element fitted from time to time to produce disturbances different from the ordinary march of the phenomena which we now observe.

"The idea of volcanic action naturally presents itself, when we search, in the existing state of things, for a term of comparison with these great phenomena. They nevertheless do not appear susceptible of being referred to volcanic action, unless we define it with M. Humboldt, as being the influence exercised by the interior of a planet on its exterior covering, during its different stages of refrigeration."

Having explained the appearance and origin of mountains, it would be necessary to refer to the probable formation of valleys, had we not already made some remarks upon this subject. Valleys have been produced in two ways, by an elevation and by denudation; the former being generally the deeper and the more precipitous. The spaces occupied by the ocean are, in fact, valleys, and the continents are but mountain chains. The sea, however, has not a uniform depth, but its basin is diversified by elevations and depressions in the same manner as the dry lands.

Valleys which separate high mountains are usually long and narrow, having frequently their salient and re-entrant angles so perfectly formed, that the sides would correspond if brought together. Instances of this have been observed in both the Alps and the Pyrenees.

CAVERNS.

There may be sometimes a difficulty in explaining the origin of those fissures and cavities which so frequently intersect strata, and are especially numerous in mountainous countries, and in limestone rocks. They may, however, be usually traced to the sinking or elevation of strata by volcanic forces, or to the action of water. Some singular theories have been proposed to account for the formation of caverns, and we remember one that assumes their elevation by the expansion of gases given off by dead bodies buried in the strata. Caverns generally consist of a series of galleries and apartments, to which the first open space is but the vestibule. Rivers take their rise in some caverns, and in others they are lost. But this is not the only proof of the existence of subterranean waters, for we are assured of the fact by the phenomena which attend the activity of the volcanic force, by springs, and other appearances. It is stated by a traveller, that in some of the caverns of Norway, the roar of the subterranean torrents may be heard as they bound along their contracted channels, beneath the floor of their gloomy recesses. A rivulet flows through the Peak Cavern, in Derbyshire. The entrance to this beautiful cave is a deep depressed arch, 120 feet wide, and 40 feet high; the cave itself is about 800 yards in length. From some caverns, that of Mount Eoto, near Turin, for example, an intensely cold wind proceeds, and others give out malignant vapours. The roofs of some are covered with stalactites, pendent masses of calcareous matter, presenting singularly fantastic forms. The grotto of Antiparos, situated in an island of the same name, one of the Cyclades, has been long celebrated for the variety and beauty of the incrustations which cover its ceiling, walls, and floors.

SPRINGS.

Springs, which frequently give birth to rivers and lakes, are found in nearly all districts. There is no class of natural appearances that presents more varied and interesting phenomena, and few that more deserve the attention of the geographer. Springs which are constantly flowing, without any apparent diminution of quantity, are called perennial others are called periodical springs. An intermitting spring is one that flows at fixed intervals, such as that at Como, in Italy, described by Pliny, which rises and falls every hour; and that at Colmars, in Provence, which rises eight times in an hour. There are also some spouting springs, such as those of Iceland, which rise to a great height, and the phenomenon is probably produced by the fall or pressure of the water contained in a reservoir at a considerable elevation above the aperture from which the water is thrown. Many springs are undoubtedly connected with the sea, for they rise and fall with it: this is the case with nearly all those in Greenland.

If we turn from modern to ancient records, still more remarkable statements in relation to springs will be discovered, but there are few of them that command belief. The Greeks, whose warm and vivid imaginations gathered flowers of inexpressible beauty from every portion of nature, with which fancy wrought a garb to cover ignorance, were never weary of tracing the history of their fountains, and the deities who presided over them. There were some springs that caused death, some leprosy, and some gave the power of prophecy: oblivion was the result of tasting the waters of some, and the mystic stream of Arethusa gave beauty. The man who has devoted any time to the perusal of the writers of antiquity, and stored his mind with the fable and imagery which give life and energy to all their descriptions, can hardly fail, when he thinks of the natural appearances that prompted them, to recall to mind the impressions which the first perusal could not fail to produce.

No one theory is sufficient to account for all the singular appearances presented by springs, though it is probable that some one cause is more active than others, and may be the general agent, while others modify its results. Some persons have attributed springs to the passage of water from the sea along subterranean channels into elevated natural reservoirs. But as water cannot ascend above its level, this theory cannot account for any of those springs which are situated above the level of the ocean, and consequently the doctrine of capillary attraction has been called in to aid the hypothesis. It is well known that water will ascend small tubes and threads to a considerable height above its ordinary elevation, and it has been supposed that such forms may exist in the interior of the earth, and the water be thus raised above its level. But this theory cannot assist the speculator, because a liquid does not flow through a capillary tube, though it may be raised in it beyond the ordinary level. There is no doubt, that many springs have their reservoirs at an immense depth below the surface of the ground from which the water is thrown; and it is more than possible that the water may be raised by the pressure of confined vapours, which, struggling for enlargement, force it through the fissures connected with its reservoirs. Dr. Hutton attributes springs to the percolation of water through rocks into natural cisterns, from which it is discharged at a level lower than that of its collected volume. There are many perennial springs in mountainous regions, and there is, perhaps, no other theory than this that will account for them. The fall of rain, and the melting of snow upon the summits of mountains, produce a considerable body of water, part of which penetrates the permeable strata, and is thrown again to the surface at a lower elevation along some fissure, or in the line of stratification.

GLACIERS.

The snow that falls upon the summit of mountains accumulates rapidly, and by its own weight, assisted by thaws and frost, becomes a consolidated mass of great thickness. Such masses are called glaciers, and are found on the upper portions and between the caps of all lofty mountains. The appearance of a glacier must depend upon the circumstances under which it is formed. If it were possible to imagine the ocean ruffled by a gentle breeze and consolidated, or a boundless mirror of ice, the reader might have some idea of the forms in which a glacier may be presented to the eye of the traveller; but nothing less than the view can give him a conception of the terrific scene, or the amazement, if not the terror, with which the appearance is first beheld. The traveller, as he passes over the mighty frozen ocean, may well imagine that he feels the billows swelling beneath his feet; he stands in a new world, surrounded by new scenes; no living object is there, and no sound except his own feeble voice, and the detonations of the ice as it tumbles in fragments down the yawning precipice; not a flower or a tree can be seen, except the lonely pine, which seems to be left as though to mourn over the grave of nature. But even this desolate region has its use in the economy of nature; for it is the reservoir of those springs which distribute fertility through the plains, and gives that in gentle streams which would otherwise rush headlong in its fury to the valleys, and leave ruin and desolation in its path.

RIVERS.

Rivers generally take their rise in mountainous countries, from the melting of ice, or from springs. When the fall of the water is gentle, the stream is called a rivulet; when violent, a torrent. Nothing adds more to the romantic character of a mountainous district, than a torrent tumbling from declivity to declivity, with accumulating velocity and fearful noise. The union of these streams produces rivers; and they, after passing over a greater or less extent of country, generally discharge themselves into either the sea or some large inland lake. As springs are most abundant in mountains, rivers usually take their rise in elevated districts, and the largest rivers in mountain chains. Every band of high land running through a continent or a country may therefore be considered as its reservoir, for on each side it pours forth the refreshing stream which meanders through the vales, and, having performed its task, discharges its surplus water into the ocean, from which it will be again raised by the process of evaporation; and is destined, when collected round some mountain's brow, to perform a similar duty in the same or some other channel.

The beds of rivers have been sometimes formed by the action of water, and at other times by the paroxysmal revolutions to which we have referred. It is evident, however, that if there were no declivities, there could be no rivers. A body of water would not move in one direction more than another over a perfectly smooth plain, but diffuse itself over the entire space, having at each part precisely the same depth. Water, therefore, must be directed into some declivity before it can collect itself together and direct its force; but when it has once obtained a momentum, it throws itself forward, and particularly if its body be large, with tremendous force, scooping out for itself a channel. Generally speaking, the mouths of rivers are considerably lower than their sources; but this is not always the case, for the sources of many of the large rivers in European Russia are very little above the level of the Baltic. The rapidity of a river does not entirely depend upon its declivity, but on this combined with the volume of its water, and the momentum it possesses at its source. The bed of the Danube is not so inclined as that of the Rhine, yet, in consequence of the greater volume of water it contains, it is more rapid. The declivity of the Amazon is not more than one twenty-seventh of an inch to every thousand feet, and yet, its momentum is great; and the Seine, between Valvais and Serves, has a declivity of but one foot to sixty-six thousand feet of its course.

Rivers may discharge themselves into the sea or lakes, or they may be lost among marshes. It was generally supposed, previous to the Landers' discovery, that the Niger, after running through an immense tract of country, was lost in marshes; and it has been proved by Sturt, that this is the fate of many of the rivers of Australia. There are some rivers that discharge themselves into lakes, as, for instance, those that flow into the Caspian, and the Murray, which terminates in the Lake Alexandrina. But by far the largest number of rivers enter the sea, and the phenomena produced by the mingling of the waters, each having a force of its own, are sometimes very remarkable. When the mouth of a river is large, it may quietly throw its waters into the sea; but if narrow, a violent struggle ensues between the tide of the one and the current of the other. To this circumstance, the bars which are frequently formed across the mouths of large rivers may be attributed. Travellers have spoken of the terrific spectacle produced when the tide of the Atlantic meets the current of the Amazon. It is like the conflict of giants—the earth trembles with the roar of their blows—and man flies with terror from the scene of encounter.

Some rivers have but one communication with the sea, others discharge themselves through several channels. The Ganges has not less than eight, each of which appears to have been at some time or other the principal. This mighty river receives the water of several tributaries as large as the Rhine, and its source has an elevation of 13,800 feet above the level of the sea.

Some rivers, especially those situated between the tropics, have a periodical rise. This was observed by the ancients in the instance of the Nile; and, as no rain falls in Egypt, they could only consider it as one of the mysteries of nature, and supply the place of truth with fable. All rivers thus situated are liable to these overflows; but the degree and period depend upon local circumstances, though they are in all instances caused by the seasonal rains which fall in tropical countries. When the thirsty earth, burnt up with the heat of a meridian sun, has been saturated with the descending torrents of rain, the rivers are swollen, and overflow their banks, not merely in those places where the rain actually falls, but throughout their courses. The rise of the Nile is occasioned by the rains which fall on the mountains in the interior of Africa; but it is not until about two months after the commencement of the rainy season, that the overflow reaches that part of the Nile which flows through Egypt; and it then rapidly quits its banks, spreads over the country, and gives fertility to a district that would otherwise be as desolate and barren as the deserts by which it is bounded.

CASCADES AND CATARACTS.

When rivers flow through mountainous countries, they are frequently thrown down precipices produced by the dislocation of rocks, and form cascades or cataracts. But cataracts are sometimes formed by the water of lakes, as, for instance, those of Niagara. They present various appearances, according to the circumstances under which they are projected over the ledge of rocks. Sometimes the water is projected in a broad and unbroken sheet; sometimes from ledge to ledge, presenting alternately the appearance of a slab and a wall; sometimes it is broken before it reaches the bottom, and is dissipated in showers, as at that of Staubbach; while at other times a fine arch of water is formed, under which the traveller may pass without receiving a spray from the descending torrent. But the most picturesque cataracts are those which consist of large bodies of water, having a considerable velocity, and discharging themselves between precipitous rocks: of these there are many examples in Scotland, Wales, and the north of England, and to a few of them we may direct the attention of the reader, as situations where the appearances they present may be studied, while at the same time beautifully picturesque scenery may be enjoyed.

Corra Linn is a celebrated waterfall on the Clyde, and is calculated to be eighty-four feet deep, but the water is thrown over in three distinct sheets, which greatly adds to the sublimity of its appearance as a natural object, and illustrates the effects of water upon rocks. Scotland abounds in cataracts, and some of them are remarkably beautiful: the Fall of Bruar, the Cascade of Glamma, in Glen Elchaig, and many others, have long been objects of interest. But the Fall of Fyers, situated to the east of Loch Ness, is the largest cascade in Scotland: it descends 212 feet, and is enclosed by broken precipitous rocks. In Ireland there are also some remarkable waterfalls, one of the most beautiful of which is that of Powerscourt, in Wicklow, a stream that flows down a steep declivity of 360 feet, amid beautifully variegated woods.

We must not attach too much importance to these interesting appearances. Being usually produced by the dislocations which rocks have suffered, they are commonly situated in districts of great natural sublimity, to the wildness of which they considerably add. To the lover of the picturesque they are therefore objects of great interest, but it is quite evident that they are not of primary importance in studying the distribution of land and water.

The largest and noblest cataract in the world is that of Niagara, which is situated in a strait of the same name, communicating with Lake Ontario. The following account is extracted from a paper by Mr. Ellicot, published in the "American Philosophical Transactions:"—"Lake Erie is situated upon horizontal strata, in a region elevated about three hundred feet above the country which contains Lake Ontario. The descent which separates the two countries is in some places almost perpendicular, and the immense declivity formed by these strata occasions both the cataract of Niagara and the great falls of Cheneseco. This remarkable precipice generally runs in a southwestern direction, from a place near the Bay of Torento, on the northern side of Ontario, round the western angle of the lake: from thence it continues its course generally in an eastern direction, crossing the Strait of Niagara and the Cheneseco river, till it is lost in the country towards the Seneca lake. The waters of this cataract formerly fell from the northern side of the slope near the landing-place; but the action of such a tremendous column of water, falling from such an eminence, through a long succession of ages, has worn away the solid stone for the distance of seven miles, and formed an immense chasm, which cannot be approached without horror. Down this awful chasm the waters are precipitated with amazing velocity, after they make the great pitch; and such a vast torrent of falling water communicates a tremulous motion to the earth, which is sensibly felt for some poles round, and produces a sound which is frequently heard at the distance of twenty miles. The great height of the banks renders the descent into the chasm extremely difficult: but a person, after having descended, may proceed to the base of the falls; and a number of persons may walk in perfect safety a considerable distance between the precipice and the descending torrent; and conversation is not much interrupted by the noise, which is not so great here as at a distance. A vapour, or spray, of considerable density, resembling a cloud, continually ascends, in which a rainbow is always seen when the sun shines, and the position of the spectator is favourable. In the winter, this spray attaches itself to the trees, where it is congealed in such quantities as to divest them of their branches, and produces a most beautiful crystalline appearance, a circumstance which attends the falls of Cheneseco, as well as those of Niagara. A singular appearance is observed at these falls, which has never been noticed by any writer. Immediately below the great pitch, a commixture of foam and water is puffed up in spherical figures, about the size of a common haycock. They burst at the top, and discharge a column of spray to a prodigious height; they then subside, and are succeeded by others, which exhibit the same appearance. These spherical forms are most conspicuous about midway between the west side of the strait and the island which divides the falls, and where the largest column of water descends. This appearance is produced by the ascension of the air, which is carried down by the column of falling water, in great quantities, to the bed of the river. The river, at the falls, is about 743 yards wide; and the perpendicular pitch is 150 feet in height. In the last half mile immediately above the falls, the descent of the water is 58 feet; but the difficulty which would attend the process prevented me from attempting to level the rapids in the chasm below, though from conjecture I concluded that the waters must descend at least 65 feet. From these results, it appears that the water falls about 273 feet in the distance of about seven miles and a half."

LAKES.

Lakes have been divided into four classes, and under one of these all those with which we are acquainted may be conveniently arranged.

The first class includes those which have no outlet, and do not receive any running water. Many of these are situated in elevated districts, and are generally so small that they might be, not inappropriately, called pools. It has been supposed that they are the craters of extinct volcanoes, and are supplied by springs, a supposition not at all improbable They all increase and decrease with changes in the atmosphere.

The second class comprises those which receive water, but have no outlets. The Caspian and Lake Aral belong to this division. The Caspian is about 600 miles long, and its extreme breadth 300, though its average breadth is not more than 100 miles. This most remarkable lake receives the waters of the Volga, a river which has a course of about 2000 miles, flowing through European and a part of Asiatic Russia, and brings down more than 518,000,000 of cubic feet every hour. The Ural, the Yaik, the Kur, and many other streams of considerable magnitude, are also received by the Caspian; but its level is not changed, though it has no perceptible outlet by which to discharge the water it receives. Lake Aral presents the same phenomena, and, though not to be compared in superficial extent to the Caspian, receives two large rivers, the Oxus and the Jaxartes. The difficulty in explaining the nature of these lakes is to account for the constancy of their level, which might be expected to rise considerably, as they are daily receiving so large a body of water. It has been supposed that they are connected by some internal channel with the sea, and the opinion has been supported by the fact that the water of both the Caspian and Lake Aral is salt, and contains marine productions; but it is stated by a modern writer, that the Caspian is at the present moment not less than 300 feet below the level of the Black Sea. It is almost certain that the phenomenon referred to may be accounted for by evaporation, though it is possible that the process of filtration may be going on, and assist this cause. Mr. Bell has mentioned several interesting facts, to show how great an effect may be produced by evaporation under favourable circumstances. In the valley of the Missouri, he says, "a climate as cold as that of the Caspian, the evaporation is so great, that a tablespoonful of water placed on the deck of a vessel was evaporated in a very short space of time, and the inkstand was daily replenished during a voyage of 1000 miles downward, from Fort Mandan, in 47° north latitude. The evaporation on the river was so great, that though more than twenty rivers of large volume fell into the

Missouri in that space, it was not sensibly enlarged." When acquainted with such facts, there can be no difficulty in believing that the evaporation from the surface of the Caspian may be the cause why it preserves its level, notwithstanding the large volume of water brought into it by the Volga and other rivers.

The third class comprehends all those lakes which receive no streams, but give birth to some. Many of these lakes occupy very elevated situations, and are the sources of some of the largest rivers. They are, no doubt, supplied by springs, the water of which rises in their reservoirs until its level is sufficiently high to admit a discharge. The lake on Monte Rotondo, in Corsica, is one of this class, and is situated 9000 feet above the level of the sea.

The fourth class includes all those lakes which both receive and discharge water, and these are more numerous than any others. Some receive the waters of many rivers, but commonly they have but one outlet. It is not difficult to explain the origin of these lakes. Should a hollow present itself in the course of any river, it is quite evident that it must be filled to the level of some part of its banks before the river can proceed, and this would produce a lake. But it may happen that there is a general declivity from various parts of a district towards some central valley, and then the waters of a number of rivers may be brought into it, while at the same time the continuation of the valley gives but one course by which the waters can be discharged. Many of these lakes, however, may be supplied by springs as well as by rivers. Lake Baikal, in Asiatic Russia, is a very large lake of this class, but the largest are those of North America, which lie between Canada and the United States.

These lakes, or inland seas, as some of them might be more appropriately called, constitute so important a feature in physical geography, that we cannot pass from the consideration of the subject without a more specific reference to a few examples, and especially to some of those which are found in the northern counties of Great Britain, which, though not large, are well worthy attention.

Lake Baikal, in Asiatic Russia, and in the government of Irkoutsk, is about 1244 miles in circumference. It receives the waters of the Bargousin, the Gelenga, the Upper Angara, and the Tunka, all of them rivers of some importance. It has only one outlet, called the Lower Angara. This lake is supposed by many persons to have been produced by the volcanic cause, and the supposition is not altogether unsupported by facts. The mountains around bear marks of a sudden and violent eruption; the surrounding districts are decidedly volcanic; earthquakes have been felt in the neighbourhood; and vessels on its surface have sometimes suffered from severe shocks when the sea has been perfectly calm. The navigation of this vast body of water is tedious, if not dangerous, but it is sometimes frozen over; and Cochrane states, that he has passed over it on a sledge, in a place where it is forty miles broad, in two hours and a half, though vessels are frequently thirty days in crossing.

The lakes of North America are very numerous, but the most important are the Ontario, Erie, Huron, and Superior. Lake Superior is the largest body of fresh water in the world, and is about 400 miles in length, and 100 in its greatest breadth. In this lake there are five large islands, one of which, Isle Royale, is said to be at least 100 miles in length. More than forty rivers discharge themselves into this vast body of water; but the Strait of St. Mary, connecting it with Lake Huron, is its only outlet—and this is not navigable, on account of the falls.

Lake Huron is about 250 miles in length, and contains several large islands. An extensive plain separates it from Lake Michigan, which is cut off from Lake Superior by a narrow tongue of land. Lake St. Clair is about 90 miles in circumference, and, although unworthy comparison with those large bodies of water already described, it has an importance from its connexion with Lake Erie, which is about 600 miles in circumference. Lake Ontario is the last of the chain, and is about 170 miles long, and 60 broad.

There are other countries where the lakes are as numerous as in North America, but there is no country in which they present so large a surface of water. Switzerland abounds in lakes, but in magnitude they cannot be compared with those of America. Geneva is the largest of these, but it is not more than fifty miles in length, and twelve in its greatest breadth. It is chiefly remarkable for the romantic scenery by which it is surrounded; and in this respect it is superior to all others, as also in the depth of its "deep blue waters."

The principal English lakes are situated in Cumberland and

Westmoreland, and of these the most important are Ullswater, Derwentwater, and Windermere. Ullswater is about nine miles in length, and two in its greatest breadth. It may be described as a long narrow body of water, situated in a scenery remarkable for its beauty and grandeur. Helvellyn and the Stone Cross Pike, the two highest mountains in the district, come fully into view as the traveller passes down the lake. Derwentwater is not inferior in grandeur, though its character is exceedingly different from that of Ullswater; and the mountains by which it is surrounded are more broken and rugged. Around this spot there is a charm which is irresistible, for here nature wears an enchanter's robe, and is painted in her most fantastic colours. But Windermere is the largest of the English lakes, though it is not more than ten miles and a half long, and two miles broad. It is surrounded with beautifully wooded hills, and on the north a fine range of mountains forms the back-ground.

But none of the English lakes can be in any way compared with the Scotch, and particularly with the romantic Loch Lomond. The solemn stillness of the dark waters, and the proud aspiring summit of Ben Lomond and its elevated companions, produce reflections in the mind of an observer not to be easily forgotten. Who that has read Wordsworth's exquisite lines "To a Highland Girl," does not desire to read them on the spot where they were written? And who that has done so, does not desire a repetition of the delight?—

"And these gray rocks; this household lawn;
These trees, a veil just half withdrawn;
This fall of water, that doth make
A murmur near the silent lake:
This little bay, a quiet road
That holds in shelter thy abode;
In truth, together do ye seem
Like something fashioned in a dream,
Such forms as from their covert peep,
When earthly cares are laid asleep!"

Lakes differ greatly in their depth, and in the character of the water they contain. The water of some is exceedingly pure and transparent, that of others is salt, brackish, or sweet; and there are some which emit noxious exhalations, destructive or injurious to animal life. Many lakes are no doubt attributable to volcanic agency, and have been produced in the manner already described in speaking of the Dead Sea. In these places there may be now no external violent evidence of the activity of the same force, but still it may be in existence; and the evolution of noxious vapours is one proof that the supposition is not without foundation. It is well known that in the neighbourhood of Vesuvius, and in other volcanic districts, there are many places from which carbonic acid is given off in large quantities, destroying animal, and considerably affecting vegetable life. The celebrated Grotto del Cane, at Naples, is an excellent example; and there are many caves in the south of France, an extinct volcanic district, particularly those of Montjoly, where similar phenomena have been observed. It is not, therefore, singular, that springs and lakes produced by the same cause should emit the same vapour, for there must be as intimate a connexion with the cause in one instance as in the other. Bishoff and Nöggerath state, that there is a pit near Lake Laæch, where there is a permanent evolution of carbonic acid gas, and they found the remains of many animals that had been killed by it. On descending into the pit, and holding their heads over the stream, they experienced the sensation that is known to attend the breathing of this deleterious fluid. Near Boudelreis, on the bank of the river Kyll, there is a spring that gives off so large a quantity of carbonic acid, as to appear, by the number of bubbles on its surface, as though it were boiling, and persons who attempt to drink from its basin are quickly driven away by the mephitic odour of the water.

Some lakes are periodical, and increase or decrease in depth at particular seasons of the year. There are some large cavities in South America, which, immediately after the rainy season, are filled with water, and become lakes; but by the process of evaporation, and by filtration, the water is soon carried off. But there are others which rise and fall in a manner unaccounted for by the causes which so easily explain the drying up of the lakes of South America. It has been supposed that there is a connexion between these periodical lakes and a subterranean reservoir, the increase or decrease of which produces a similar effect upon the lake itself. It is still more difficult to explain those occasional disturbances to which inland lakes are sometimes subject. Loch Lomond is frequently agitated in a most violent manner during the calmest weather, and without any apparent cause It may be well to remember that this lake has suffered a similar agitation during the presence of earthquakes in very distant places. The same causes may not explain the phenomenon in both instances, but there is some reason to believe that they are not altogether distinct. It may also be mentioned, that lakes frequently contain islands, which are so light as to float upon the surface of the water: they are sometimes exceedingly numerous, and of considerable size.

THE SEA.

Although the sea has so large a proportion to the dry land, occupying seven tenths of the surface of the earth, yet its present quantity and conditions are absolutely necessary tc man, that he may fulfil the objects of his terrestrial being. The earth without an ocean would be an arid and unfruitful desert, incapable of producing any vegetable substance, and consequently unfit for the residence of animals. But a constant interchange is going on between the ocean, the atmosphere, and the dry land. By the action of solar heat upon the surface of water, it is vaporized, and carried in an elastic form into the atmosphere. By a variety of causes, and especially by the agency of electricity, this aqueous vapour is condensed and returned to the earth, a part falling upon the sea itself, and a part upon the dry land. Having performed its purpose in watering the earth, and in giving fresh vigour to vegetable growth, it is, directly or indirectly, returned to the ocean, to pass again through the same series of changes and circumstances. But the ocean serves another important end, in the abstraction and decomposition of many of the noxious substances contained in the atmosphere; and there is little doubt that it is the means of checking some of those principles of disease which are known to be wafted from clime to clime on the wings of the wind. It is also worthy of remark, that although the sea separates the inhabited portions of the earth's surface, yet it offers a ready means of communication. Upon its own bosom it carries the proudest trophy of human ingenuity, a vessel that contains within itself the source of power, and can plough its way from shore to shore, in spite of the ordinary opposition of winds and tides. Thus it is that the intercourse of nations, and the inerchange of manufactured and natural productions, are carried on, to the social and intellectual advantage of man.

Oceans are collections of water in valleys, and their basins must present the same inequalities as are observed upon the surface of the land. Mountains, hills, and valleys are to be found in the bed of the ocean as well as on dry land; and the causes which effected changes in the relative positions of the one must have had some and a similar influence upon the other. The depth of the sea, therefore, must vary considerably in different places. But there is much difficulty in ascertaining the depth at any place; for not only are substances moved more readily in water than in the atmosphere, on account of their loss of weight in that medium, but they are also subject to rapid transportation by currents. On these accounts, there are many situations in which the heaviest sounding-lead can be of little or no value. Lord Mulgrave sounded in the Northern Ocean in a place where he gave out 4700 feet of line without finding a bottom, and Mr. Scoresby could not find a bottom in one part of the Greenland Sea at the depth of 7200 feet. According to the calculations of La Place, in his "Mécanique Celeste," founded upon the oscillations of the ocean, the mean depth of the water is a fraction of the difference produced in the diameter of the earth by the flattening of the poles, and it has been estimated at between two and three miles.

LEVEL OF THE SEA.

From the universal law by which water is known to be governed, it might be deduced that the surfaces of all connected bodies of water must be on the same level; and if there were no deranging causes, this would be the case, and the surface of the ocean would give the precise form of the earth. The great law of gravitation has its action in this as well as in all other instances; and water, wherever situated, not only seeks the lowest places it can reach, but also attempts to maintain the same level. But it is impossible that there can be a universal level at any moment, so long as the disturbing causes, intimately connected with the present physical condition of the earth, exist. The influence of the moon producing tides is one of these causes, and occasions a considerable difference in the height of the water, in near as well as distant parts of the same ocean or sea. The level is also liable to alteration from the local influence of winds, and it has been ascertained that in all gulfs and inland seas, the level is always higher than on the ocean. This is especially the case with those which are open only to the east, for they are more exposed to the great oscillation of the water from east to west, to which the ocean is periodically subject. By this movement, the water is carried into these inlets, and the more confined their openings, the higher will be the level. M. Humboldt made some experiments on the Isthmus of Panama, from which he deduces that the level of the Gulf of Mexico is from 20 to 23 feet higher than that of the Pacific. The influence of the tides is well known, and is observed more or less upon all bodies of water connected with the ocean. Winds also have an effect in destroying the level, not only by the formation of waves, but also by driving in one direction a body of water in greater volume than usual. Upon seacoasts this effect is frequently produced; and navigators are aware that in consequence of the easterly trade-winds, urging the waters of the ocean towards the African coast, the level of the Red Sea is always about twenty feet above the level of the ocean. These are the causes which produce an elevation of the level in some places; and there is one agent, evaporation, which sometimes lowers it. The Mediterranean Sea, for instance, is a little below the general level, for the waters it receives from the numerous rivers whose basin it is, are not sufficient to compensate for the loss by evaporation, and a constant supply is consequently furnished through the Straits of Gibraltar.

But although these disturbing causes are in action, there is a general ocean level, and even the variations are so entirely under the control of laws that are perfectly understood, that no change can be effected which is not capable of explanation, and usually of prediction. The necessity of these restraining laws is evident; for so powerful is the influence of a large body of water in motion upon the district over which it moves, that if it were governed by laws less capable of restraining its limits, such scenes of destruction would be constantly presented as would give an insecurity to all the provisions necessary for the sustenance of animal life. It would not be difficult to select instances in which the deranging causes now active have produced most alarming effects. The loss of life and destruction of property in St. Petersburgh, in the year 1825, will be in the remembrance of many of our readers, and this was produced by a flood that was occasioned by a no more violent cause than a strong wes- ly wind, impeding and partially preventing the flow of the waters of the Neva.

It was, during the last century, much disputed whether the sea maintained its level; and many geographers were of opinion that it was constantly falling, and the Baltic in particular. The question is to the present day undecided, although experiments have been made to determine it. Of these there are many that favour the supposition of a decreasing level, but they are opposed to others which lead to an opposite conclusion. In the year 1820, Mr. Bruncrona collected the results of the experiments made during half a century on the western coast of the Baltic, and from these it may be deduced, that the level of the water is there constantly falling; and this conclusion is supported by the opinion of the Baltic pilots, who state that the sea is shallower than it was, and that the straits which separate the islets along the coast of Sweden could once be passed by vessels drawing ten feet of water, though they are now not practicable for boats that draw more than three feet. Mr. Hallstrom states, that the same effect is going on in the Gulf of Bothnia, with this difference, that in the Baltic the lowering decreases from the north, and disappears at the southern extremity; but in the Gulf of Bothnia, it is nearly uniform throughout. These results lead to the conclusion that the level of the Baltic is falling, unless we accept the opinion of those who state, that the currents from the north to the south of the Baltic, produced by the streams which flow into it, drive the waters to the southern shore, where the level is rising, though it is falling on the northern. But whatever opinions may be formed from a consideration of these facts, we have at present no means of determining whether the general level of the ocean is constant.

THE COLOUR OF THE OCEAN.

The colour of the ocean is not fixed, but is influenced by the direction of the light, the chymical composition of the water, and the nature of the rocks over which it flows. The sea commonly appears to have a deep blue tinge; but, as the depth decreases, it becomes clearer and has a lighter shade. When a small quantity of seawater is examined, it has no colour; and this is also true of a small quantity of atmospheric air; both of these media are, in minute volumes, incapable of intercepting so large a quantity of any ray as to give colour to the volume. Yet they differ in their powers of interception; air reflects the most refrangible rays, the violet, indigo, and blue, which produce the azure hue that is known to distinguish it; but water, on account of its density, as well as its depth, reflects some of the less refrangible rays, and hence its greenish blue colour. Under peculiar circumstances, the sea exhibits other shades, but these are to be attributed to local rather than general causes,—the character of the bed over which the water flows, and sometimes the animalculæ, insects, or plants, which float over or immediately beneath its surface. In the Gulf of Guinea the sea is white; around the Maldives it is black; in the upper part of the Mediterranean it has a purple teint; and the West Indies are washed by an ocean so transparent, that the bottom of the sea lies open to examination. There are also in all places changes of colour, produced by the shadows thrown upon the sea by the interception of the clouds, and these shades are so evanescent and varied when the sky is thickly covered with broken clouds, that we may almost fancy the eye is deceived.

PHOSPHORESCENCE OF THE SEA.

The sea has sometimes a luminous appearance, a phenomenon that has been observed by all sailors, who consider it the forerunner of windy weather. It is said to occur most frequently in the summer and autumn months, and varies so much in its characters as to induce a doubt whether it can be always attributed to the same cause. Sometimes the luminous appearance is seen over the whole surface of the water, and the vessel seems as though floating upon an ocean of light; at other times the phosphorescence only encircles the ship. A portion of water taken from the sea does not necessarily retain its luminous appearance, but its brilliance will generally continue as long as the water is kept in a state of agitation. Some philosophers imagine the phosphorescence of the sea to arise from the diffusion of an immense number of animalculæ through the medium, and others attribute it to electricity. Dr. Buchanan has given an accouut of a very

remarkable appearance of the sea, observed by him during a voyage from Johanna to Bombay. About eight o'clock in the evening of the 31st of July, 1785, the sea had a milk-white colour, and was illuminated by a multitude of luminous bodies, greatly resembling the combination of stars known as the milky way, the luminous substances representing the brighter stars of a constellation. The whiteness, he says, was such as to prevent those on board from seeing either the break or swell of the sea, although, from the motion of the ship and the noise, they knew them to be violent, and the light was sufficiently intense to illuminate the ropes and rigging. This singular phenomenon continued until daylight appeared. Several buckets of water were drawn, and in them were found a great number of luminous bodies, from a quarter of an inch to an inch and a half in length, and these were seen to move about as worms in the water. There might be, says Dr. Buchanan, four hundred of these animals in a gallon of water. A similar appearance had been observed before in the same sea by several of the officers, and the gun-
had seen it off Java Head in a voyage to China.

TEMPERATURE OF THE SEA.

The ocean has not always the same temperature in the same latitude. Within the tropics there is little or no difference between the temperature of the northern and southern hemispheres; but, as we approach the poles, the temperature is less for any degree of latitude in the northern than the southern. In eighty degrees north latitude ice generally melts in the month of May, though it remains all the year round in sixty degrees south latitude. Ice also extends nearly eight degrees farther from the south pole than it does from the north, for icebergs have been found as low as forty-eight degrees south latitude. This greater decrease of temperature in the southern hemisphere has been attributed to the almost entire absence of land in the antarctic circle, whereas the arctic sea is almost surrounded by land. Peron invented an instrument, which he called a thermo-barometer, for the measurement of the temperature of the ocean; and from a great number of experiments, deduced a series of singular results; but some of these have been controverted by Humboldt. Peron states, that in the neighbourhood of islands or continents, the temperature of the water is always higher than in the open sea, and that near a shore the cold increases with the depth. But Humboldt objects to this statement as a general law; for although the temperature of the tropical seas, and the Mediterranean, and Baffin's Bay, does diminish with the depth, yet in the Greenland seas and in the Arctic Ocean the temperature increases with the depth. The experiments made in the south seas during Krusenstern's voyage of discovery tend to establish the law that the cold increases with the depth. Saussure estimates the mean temperature of the sea at 53°, but it appears to range between 26° and 68° of Fahrenheit's thermometer.

MARINE ICE.

It was once much doubted by geographers whether the waters of the ocean could be frozen, but the voyages which have been undertaken in polar regions have entirely removed this doubt. Bays and inland seas, situated in sixty degrees north latitude, are entirely frozen over during the winter season, and in seventy degrees the sea is covered with fields of ice. The more enclosed the water, and the greater the projections of land, the more readily will ice be formed; and it is on this account that the Baltic, the Gulf of Bothnia, and other inland seas, are frequently frozen, when the ocean in the same latitude is altogether unencumbered. In about the eightieth degree of north latitude the ice becomes fixed, and during the winter months presents an immoveable mass, having a porous and diaphanous structure. When the spring returns it begins to melt, the mass is broken, and an uncertain passage is opened to the adventurous mariner. But the summer soon passes, and the vast surface is again covered with a thick crust of ice, over which the polar bear wanders, in search of that sustenance which seems to be denied all creatures in this inhospitable region.

ICEBERGS.

An iceberg is an island of ice, sometimes immoveably fixed upon some projecting mass in the sea, but more commonly floating from place to place, according to the action of the winds and currents. Icebergs are usually very perpendicular on one side, and on the opposite have a more gradual sloping direction. Their height is variable, and some of them have an elevation of two hundred feet above the level of the ocean. The colour of these vast masses of ice is various, depending in part upon the direction of the incidental luminous rays, and in part upon the constitution of the bergs themselves; they not unfrequently appear as though formed of emerald or sapphire, and the colours produced by the refraction are frequently so beautiful, that they seem as though they were built of light, and mimicked the representations of oriental fable. It has been supposed that the iceberg is formed by the piling together of the fragments produced by the breaking up of the large fields of ice, but it is more commonly allowed that they are masses broken off from the enormous glaciers abounding on the coasts of Greenland and Spitzbergen. Some, however, may be produced by the consolidation of driven snow, and contain trees, which occasionally take fire, in consequence of the great friction to which they are exposed, presenting the singular appearance of a burning mountain of ice. The bergs are sometimes enveloped in a thick fog; and if a ship should come in contact with them, almost certain destruction must result from the collision. Very many of the vessels employed in the fisheries are every year lost, we are informed, by accidents of this kind.

Mr. Scoresby has given, in his "Arctic Regions," a very interesting sketch of the seven icebergs of Spitzbergen, from which we may select the most important facts. "I speak not here," he says, "of the islands of ice which are borne to southern climates on the bosom of the ocean, but of those prodigious lodgments of ice which occur in the valleys adjoining the coast of Spitzbergen and other polar countries, from which the floating icebergs seem to be derived. Where a chain of hills lies parallel to the line of the coast, and within a few miles distant of the seabeach, having lateral ridges jutting towards the sea, at intervals of a league or two, we have a most favourable situation for the formation of icebergs. Such is precisely the nature of the situation a little to the northward of Charles Island, where the conspicuous bodies of ice noticed by Martens, Phipps, and others, and known by the name of the seven icebergs, occur. Each of these occupies a deep valley, open towards the sea, formed by hills of about two thousand feet elevation on the sides, and terminated in the interior by a chain of mountains of perhaps three thousand to three thousand five hundred feet in height, which follows the line of coast. They are exactly of the nature and appearance of glaciers; they commence at the margin of the sea, where they frequently constitute a considerable precipice, and extend along the valley, which commonly rises with a gentle slope, until they are either terminated by the brow of the mountain in the back-ground, or interrupted by a precipitous summit. Besides these icebergs, there are some equally large near the northwest angle of Spitzbergen, in King's Bay, and in Cross Bay, and some of much greater magnitude near Point Look-out, besides many others of various sizes in the large sounds on the western side, and along the northern and eastern shores of this remarkable country."

The Seven Icebergs, according to Mr. Scoresby, are each on an average about a mile in length, and two hundred feet in height above the level of the ocean; and there is one to the northward of Horn Sound eleven miles in length, and four hundred and two feet high. These vast masses of ice are, during stormy weather, attacked by the waves, which gradually precipitate large fragments into the sea. The ice is everywhere traversed by deep fissures, from a few inches to several feet wide, and so deep, that, in looking into them, the traveller finds that the rays of light have never penetrated to the bottom. These rents are supposed by Mr. Scoresby to have been produced by the passage of streams of water over the surface of the ice; but Dr. Latta imagines them to have been produced by expansion during the process of freezing. Suppose the iceberg, says this gentleman, to be but a few feet thick, the heat of summer will render it spongy and porous, and its surface will be hollowed in channels by the little streams that flow over it. When winter returns, and these streams of water are congealed, the walls of the cavities will be, in some degree, forced asunder, and a partial rent be formed. Into these rents water will again flow, and being solidified as in the previous instance, the rent must be increased in length, width, and depth, while the damming up and freezing of the little streams below assist the action, by elevating the mass from its bed. This process, says Dr. Latta, annually repeated, might induce the appearance now presented by the icebergs, and, being wedged in between mountains, they cannot extend laterally, and necessarily become arched or convex, impelled, as it were, by a central force in the expansion of water.

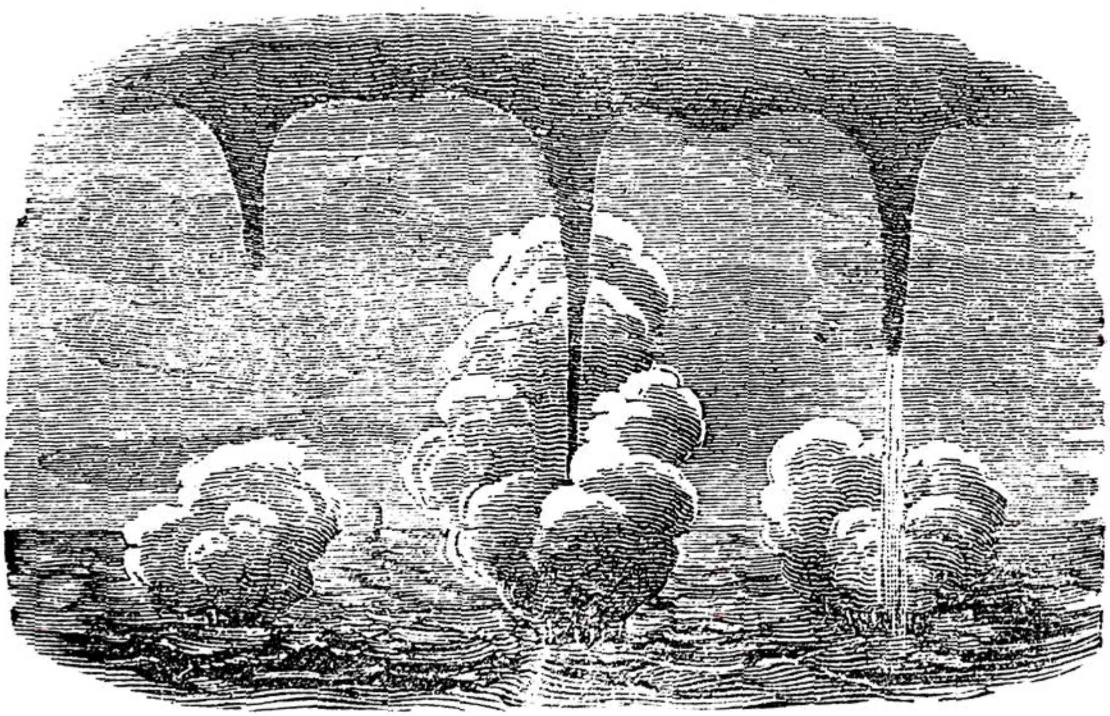
Nothing can be more beautiful than the appearance of these wonderful masses of ice; and the contrast between their glittering surfaces, and the dark monotonous gloom of the rocks and snow-clad peaks by which they are surrounded, presents the beholder with scenes of interest, even within the confines of the polar circle, where nature almost loses the spark of vitality, and struggles incessantly to free itself from the iron band of eternal frost.

WATER-SPOUTS.

Among the most interesting phenomena observed at sea, we may mention the formation of water-spouts. This curious and perplexing phenomenon is not to the present moment thoroughly understood; for it is still a matter of dispute among meteorologists, whether it is due to the agency of electricity, or to the mechanical action of whirlwinds. It is quite certain that water-spouts are commonly attended with electrical phenomena; but it cannot be determined, from the data in the hands of the philosopher, whether electricity is an effect or a cause, for it is equally certain that the spiral motion of the water must result from a gyratory motion of the air, which also may be an effect or a secondary cause.

Mr. Steward, speaking of the water-spouts seen by him in the Mediterranean, in the year 1701, says that they all consisted of a transparent tube " It was observable of all of them, but chiefly of the large pillar, that towards the end it began to appear like a hollow canal, only black in the borders, but white in the middle; and, though at first it was altogether black and opaque, yet one could very distinctly perceive the seawater to fly up along the middle of this canal, as smoke does up a chimney, and that with great swiftness, and a very perceptible motion; and then, soon after, the spout or canal burst in the middle, and disappeared little by little, the boiling up and the pillar-like form of the seawater continuing always the last, even for some time after the spout disappeared, and perhaps till the spout appeared again or reformed itself, which it commonly did in the same place as before, breaking and forming itself again several times in a quarter or half an hour."

Dr. Buchanan observed this phenomenon once or twice during a voyage to and from India. When his attention was first called to it, he observed a dark thick cloud which threw out a long curved spout, while at the same time a thick fog rose out of the sea. After an interval of about two minutes, the spout rushed down and joined the cloud which had risen from the sea. The cloud from which the spout descended then moved, says Mr. Maxwell, slowly along, and probably by its motion produced the curvature of the spout. The fog proceeding from the sea was of the same colour as the spout, and resembled the smoke of a steam-engine. The surface of the water under the spout was during the whole time in a state of violent agitation, and a noise was heard like that of a waterfall. The spout soon withdrew itself again into the cloud from which it had descended, and the fog receded into the sea. The whole exhibition did not last more than three minutes. The same author had opportunities at other times of observing similar appearances, and in all cases they presented nearly the same phenomena, and he has represented in the following diagram the different states in which they occur. At their first formation, he says, they appear of a conical tubular form, dropping from a black cloud before the disturbance of the sea is observed. The black conical cloud then descends, and the smoke-like appearance from the



States of the Water-spout.

sea ascends, until they join. When the spout begins to disperse, the black cloud draws itself up, and a thin transparent tube is left still united to the cloud that rose from the sea. This, however, is at last broken, and the phenomenon disappears.

The Honourable Captain Napier has made some remarks, in the Philosophical Journal, upon a phenomenon of the same kind which he observed, and upon the probable cause of the appearance. On the 6th of September, 1814, in latitude 30° 47′ north, and longitude by chronometer 62° 40′ west, at half past one, P. M., the wind being variable between W. N. W. and N. N. E, the ship steering S. E., an extraordinary sort of whirlwind was observed to form about three cables' length from the starboard bow of H. M. ship Erne. It carried the water up along with it in a cylindrical form, in diameter to appearance like a water-butt, gradually rising in height, increasing in bulk, advancing in a southerly direction, and when at the distance of a mile from the ship it continued stationary for several minutes, boiling and foaming at the base, discharging an immense column of water, with a rushing or hissing noise, into the overhanging clouds, turning itself with a quick spiral motion, constantly bending and straightening, according as it was affected by the variable winds, which now prevailed alternately from all points of the compass. It next returned to the northward, in direct opposition to the then prevailing wind, and right upon the ship's starboard beam, whose course was altered to east, in hopes of letting it pass astern. Its approach, however, was so rapid, that we were obliged to resort to the usual expedient of a broadside, for the purpose of averting any danger that might be apprehended, when, after firing several shots, and one in particular having passed right through it at the distance of one third from its base, it appeared for a minute as if cut horizontally in two parts, the divisions waving to and fro in different directions, as agitated by opposite winds, till they again joined for a time, and at last dissipated in an immense dark cloud and shower of rain. At the time of its being separated by the effect of the shot, or, more probably, by the agitation occasioned in the air by the discharge of several guns, its base was considerably within half a mile of the ship, covering a portion of the surface of the water at least half a furlong, or even three hundred feet, in diameter, from one extreme circumference of ebullition to the other; and the neck of the cloud into which it discharged itself appeared to have an altitude of forty degrees of the quadrant, while the cloud itself extended over head and all round to a very considerable distance. Allowing then from the ship a base of a little more than one third of a nautical mile, say 2050 feet, and an angle of 40° to the top of the neck, we shall then have for the perpendicular height of the spout about 1720 feet, or very nearly one third of a statute mile. A little before it burst, two other water-spouts of an inferior size were observed to the southward, but their continuance was of short duration.

If Captain Napier's calculation of the height of this water-spout be even an approximation to the truth, it entirely destroys that theory which attributes the phenomenon to the formation of a vacuum. Liquids will rise in exhausted tubes to the height at which they exactly balance a column of atmospheric air having the same base, and water obeying this law will rise to the height of about thirty-two feet, as it does in pumps. Now, if this force acts at all in the formation of water-spouts, it must be aided by some other agent, but what that is cannot be determined in the present state of our knowledge upon the subject; it may be a result of an electrical attraction dependant on the different electric conditions of the cloud and the ascending fluid, or may be produced by the rotary motion of the air.

MOTION OF THE SEA.

The sea is subject to a motion of three different kinds: it is agitated by the action of the wind, producing waves; by tides, which result from the attractive influence of the moon; and by currents, produced under various circumstances, and resulting from a variety of causes. To all these we must briefly refer.

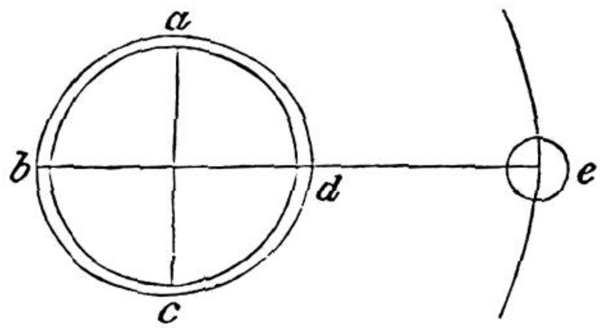
WAVES.

Waves necessarily result from the laws which govern fluids. Whenever the level of a liquid is disturbed, there will always be an effort to restore the equilibrium, and a mass of fluid will rush to occupy the place which has been vacated. The wind, acting upon the surface of the sea, piles up, if we may so speak, ridges of water, leaving small narrow indentations, into which the water on all sides attempts to enter. This disturbance, therefore, is communicated, and extends over a large or small space, according to the force of the disturbing cause, and billow rolls after billow, increasing the uproar of the wild waters. This also accounts for the fact, that when the waves have been some time in motion, they do not immediately sink to rest when the wind ceases, but the level is restored by degrees, the waves decreasing in height, and becoming shorter, until they are reduced to a mere ripple.

It is well known to mariners that there is a great difference in the appearance and effects of waves in different seas. It has been frequently stated that the waves of the British seas are quick and violent, much more dreaded by sailors than the slow, spreading, heavy waves of the Bay of Biscay. The imagination can scarcely fancy a vast mass of water rolling up the Bell Rock lighthouse to the height of one hundred feet, yet this has been frequently known; and Mr. Macdonald, who was there during the gales of October, 1824, states, that the waves rose in an unbroken state to the height of sixty-four feet, and some to the height of ninety feet, and, being separated, they darted to the leeward of the house, leaving it at one end of an avenue of water.

TIDES.

The most constant and important motion of the sea is that which it periodically suffers in consequence of the attractive force of the sun and moon. The tides, as these oscillatory movements are called, have long been supposed to have some connexion with the position of the moon; for Pythias, Pliny, Ptolemy, and other ancient astronomers, confess their belief in this doctrine. Galileo, Descartes, Kepler, and others, also refer to the same cause, though their notions were exceedingly indefinite. "The orb of the attracting power possessed by the moon," says the illustrious Kepler, "is extended as far as the earth, and draws the water under the torrid zone, acting upon places where it is vertical, insensibly upon confined seas and bays, but sensibly on the ocean, whose beds are large, and where the waters have the liberty of reciprocation, that is, of rising and falling." But it was left for Newton, the greatest of all philosophers, to determine the nature of the lunar attraction, and the laws by which that force is governed. Great as the volume of water upon the surface of the earth is, it has a constant oscillation, ebbing and flowing alternately. In six hours it rises from its lowest to its highest level, and, after remaining stationary for a few minutes, descends in the same period of time to the level it had at low water. The total period that intervenes between the times when the sea at any place has the same level, is twelve hours and fifty minutes; but the time of high water is fifty minutes later every day than it was the day previous; which answers to the motion of the moon rising later on every day than on the preceding, and performing her revolution in about thirty days. The cause stated generally is the diminution of the gravity of the water.



Let *a b c d* be the earth, and *e* the moon. That part of the earth nearest to the body of the moon must necessarily feel most of its attractive force, for the power of gravity increases as the square of the distance decreases. The waters at *d*, that is, the side of the earth near the moon, will be more attracted than the central parts *a c*, and these more than the opposite side *b*. It must also be taken into consideration, that the force of attraction acts in right lines, and when it operates upon the edges of a body, as at *a* and *c*, it must depress rather than raise the fluid, for it draws it away as far as possible to the point nearest the attractive body. But at the same time the water will rise on the side of the earth distant from the moon,—the ocean, therefore, assumes a spheroidal form in both hemispheres, and there will be high tide at places situated opposite to each other. But the moon is not the only body that exerts an attractive force upon the ocean: the sun is also active, and, in fact, all the planetary bodies, for every particle of matter has an influence upon every other particle. The sun being greatly superior in size to the moon, it might be supposed that it would have the greater effect upon the waters of our planet; but, as its distance is incomparably greater than that of the moon, it has a much less effect. But still it is necessary to take its influence into consideration; and as the subject is one of the most interesting and important connected with the phenomena observed upon the ocean, it will be necessary to examine it with some degree of particularity.

It may not be very clear to a reader why the waters should rise on that side of the earth most distant from the moon, though he may perfectly understand why they are elevated on the side near to her. If it be borne in mind that the water is drawn towards the body by the difference of her attractive power at the surface and the centre, the whole matter will appear distinct. The ocean on that side the earth near to the moon is drawn towards it, because it is more attracted than the centre; and the ocean on the opposite side rises up, because the centre is more attracted than it, and the water acts as though it receded from the earth's centre, being less operated upon by the attractive force.

Without entering with any minuteness into a consideration of all the important questions connected with the origin and inequalities of tides, there are two subjects worthy attention; the origin of high and low, neap and spring, tides.

The moon crosses the meridian of any place on the earth's surface once in twenty-four hours fifty minutes, in consequence of the diurnal revolution of the earth. There must, therefore, be a high tide at every place once in twenty-four hours fifty minutes, that is to say, when the moon crosses its meridian. But the time of high tide does not coincide with the time when the moon is on the meridian of the place, and the cause of this is evident; for the water, having received motion, continues to rise after the moon has passed from its meridian; and although the moon's greatest power is afterward exerted upon other spots, yet it continues to attract the waters at this place, though in a smaller degree. But we have already seen that a high tide also happens at that place most distant from the moon, and therefore there are two high tides during one revolution; and it follows there must be two low tides, which happen when the place is removed ninety degrees from those relative aspects in which it suffered high tide.

In this explanation we have omitted to consider the influence of the sun; but although this body is at so much greater distance from the earth than the moon as to have a much less effect upon the ocean, yet it cannot be altogether unnoticed in a theory of the tides, for it acts in the same manner, though in a less degree. There are times when the sun and moon act together upon the ocean, and it is then that the waters rise the highest, and we have spring tides; there are other times when the moon acts in opposition to the sun, and there are then neap tides. If the moon moved in the plane of the equator, the highest tides would always be under the equator, and in the polar seas there would be no tide. But as the moon moves in a path inclined several degrees to the plane of the equator, various parts of the earth's surface must come successively under its influence. At the time of new and full moon, the two luminaries co-operate in raising the waters of the ocean, and spring tides are produced; when the moon is in her quadratures, the luminaries oppose each other, and neap tides are the result. On account of the counteracting forces produced by the difference in the motions of the two attracting bodies, there must necessarily be a great irregularity in the tides; and to determine the period and character of these requires the application of a precise analytical reasoning. But it may be mentioned, that to the existence of this opposition of forces we may trace the origin of the circumstance, that the highest tides are always within the tropics, and the lowest within the polar circles.

There are other irregularities in the tides besides those we have already mentioned, and we may especially notice the disturbance and obstruction of the water resulting from the obstacles offered by banks and projecting masses of land. The tides in bays, gulfs, or harbours, situated on the same shore, may be very different, though, if there were no such disturbing causes, they would be equal as to the circumstances of time and height. Local situation must, therefore, be considered in estimating the height and time of high tide. The tide of the German Ocean requires some hours to make its way up the narrow channel of the Thames to London Bridge. On some of the islands of the South Sea, the tide does not ordinarily rise more than two feet; at Annapolis, in the Bay of Fundy, it has an elevation of 120 feet; and at St. Maloes, in Bretagne, and at Bristol, there is a difference of fifty feet between high and low water. These facts will be sufficient to prove the influence of locality upon the tides; and we might have mentioned the effect of wind, increasing or restraining the rise, according to circumstances.

CURRENTS.

We must now advance to a consideration of the third kind of motion to which the sea is subject,—that produced by currents. These currents have been sometimes arranged in classes, according to the circumstances which regulate their motion, some being constant, some periodical, and others temporary; but it will not be necessary that we should confine our remarks in this general sketch to the classification here marked out. In relation to their cause, we must speak much less decidedly than we did in the description we gave of the tides; but we may imagine several agents to assist in their production. The difference of temperature or saltness occasioning a difference of specific gravity—the action of the air in violent motion—the periodical melting of the polar ice, or unequal evaporation, may occasion a current, or two or more of these causes may act together to effect the same result. It is extremely difficult, in the present state of our knowledge, to assign either one of these causes as the positive origin of a current; the state of our information on this subject is rather negative than positive; it is often possible to say what is not a cause, when the cause itself cannot be ascertained. We shall, however, only attempt to trace the direction of one of the most important, constant, and periodical currents affecting the ocean.

The Florida, or Gulf Stream, is one of the most singular phenomena in hydrography;—it is a perpetual current of water, rising in the Gulf of Mexico, and flowing in a curved line into the Northern Atlantic. The direction of this current is, in a great measure, to be attributed to the obstacles thrown into the way of the various and universal movements to which the water is periodically subject. This will appear evident if we trace the motion of the sea, and the direction it takes. It is proved, by the masses of ice and other substances floated from the polar regions towards the equator, that there is a general movement of the ocean in that direction; and, it will be remembered, that it was this current that caused the failure of Captain Parry's last attempt to approach the North Pole, the current driving his vessel more rapidly towards the south than he could advance to the north. It is quite possible that the action we have already described in reference to the atmosphere may be going on in all collections of water; and there may be an upper and an under current, a stream of cold water rushing to the equator, and streams of heated water towards the poles. But the water of the arctic regions is urged to the tropics, not only by its lower temperature, but also by its being less attracted by the heavenly bodies. Now, as this mass of water advances towards the equator, it comes under the influence of a greater centrifugal force; but, being unable at once to acquire the increasing motion of the earth, it is left behind, if we may so speak, by the earth, which is turning from west to east, and it has consequently the appearance of a general movement from east to west. But this effect is aided by two causes; the motion of the wind, and the tides. The tradewinds have, as we have already seen, a general westerly direction; and it has been observed by all navigators, that when the wind acts for any considerable time upon a body of water, it never fails to form a superficial current, moving in the same direction. But the tides also, where uninfluenced by the land, have the same direction; so that there are three causes acting in concert, all assisting to produce a westerly current. But this effect is modified by the conformation of coasts, and by the other obstacles thrown into its path by the channels in which it flows. By this general westerly movement, the waters of the Atlantic are thrown from the coasts of Europe and Africa towards the eastern coast of America. Without attempting to trace the course of the Gulf Stream here produced, or the geographical formation that alters its direction, it may be stated, that, entering the Gulf of Mexico, it passes along the Mexican coast to the southern extremity of Florida, where it changes its path, flowing northward with great impetuosity through the Gulf of Florida, and, after some variations of course, is brought to the southern extremity of Newfoundland. It then turns to the eastward, and, successively passes the Azores, the Straits of Gibraltar, Madeira, and the Canaries, completing its course by a union with the westerly tropical currents.

There are many other permanent currents of great importance to the navigator; and those that are periodical are not less worthy his attention, and might be properly referred to in a more practical work than this is intended to be. But the reader may obtain an idea of the great impediment or assistance these currents are to the navigator, from a statement made by Baron Humboldt—that the Gulf Stream, in the twenty-sixth and twenty-seventh degrees of latitude, moves with a velocity of eighty miles in twenty-four hours.

CHYMICAL COMPOSITION OF SUBSTANCES.

Having explained the most important appearances presented by land and water, we might now, in the order of our subject, direct the attention of the reader to an inquiry into the composition of the bodies which constitute the earth. But here we should start into a subject which it would be impossible for us to explain in the limits of a few pages. This work, however, must be left in a state of great incompleteness, if some attempt be not made to put the reader in possession of so much information, at least, as shall enable him to understand the composition of bodies, the elements of which they consist, and the laws which govern their union The sciences of chymistry and mineralogy are now both open before us; sciences which, during the last few years, have received perhaps greater additions than all others, and now imbody so vast a number of facts, that it is only by considerable and long-continued attention to these interesting branches of knowledge, that the student can become perfectly acquainted with them. But, at the same time, it may be remembered, as an encouragement to the study, that all the economical processes are regulated by their decisions, and there are few subjects so interesting in themselves, or leading to so useful results. But we can only refer to those general principles which may enable us to explain the constitution of the substances forming a part of the earth's body.

ELEMENTARY SUBSTANCES.

The simplicity of the means employed by the Creator to accomplish his objects is peculiarly evident in nature. The hypotheses of men are complex, and overloaded with machinery; the methods adopted by the God of Nature are simple and effective; and as science opens successively the pages upon which the history of material existence is written, we are surprised that an explanation so simple should not have been immediately discovered. The laws which govern matter are universal; and, when once understood, offer a ready explanation of a great variety of appearances, though certain minute differences may be observed, arising from either the nature of the substance upon which they act, or the circumstances under which the forces are developed. But this simplicity of design is equally evinced in the constitution of bodies. All the circumstances of motion and rest to which bodies are subject can be traced to gravitation and centrifugal force, and their composition is attributable to the forces of cohesion and chymical affinity,—the number of physical forms which bodies may take are few, being either solid, liquid, or gaseous, and their chymical composition is directed by laws not difficult of explanation.

Although a superficial examination of the various substances composing terrestrial bodies would lead to a suspicion that there must be an immense number of elementary principles, when the means offered by chymistry are employed, it is found that all, or nearly all, substances are compounds, and that their varieties of form, character, and properties, are to be traced to the admixture, in different proportions, of a few simple principles. According to the present state of chymistry, there are fifty-four elementary substances, or, in other words, substances which the chymist has not yet been able to decompose. Many of these possess properties in common, while others are perfectly opposed to each other in character and effect; there are some which readily unite with others, and are found abundantly in nature; there are others which can scarcely be made to enter into the same combinations, and are rarely found; some are essentially necessary for the maintenance of the present condition of material and animated nature, and others seem so unimportant that their annihilation would not, in the slightest degree, affect any of the present arrangements of nature. Forty-one of these simple substances are metals, and these constitute, in combination with each other and with other substances, the greater portion of matter as exhibited upon the surface of the earth. The following table gives the names of the elementary principles now known to chymists; and, without entering upon a description of all their properties, the means by which they were discovered, and the compounds they form, we shall state so many of their peculiarities as may enable the reader to understand the remarks to be after ward made upon the constitution of land and water:—

1. Oxygen
2. Chlorine
3. Bromine
4. Iodine
5. Fluorine
6. Hydrogen
7. Carbon
8. Nitrogen
9. Boron
10. Silicon
11. Phosphorus
12. Sulphur
13. Silenium
14. Arsenic
15. Antimony
16. Tellurium
17. Chromium
18. Uranium
19. Vanadium
20. Molybdænum
21. Tungsten
22. Titanium
23. Columbium
24. Potassium
25. Sodium
26. Lithium
27. Calcium
28. Magnesium
29. Strontium
30. Barium
31. Aluminium
32. Glucinium
33. Yttrium
34. Zirconium
35. Thorium
36. Iron
37. Manganese
38. Nickel
39. Cobalt
40. Cerium
41. Zinc
42. Cadmium
43. Lead
44. Tin
45. Bismuth
46. Copper
47. Mercury
48. Silver
49. Gold
50. Platinum
51. Palladium
52. Rhodium
53. Iridium
54. Osmium.

Oxygen is a gaseous substance, and exists in great abundance in nature, combining more or less readily with all substances; forming, according to the quantities in which it chymically combines, oxydes of those bodies and acids. It enters into the composition of both air and water, is the best supporter of combustion, and is essential to the existence of both animals and vegetables. As it unites with so many substances, it may be obtained from several sources, but it is usually procured from the peroxyde of manganese.

Chlorine is a gas, but it never occurs in this state in nature; but in combination with some metal or other substance, from which it may be abstracted by a chymical process. When it combines with sodium, of which metal soda is an oxyde, it forms the common seasalt, or chloride of sodium, and from this it may be abundantly collected. It has a yellowish green colour, an astringent taste, and is destructive to human life, producing a violent spasm of the glottis.

Bromine and iodine are both found in combination with other bodies, most frequently in seawater, and in small quantities. Iodine is the more important of the two, forms several compounds, and is useful in medicine and the arts.

Fluorine is a principle found to exist in the mineral called fluor spar. It has not yet been obtained in a perfectly pure state. The fluoric acid gas, into the composition of which the fluorine enters, is remarkable for its property of corroding glass.

Hydrogen, or, as it has been called, inflammable air, is one of the component parts of water. It is an exceedingly inflammable substance, and, when united with oxygen gas, explodes with great violence on the application of a flame, and produces water. It is an ingredient in many other compounds, and sustains an important place in the constitution of those which appear to be the most essential to animated beings.

Carbon or charcoal is another elementary principle, and enters into the composition of all vegetable and many animal substances, and is also found in the mineral kingdom. The diamond is a crystallized carbon. Carbon and oxygen combined produce carbonic acid, a substance formed in large quantities in the atmosphere. It unites with many other bodies, both the earths and the metals.

Nitrogen constitutes four fifths of atmospheric air, and is an ingredient of animal substances. This element is remarkable for its negative qualities; it is neither combustible, nor a supporter of combustion; neither acid nor alkaline. No animal can exist in it; not because it has any injurious effect upon the lungs, but solely from the absence of oxygen. Nitrogen, however, when it combines with other substances, forms compounds which are not distinguished by negative qualities, but are highly important in the arts and medicine.

Boron is a dark olive-coloured powder, and is the base of borax, a substance found in the East Indies, and in the lakes of Thibet and China. It has no taste, and is insoluble in water.

Silicon is the base of silica, or common flint, a substance very extensively distributed in nature, forming a great portion of quartz, granite, sandstone, and other rocks. It has a brown colour much resembling boron, and, like that substance, is highly inflammable. Silica is an oxyde of silicon, and is produced by its combustion, during which process the oxygen of the atmosphere unites with it.

Phosphorus is never found, in nature, uncombined; nor can it exist in this state, for it is exceedingly combustible, and (according to Dr. Higgins) burns at a temperature of 60° Fahrenheit, in atmospheric air. It combines with nearly all the metals, the earths, and the principles already described.

Sulphur is sometimes found in an uncombined state, and especially as the product of volcanoes. It is a very abundant principle, and, uniting with the metals, produces many compounds; it is also found in almost all animal and many vegetable products.

Silenium was discovered by Berzelius, but its quantity in nature is so small, that it is difficult to say what purpose it can have to accomplish. It is usually combined with sulphur. Silenium forms two acids with oxygen, and a deleterious gaseous compound, hydrosilenic acid, with hydrogen.

Having explained the characters of the non-metallic elementary principles, we must now proceed to a consideration of those which are metallic. Of these there are forty-one, and they are usually found in combination with other metals, acids, oxygen, or sulphur, from which they are separated by fusion or by the voltaic battery. They are differently classed by chymists, but the order in which they are mentioned is not a matter of much importance in our inquiry.

Arsenic sometimes occurs native, but it is usually in combination with cobalt or iron. The white arsenic of commerce is not the pure metal, but contains oxygen, and is the arsenious acid. This and the arsenic acid are known for their extremely poisonous qualities. Pure metallic arsenic has a bright bluish-white colour, a crystalline texture, and is very brittle. When cold, it has no smell; but its vapour has the odour of garlic, by which the metal may be always distinguished.

Antimony was discovered by Basil Valentine, in the fifteenth century, and is said to have received its name from the circumstance that several monks were killed by taking it as a medicine. It is sometimes found native, but more frequently as a sulphuret. The metal has a bluish-white colour, considerable brilliancy, and is very brittle. The oxydes of antimony are used in medicine.

Tellurium, chromium, uranium, vanadium, molybdænum, tungsten, titanium, and columbium, are not abundant in nature, and, excepting chromium, which is sometimes used in the preparation of colours, are useless in the arts; the mere mention of their names will therefore be sufficient.

Potassium is the base of that well-known alkaline substance potash, but is never found in its metallic state on account of its great affinity for oxygen. Potassium has a white colour and a lustre resembling that of polished silver.

Potash is an important ingredient in mineral, animal, and vegetable productions, and especially in the last.

Sodium greatly resembles potassium in its properties, though it is less fusible, and has not so strong an affinity for oxygen. Soda is an oxyde of sodium. Common salt, which occurs as a mineral, and is a principal ingredient in seawater and in many springs, is a chloride of sodium, though this substance is never quite pure; it is commonly united with small quantities of the sulphate of magnesia and lime, and the chloride of magnesium.

Lithium is the metallic base of lithia, a substance found in a mineral called petalite by M. Arfwedsen, and since found in spodumene, lepidolite, and other minerals. Lithium is a white-coloured metal, and has a great affinity for oxygen. We are indebted to Davy for the knowledge of lithium, potassium, and sodium, all of which were detected by the application of voltaic electricity to their several oxydes.

Calcium is the base of lime, and is a white metal of great brilliance. Lime is one of the most abundant principles in nature; many of the largest mineral masses are entirely composed of this earth. It also enters into the composition of animal bones, and is found in nearly all collections of water and in springs.

Magnesium resembles calcium in its properties, and is the base of magnesia. This metal has the colour of silver, and a metallic lustre. Magnesia occurs abundantly in nature, but it does not, like lime, constitute large masses; though blended with other compounds, it is frequently present in rocks, and is always found in animal bodies.

Strontium, the base of strontian, is a heavy metal, and not abundant in nature. Barium is a dark gray-coloured metal, that has a strong attraction for oxygen, and is the base of barytes.

Aluminium is a most important principle, and, although it is never found pure, it constitutes, when combined with oxygen, one of the most extensively distributed mineral substances. Aluminium is the base of alum, clay, and other mineral compounds, but does not seem to form any part of organized beings.

Glucinium, yttrium, zirconium, and thorium, are metallic principles discovered by the analysis of some rare minerals. They appear to exist in very small quantities, and it is therefore only necessary that their names should be mentioned

Iron is not only a valuable substance as connected with the arts, but it is so abundant in rocks, as to derive importance as a constituent of the earth's crust. It may also be detected in animals and vegetables, and frequently acts as a colouring matter. Iron has been rarely found in a native state, except in meteoric stones, which also contain nickel and cobalt It is frequently combined with oxygen and sulphur. Those minerals which contain iron in sufficient quantity, and in such a state as to admit the extraction of the metal for economical purposes, are called ores of iron.

Manganese is never found in a metallic state, for it has so great an affinity for oxygen, that it is oxydised by mere exposure to the air. It was first procured in a metallic form by Gahn, in the year 1775. Manganese is a bright metal, of a darkish-white colour, brittle, but hard. It combines with oxygen in five different proportions, and in these states is found in nature, but not in great abundance.

Nickel is a white, ductile, malleable metal. Its principal ore is a copper-coloured mineral, called kupfer, or copper nickel, which is an arseniuret. It is not abundant as a mineral, but is found in nearly all meteoric stones.

Cobalt is a grayish-coloured metal, brittle, and difficult of fusion. Both cobalt and nickel obey the magnetic force. The ores of cobalt are procured from Sweden, Saxony, and from some parts of England.

Cerium was discovered in the year 1804, but its properties are not known, and it has been obtained only in very small quantities.

Zinc is one of the most combustible of all the metals, has a bluish-white colour, laminated texture, and great fusibility. Calamine, a native carbonate, and blende, a native sulphuret, are its most important ores.

Cadmium is a soft, ductile metal, usually found in combination with zinc. It was discovered in an oxyde of zinc, in the year 1817, by Stromeyer

Lead is chiefly obtained from a mineral called galena, which consists of lead and sulphur. The ores of this well-known metal are very abundant, and the metal itself is extensively employed in the arts.

Tin was known to the ancients, and Cornwall has been long celebrated for its production. It chiefly occurs as an oxyde among the primitive rocks. Tin is a white, malleable metal, and is extensively used in the arts, and in the manufacture of metallic goods.

Bismuth is a reddish-white laminated metal, and is found native, as well as in combination with other substances.

Copper is one of the most abundant of the metals, and is chiefly obtained from the native sulphuret, though it is also found in its metallic state. It may be distinguished from all other metals, except titanium, by its red colour.

Mercury, or quicksilver, is the only metal that is fluid at common temperatures. It is found in various states, both native and in combination, chiefly with sulphur. Mercury freezes at thirty-nine degrees below zero of Fahrenheit's scale, and in Hudson's Bay it was not only solidified, but beaten into sheets as thin as writing-paper. The mercury of commerce is chiefly obtained from Spain and Peru.

Silver is found native, and in combination with sulphur and several of the metals. Although this metal has a great commercial value, yet, as an ingredient in the composition of the earth's crust, it is very unimportant. It has, however, many properties, such as malleability, ductility, and tenacity, which would make it valuable in the arts, if it could be obtained for such purposes.

Gold has always been found in a metallic state, either pure or in combination with some other metal. Gold is chiefly obtained from Africa and South America, but in so small quantities, that it must be considered as an unimportant mineral principle.

Platinum is the heaviest of all metals, has a brilliant white colour, and is very ductile. It is found in many parts of South America, and usually in grains. The largest mass ever found, now in the Royal Museum at Madrid, does not weigh more than a pound and three quarters.

Palladium, rhodium, iridium, and osmium, are also obtained in very small quantities, and together form so inconsiderable a portion of the earth's crust, that we need not take any farther notice of them.

This very general sketch of the character and properties of the elementary principles of which all things we behold, and the earth itself, so much of it at least as we are acquainted with, are composed, may assist in explaining the constitution of land and water. But, before any idea can be formed of the manner in which these principles can be so combined as to produce all the varieties of constitution which characterize land and water, it will be necessary to understand the formation of the elementary bodies themselves, and the laws by which their combinations with each other are produced. In the vast laboratory of the earth, these principles have been at various times so submitted to each other, as to produce the compounds which are now found in large masses, constituting rocks, and in smaller portions as mineral specimens. But all these compounds have been formed in obedience to the same general laws as now influence the union of particles and masses, and it is upon our knowledge of these laws that we must depend, for an explanation of the many difficulties that are felt in accounting for the present state of mineral and other compounds.

COHESION.

It was long supposed that matter might be divided without end, and in one sense this is true; but there can be no doubt that it consists of ultimate particles or molecules which are incapable of division or change. A knowledge of this fact is not obtained by the actual observation of the particles themselves, but is deduced from the circumstances under which the elementary principles and their compounds unite together. It is not necessary that the idea of size should be connected with our conception of ultimate particles; but, from our knowledge of the great divisibility of matter, it is certain that they are inconceivably minute, and are far beyond the limits of our senses. Whether we examine mineral, vegetable, or animal substances, we may find evidence of this fact. Animalcules have been discovered, by the aid of strong magnifying-glasses, so minute, that a million of them would not have a magnitude so great as a grain of sand; and no discovery is more calculated to convince us of the great divisibility of matter; for those creatures possess all the organs and members calculated to assist them in locomotion and in the supply of their wants, which are as real as those of larger animals. But, although they are minute, that on which they subsist must be smaller, and it is possible that animated beings, lower in the scale of existence than themselves, may be their prey, as they are the prey of larger animals. In this way we may trace matter in forms of such minuteness as to elude conception as well as sight.

But although matter may exist in this extremely minute form, and be divisible, there is a limit beyond which it cannot be divided; there are ultimate particles of matter. Every substance, therefore, consists of a number of ultimate particles, which are united together by some force, and that force is called cohesion. If there were not some power by which the molecules could be bound together, all matter must exist in loose unconnected parts, and none of the states of matter now observed could ever have been brought into being. But this cohesive force is not equally powerful in all circumstances; and it is for this reason that matter may exist as a solid, a liquid, or a gas. It is strongest in solids, though the particles of all solids are not combined by forces of the same intensity. There are substances, the molecules of which appear to have a large sphere of attraction, and hence they possess the property of elasticity. India-rubber, as a familiar example, may be drawn out to a great length, which must cause a separation of the particles to a much greater distance than they ordinarily assume; but, as soon as the force which separates them ceases to act, they are again drawn to each other, and appear to assume their original position. The same force may be applied to the metals, but extension cannot be produced; and, if the power be increased until it overcomes the cohesion, fracture is the result, not elasticity. From this simple experiment, then, we may learn that the force of cohesion varies in solid bodies, in some instances having so large a sphere as to admit of great expansibility, in others a smaller sphere but greater power, varying in both these characters according to the nature of the ultimate particles.

Solidity is an accidental circumstance, if we may so denominate a state that is governed by fixed and immutable laws. These laws, however, are not of such a nature as to prevent a solid from taking any other form; but we find, on the contrary, that, under different conditions, it may become a liquid or a vapour. In the production of these changes, heat is the primary agent; entering among the elementary particles of a substance, it becomes, in fact, a part of it; and if that substance be, in a solid state, a simple body, of which a doubt may be entertained, it is no longer so when it takes the liquid or vaporous condition, but is a compound of an element and caloric. The parts of a solid are supposed to have a fixed and permanent position, so that the movement of one particle gives motion to all; but fluidity is characterized, and in fact produced, by the unrestrained motion of the particles among each other. The cohesive force must therefore be stronger in solids than in liquids. Gases and vapours may be almost supposed to result from the destruction of the cohesive force; it is, however, so neutralized by the principle of heat, that the particles before united by a powerful attraction are now separated by a not less energetic repulsion.

Philosophers are undecided as to the origin of the properties of matter, such as hardness, tenacity, toughness, ductility, and others; and, in fact, some difficult questions must be decided before any show of certainty can be attached to the theories which have been proposed. There are four hypotheses that may be entertained. We may suppose the properties of any body to result from the varied intensity of the cohesive force; but then we are required to show the causes calculated to effect an alteration in its intensity, when operating upon elements and compounds, and by what process it can make one substance more ductile than another. If peculiarities of physical character be assigned to the matter itself, it will be necessary to prove that there is an essential difference in character between the matter of one substance and another, and that the properties by which they are distinguished are not attributable to the variety of circumstances in which matter may be placed. To attribute them to the form of the particles, is to invade the elements of all philosophical knowledge. The peculiar combination of particles is sometimes urged as a reason for the properties of matter, and the explanation is recommended to us by many arguments, and supported by a knowledge of facts. Viewed alone, it is an inefficient cause; but when it is acknowledged that the agents which act upon masses have a similar influence upon particles, nearly all difficulties vanish. These remarks lead us at once to consider the phenomenon of crystallization.

CRYSTALLIZATION.

Frequent mention has been made of crystallization, as a distinguishing property of rocks. Minerals may be formed in irregular shapeless masses, or they may, by the arrangement of their particles, take regular geometrical forms. The effects which are observed in nature may be produced at pleasure in the laboratory, and consequently the philosopher may estimate the causes which produced the one by a knowledge of those which accomplish the other. When a fluid gradually assumes the condition of a solid, the particles having free exercise among themselves, undisturbed by the motion of the mass, they usually crystallize. Substances do not take forms at random, sometimes assuming one kind of crystal and sometimes another, but have shapes peculiar to themselves. Fluor spar crystallizes in cubes, calcareous spar in rhombohedrons, and other substances have determined structures, so that there appears to be a close connexion between the character of a substance and the form of its crystals. This fact is of great value to the mineralogist and chymist. External characters in general are calculated to mislead, and can never be employed by those who have not been long in the habit of examining mineralogical specimens. Many substances may have the same colour, brilliance, degree of hardness, and other properties, so that these are not peculiarities, though they are, in a limited degree, points of distinction. But all these properties may be lost by a partial admixture with some casual ingredient, or by the circumstances under which the body possessing them was formed. The same remarks cannot with equal propriety be applied to crystallization. An observer may, without doubt, state what a substance is not, by the form of its crystals, though he may not be always able to state what it is, as many substances may take the same form. We may, however, depend with much more certainty upon crystallography than upon the circumstances of colour, hardness, and other properties, which are valuable secondary guides under the direction of the other more applicable principle.

Without entering farther into the discussion of this interesting branch of science, or referring to the discovery made by Professor Michterlich, that various substances have the property of assuming the same crystalline form, and may be substituted for each other in combination without affecting the external character of the compound, we shall at once proceed to mention the difficulties which attend the explanation of this phenomenon. Many opinions have been, and are, entertained as to the cause of crystallization. It was once a favourite theory that the ultimate particles of all matter have a spherical form, and that the structure of a crystal might be attributed to their arrangement and number, altogether independent of their nature. Professor Michterlich is of opinion, that isomorphous elements, that is, elements having the same form, produce crystals which are similar. Dr. Prout maintains that the molecules of bodies are spheroidal, and are influenced by two kinds of polarizing forces, one acting in the direction of the axis, and the other in that of the equator. As the electric and magnetic forces have this relation to each other, he supposes them to be analogous to, if not identically the same, as the crystallizing forces. This theory may be supported by sound and legitimate arguments.

CHYMICAL ATTRACTION.

If the particles of matter were acted upon by no other force than that of cohesion, all substances would be equally ready to combine with each other. But it is universally known that there are some substances, such as oil and water, which cannot be mixed together. It is, then, to be determined, why some compounds readily unite, and others refuse to combine. A force, called affinity or chymical attraction, altogether distinct from that of cohesion, does exist, and to this may be attributed the choice of substances with which to combine, evinced by all the elementary principles. A knowledge of the circumstances under which this force acts is essential to the chymist, for by it he regulates all his operations; and it is not less necessary to him who confines his attention to the operations of nature, for it explains all the varied forms he observes in mineral substances.

Affinity is a force which acts upon ultimate particles, causing different elements to unite and produce substances having properties more or less unlike those which distinguished the original principles. From this definition it might be imagined that the sphere of attraction is small, and, in fact, it only acts when the particles are in apparent contact, every cause that separates them having consequently a tendency to prevent the operation of chymical attraction.

Cohesion is a force which opposes and prevents the operation of affinity, and this it does by preventing the particles from having a contact with each other. Bodies seldom act chymically upon each other in a solid state, for their particles cannot be brought sufficiently near for the operation of that attraction which they may have. But, reduce them to a liquid form, that is to say, destroy the cohesion, and the affinity begins to act. Affinity will frequently operate when a liquid and a solid are brought into contact; but, to ensure the action, the cohesion should be decreased as much as possible. When both substances are liquefied, this is accomplished; for, however slight the chymical attraction may be between two particles, it will be sufficient to produce the combination; from which it may be supposed that the cohesion of particles is entirely destroyed when they are liquefied. Mechanical division and increase of temperature assist in producing a state more suited for combination, but cohesion exists still; and all these processes can do is, to diminish the energy of that force, and present a larger surface for the activity of chymical attraction.

From these statements, it might be supposed that elastic fluids would readily unite when placed in communication with each other, the cohesion being in this instance entirely destroyed; but, on the contrary, there are few gases that will do so, and this may be attributed to the great repulsive power which surrounds the particles of matter in this state, preventing them from coming within the sphere of chymical attraction. Elasticity may, however, and frequently does, act as a decomposing agent, and nothing is more common than the separation of two substances feebly combined, when the compound is compelled to take a gaseous form.

There are other circumstances which have a tendency to prevent the chymical force from operating upon the particles of matter; but, supposing these to be removed, there is an election or choice displayed by particles of one kind of matter for those of another, and, when united together, a third substance is formed, distinct in character and properties from either of its constituents.

The most simple instance of chymical affinity is where two substances mix together, as when sugar dissolves in water. There are substances which will thus unite, and there are others which cannot be combined; oil will not combine with water; for, however intimately they may be mixed, they will separate as soon as the mechanical force by which they were united ceases. Between these extremes, there may be a great variety of degree in the power of combination evinced by bodies, being in some instances extremely active, and in others as weak.

But affinity is sometimes exercised under a more complex orr. All kinds of matter are not attracted with the same force, but every particle exercises, as it were, a determined choice, always combining with one kind of matter in preference to another. Thus, for instance, a compound, whatever its elements may be, which we will suppose to be two, is the result of chymical attraction; but the affinity existing between the parts may not be so powerful as it would be if exercised between one of these and some third body. If, then, the compound be presented to this third substance, the process of decomposition and composition will be evinced at the same moment. The union of the two combined elements will be destroyed, and one of them will attract the third principle, producing a substance different from that of which it was before a part.

But still more complicated changes may be produced. Two compounds may be presented to each other of such a nature that one of the elements of each may have a greater affinity for an element of the other than it has for that with which it is combined. When this happens, a double decomposition and recomposition must necessarily be produced. Thus, if a solution of nitrate of potash be poured into a solution of sulphate of ammonia, this double decomposition is effected. The sulphuric acid leaves the ammonia and joins the potash, the nitric acid leaves the potash and unites with the ammonia, thus producing two new substances, the sulphate of potash, and the nitrate of ammonia.

The laws which govern the combination of bodies in small masses assist us in explaining the composition and origin of those substances which constitute the superficial covering of the earth. The chymist does but mimic in his laboratory the operations of nature; and the laws which govern the composition and decomposition of compounds in one case are equally applicable in the other. In our examination of these laws, we have been guided by a hope of explaining with the more precision the causes to which we may attribute the variety of forms, states, and composition possessed by matter as it exists in nature. If the surface of the earth has been constantly subject to changes effected by the agency of water and heat, it is evident that chymical action must have been often produced. In rocks universally acknowledged to have had an igneous origin, minerals, which are but the products of the terrestrial laboratory, are found; and they give evidence of the agents that produced them. They are characterized by the same peculiarities of crystallization as the compounds more artificially formed, and their elements have been united by the agency of the same chymical attraction. All natural products are decomposable into the few principles described in the previous pages; and although the forms and properties of their compounds are variable, they are not more so than might be anticipated from a knowledge of the almost unlimited interchange of combination.

When geological science was in its infancy, observers were accustomed to examine the mineralogical features of rocks with much more accuracy than is now considered necessary. The external characters of a rock are found to be of little assistance in determining its age, or, in other words, its relation to a series. This circumstance has tended to repress among geologists the study of mineralogy, and to give a new aspect to their pursuits. But, to say nothing of the necessity of the study in the examination of the more ancient masses, it may be doubted whether some acquaintance with their character and composition is not essential to a right explanation of the appearances by which they are distinguished. There are many persons who, from the habit of examining hand specimens, are generally able to distinguish not only rocks, but also the minerals of which they are composed. But although this knowledge is highly important, it is not all that is necessary; for, to conduct a mineralogical examination with a chance of success, the chymical characters and composition of the constituents must be understood; and without this information, not even a conjecture can be formed as to the circumstances under which many of the masses were produced.

COMPOSITION OF WATER.

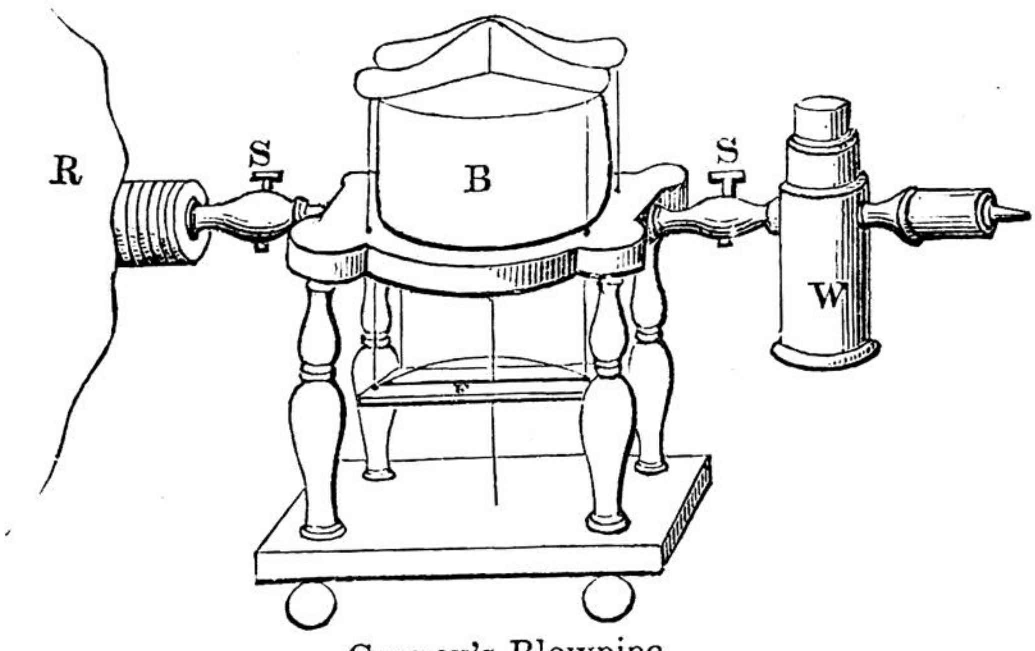
Water is a compound substance, consisting of the two elements hydrogen and oxygen. Its most simple state, if we may so call it, is that of ice. When we say that ice is the most simple state of this substance, we mean that it is then free from the caloric of composition which unites with it when in a liquid or vaporous condition. A mass of ice at 32° Fahrenheit must absorb 140° of caloric or heat, that is, 140° inappreciable by the thermometer and the sensation of touch, before it can be liquefied.

It may be proved, in the following manner, that 140° of caloric is necessary to liquefy ice. Take any quantity of ice at 32°, and pour upon it an equal quantity of water at 172°, the ice will be liquefied, but the water will still be at a temperature of 32°. From this experiment it is evident that 140° of heat have disappeared, for the water has been reduced to the temperature of the ice, which has suffered no other change than liquefaction. There is only one way of explaining the result that it is here observed, and it is by allowing that 140° of heat must be combined with the elementary principles of water, before their cohesion can be so destroyed as to admit their assuming a liquid form.

Water consists of eight parts by weight of oxygen, and one of hydrogen; and by measure, of two parts of hydrogen, and one of oxygen. The compound nature of water may be proved by both analysis and synthesis. The simplest possible means of decomposition is to pass aqueous vapour over red-hot iron in a tube; but the most satisfactory is that effected by the voltaic battery. If two thin wires connected with the poles of a voltaic battery be so placed that one end of each shall enter a glass vessel, a tube being placed immediately over the point of each wire, a portion of water will be decomposed, and the gaseous products will be collected in the tubes. The wire connected with the positive pole of the battery gives out oxygen; that with the negative, hydrogen. For this experiment we are indebted to Messrs. Nicholson and Carlisle, and by it we ascertain the proportions by volume in which the two gases unite to produce water. But we need not satisfy ourselves with this analytical examination; for, if the products of the decomposition be collected in the same tube, and inflamed, they will reassume the liquid state producing water. But, if we take an additional measure of hydrogen, that is, three of hydrogen and one of oxygen, and explode them, one measure of that gas will remain uncombined.

Oxygen and hydrogen, mixed in the proportion to form water by combustion, have been employed by Mr. Gurney for the production of intense heat. It is a singular fact, that these gases, thus united, are so explosive, that it is unsafe to experiment with them except in very small quantities, or with especial provisions calculated to prevent their explosion. Mr Gurney succeeded in obtaining such means, and invented his oxy-hydrogen blowpipe, which is now employed for the purposes of microscopic exhibition.

The following diagram is a representation of Gurney's blowpipe. R is a bladder containing oxygen and hydrogen, mixed in the proportion necessary for the production of water. S is a stop-cock, which opens or closes the communication between the bladder and the reservoir (B), which is a smaller bladder adopted for the purpose of preventing accident, should the gases explode. F is a board beneath the bladder, connected with that which lies upon it by wires. When the instrument is to be used, a weight, or the hand, is applied to this, for the purpose of driving the gases through the tube (S), and from thence to the jet. W is a safety apparatus,



Gurney's Blowpipe.

which may be made in several ways, to prevent the flame of the ignited gas from passing into the bladder B. When the gases are ignited, and the flame is thrown upon lime, a light of the greatest intensity is produced. The product of the combustion is water.

Water is never found perfectly pure. Rain water, and snow when melted, afford the purest kind of water that can be obtained without distillation, although this is not, on account of the great solvent powers of the fluid, quite free from admixture with other bodies, but contains carbonic acid and air collected from the atmosphere. In passing through strata it is liable to great alterations of character, by its combination with minerals; and although it does not always happen to such an extent as to prevent its use in nature, and by man, yet it always acts in some degree. Now, according to the nature of the rocks through which the water percolates, will be the alteration effected in the character of the water; and all mineral springs might be easily accounted for, did we know the composition of the beds through which the waters pass.

But we can only refer to the composition of seawater, and this we must do without entering into those minute analyses which have recently received so much of the attention of chymists. That which in the estimation of ancient philosophers was a pure elementary substance, is not only found to be in itself a compound, but to contain singular combinations of compound substances. There is, perhaps, no substance in nature that has a more complicated composition than sea-water; and, if we consider the extent of the ocean, and the great solvent power of the fluid, we might expect to find in it an immense number of adventitious substances; but of all these, the most abundant is common salt. It was once maintained by chymists, that the water taken from different parts of the ocean did not materially differ in composition; but the experiments which have been made during the last few years prove that it differs not only in relation to place, but is also conditionally dependant on the depth. Bouillon, Lagrange, and Vogel, severally examined the waters of the English channel, the Bay of Biscay, and the Mediterranean Sea, and found them to contain 3.47 per cent. of saline matter. Dr. Murray estimates the saline matter of the waters of the Frith of Forth at 3.03 per cent. Dr. Fyfe examined the waters collected in the North Seas by Mr. Scoresby during his voyage, and by Captain Ross in his Polar expedition, and the results lead to the general conclusion, that the waters of the ocean, from 61° 52′ to 78° 35′ north latitude, do not essentially differ in the amount of saline matter, the maximum being 3.91 per cent., the minimum 3.27. The experiments made by Pages, on the water collected by him in southern latitudes, induce the supposition that the saline matter is least abundant in the waters of the northern hemisphere. But the most important series of experiments made upon sea-water with the view of determining the amount of saline matter contained in it, is that performed by the late Dr. Marcet, from which the following conclusions have been deduced:—

1. The proportion of saline matter contained in the water of the southern ocean is to that in the northern as 1.02919 is to 1.02757.

2. There is no great difference in the proportions under different meridians, but the sea under the equator appears to range between the two hemispheres.

3. The waters drawn from a great depth do not generally contain a larger quantity of saline matter than those taken from the surface.

4. Inland seas are always much less salt than the ocean, and so are those bodies of water situated near to large masses of ice. Inland seas do not contain so large a quantity of salt as the ocean, on account of the large volumes of fresh water brought into them by rivers. But the waters of the Mediterranean contain a larger proportion of salt than the ocean, although the same cause might be supposed to act in producing the same result in this as in other cases. It has been, since the discovery of this fact, an object with philosophers to account for it, but now the chief difficulty is to explain the reason why the waters of this sea do not gradually become salter. Although so large a quantity of water is carried into it by the numerous rivers of which it is the basin, yet its amount is not sufficient to compensate for the evaporation which is going on at its surface, but it is supplied, for the maintenance of a general level, by a constant current flowing eastward through the Straits of Gibraltar. Now all these circumstances would apparently tend to increase the saltness of the Mediterranean Sea, and ultimately convert it into a saturated brine. The cause which prevents this is said to be an under-current which flows out of the sea through the Straits of Gibraltar, and discharges the constantly accumulating saline matters. There are many facts which strongly support this opinion. Dr. Macmichael states, upon the authority of the British Consul at Valencia, that some years ago a vessel was lost at Ceuta, on the African coast, and its wreck was afterward thrown up at Tariffa, on the European shore. But the most remarkable fact is that recorded by Dr. Hudson, in the "Philosophical Transactions." In 1712, M. de L'Aigle, of the Phenix, came up with a Dutch ship in the middle of the Gut, between Tariffa and Tangier, and with one broadside sank her. A few days after this, the ship rose again off the shore near Tangier, at least four leagues to

the west of the place where she sank, and it must therefore have floated in a direction contrary to that of the superficial current.

The presence of saline matter in the ocean is of considerable importance in the general economy of nature. Among the most singular effects of this arrangement, we may mention that the freezing point of water is lowered, and the tendency to evaporation diminished, while at the same time it is better suited to sustain all the provisions of animal life. We frequently trace effects to their causes, without perceiving the immediate results intended by the Creator; but it is well to remember that the ultimate object being determined upon in the Eternal Mind, the causes were so arranged as to produce effects calculated to fulfil them.

CHAPTER X.

SUPERFICIAL TEMPERATURE OF THE EARTH.

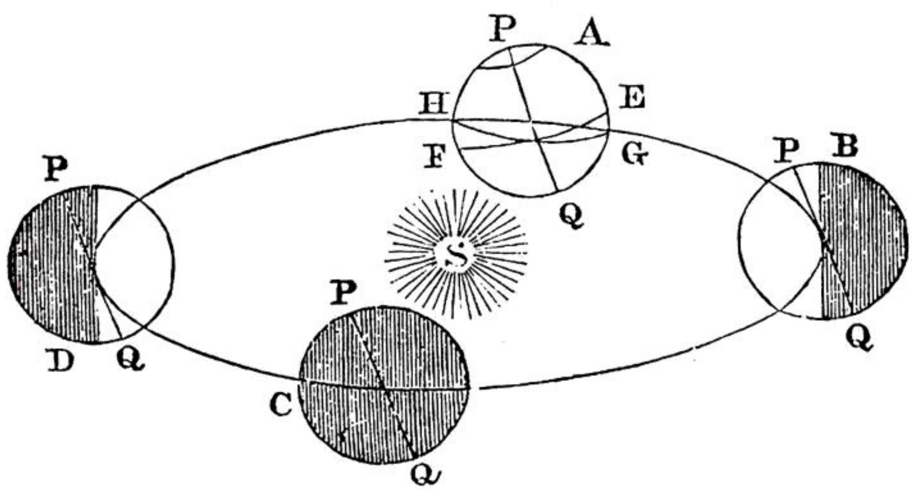
In tracing the circumstances that give rise to the superficial temperature of the earth, it is necessary to keep in mind the difference between that which results from celestial, and that which depends upon geographical position. The general superficial temperature is regulated by the position of the earth in relation to the solar system, and especially to the sun; and it is universally known, that the most intense heat is suffered in places under and near the equator, and the greatest cold at or near the poles; the places situated between these having a medium approaching nearer to the one or the other of the extremes, according to their geographical position. But the causes which modify the superficial temperature are so numerous, that it is not possible to ascertain the temperature of any locality without positive experiment. Every place, however, is distinguished by a certain mean temperature; and although seasons may vary, and there may appear to be an entire change in all the circumstances which have distinguished a country from year to year for ages, yet the mean temperature remains fixed and unchangeable.

There are three subjects which demand attention in this part of our work;—the seasons, climate, and the variations to which the superficial temperature has been subject

THE SEASONS.

There is no part of the earth's surface on which the temperature is precisely the same at all periods of the year; there are everywhere recurring variations called seasons. To understand the origin of the seasons, it must be remembered, that the earth performs a revolution round the sun, and the period which is occupied in fulfilling that revolution is called a year. During this period, a place on the surface of the earth is exposed to an exceedingly variable temperature, which causes the four distinct seasons; spring, summer, autumn, and winter. In performing this annual revolution, the axis of the earth preserves the same direction as though it had no orbitual motion, and is carried round always presenting the poles to the same points of the celestial sphere. In attempting to explain the origin of the seasons, we shall speak of the orbit of the earth as though it were circular; for although it is really elliptical, its form has little to do with the production of the effects to which we refer.

Let S represent the sun, and A B C D four several positions of the earth in her orbit. A may be considered the vernal equinox, or the position of the earth on the 21st of March; B the summer solstice, or its position on the 21st of June; C the autumnal equinox, or its situation on the



21st of September; D the winter solstice, or its position on the 21st of December. P Q represents the direction of the axis, which is not changed: this is an imaginary line around which the earth revolves, producing day and night.

Now it is evident that the sun can diffuse its calorific rays over only that half of the globe turned to it; and the temperature of any place will be in proportion to the time during which it is thus exposed. Upon this self-evident principle we must found our explanation of the seasons.

When the earth is in the vernal equinox (A), the sun is vertical to the intersection of the equinoctial (F E), and the ecliptic (H G). In this position, therefore, the two poles will be the confines of the enlightened side, and the day and night will be equal all over the globe, for half the northern and half the southern hemisphere will be illuminated at the same moment. When the earth is situated in the autumnal equinox (C), the same effect is produced.

But we may suppose the earth to remove from the vernal equinox (A) to the summer solstice of the northern hemisphere (B). In this position, the space included within the arctic circle, which is a circle having the north pole for its centre, and 23° 38′ as a radius, is constantly enlightened, and it has consequently a perpetual day, while to the same distance round the south pole there must be constant night. Hence it follows, that at every place north of the equator the sun will be, at this time, longer above than below the horizon, and the length of time will be in proportion to the nearness of the place to the poles; the reverse is true of all places to the south of the equator.

When the earth comes to the winter solstice of the northern hemisphere (D), the south pole enjoys the constant day, and the north an unbroken night.

These are the facts deduced from a knowledge of the relative condition and motion of the earth as a member of the solar system; but it yet remains to be proved how these changes affect the temperature of places, causing all those variations called the seasons. The temperature of any place upon the earth's surface is chiefly governed by its exposure to the solar rays; the longer the sun is above the horizon of any place, the greater must be the amount of heat it receives, and the higher must its temperature be raised; so, also, the longer it is beneath the horizon, the greater must be the amount of heat it radiates. The equilibrium of temperature in any place is, therefore, supported by receiving and parting with the same amount of heat during a year. When any place is more than twelve hours above the horizon, the temperature will increase; when less, it will decrease. Now, as the days lengthen in the northern hemisphere, when the earth is moving from A to B, the temperature increases; in one position there is spring, in the other summer. From B to C the days approach equality, and from D to C they decrease; so that when the earth has the position represented at D, the northern hemisphere is under the sharp government of hoary winter. From this description it will be perceived, that the effects produced as the consequents of the annual revolution are precisely analogous to those which result from the diurnal. If the temperature of any place be taken every hour during one day, at no two of the twenty-four will it be equal; and so, if this be done for an entire year, and the mean amount of each day be compared with that of every other day, it is not to be expected that any two will perfectly agree, but the temperature will be in proportion to the period of solar influence, modified by local and other disturbing causes.

MEAN TEMPERATURE.

These are the causes which regulate the seasons, and their influence is felt over the entire surface of the earth, though the length of the seasons, and the difference of temperature between them, may greatly vary in different places. But this is not the only thing to be considered in estimating the superficial temperature of the earth; the amount of heat received by different places varies according to their positions in relation to the equatorial regions, and consequently their temperatures cannot be equal. As a general law, it may be stated, that the mean temperature decreases from the equator to the poles, and from the level of the sea upward; both these circumstances, however, are to be considered in relation to a variety of accidental conditions, which frequently have a great influence upon their results.

The term, mean temperature, so fully expresses the meaning usually applied to it, that there seems little necessity for a definition. Nothing could be more rash than to pretend to determine the temperature of a locality by a single observation of the thermometer, and it would be still more absurd to attempt a comparison, upon such a result, with that of any other place. If we would determine the temperature of any day, and compare it with that of some other day, it would not be sufficient to have a record of the thermometer for some one period in each, but a series of observations would be taken, one every hour, for instance, and the sum of these, divided by the number of experiments, would give the mean temperature. So, in taking the annual mean temperature of a place, it will be necessary to make a number of observations, and the sum of these, divided by the number of experiments, will give the element required. The more frequently and regularly these observations are made, the more accurate will be the result; and we may be forgiven the wish, if it should appear enthusiastic or absurd, that the temperature could be constantly registered once in every six hours for a few years, throughout all the possessions of the British empire, and the difficulties which now surround this interesting branch of meteorology would soon disappear.

To a casual observer, climate appears to be the most irregular of all natural appearances; and to such a person it must seem almost impossible to reduce the phenomena into such a shape as to bear the semblance of a law. Those who have merely noted the atmospheric phenomena from day to day, or from month to month, may be able to inform us how much hotter or colder a particular day, month, or season, has been this year than it was at some one which is past; but they will probably fall into the error of supposing that the climate itself has changed, should it happen that the summer has for a consecutive period been hotter than usual, or the winter colder. But if, instead of dealing in these generalities, the measurement of the temperature be taken at fixed periods throughout the year, and the sum reduced to a mean, little difference will be found in successive years. The mean temperature of London is 50 4-10, and it seldom or ever deviates much from this, even when there is an extreme degree of heat or cold at a particular season. In 1808, the summer was so hot that the thermometer stood in London at $93\frac{1}{2}^{\circ}$, but the mean temperature of the year was $50\frac{1}{2}^{\circ}$; and notwithstanding the severe winter of 1813-14, when all the large rivers of England were frozen over, the mean temperature of the years was 50 1-10.

For the present state of our knowledge upon the subject of superficial temperature, we are chiefly indebted to Baron

Humboldt, who, uniting a profound and universal acquaintance with the physical and natural sciences, with an elevated genius and quickness of perception, has—assisted by the patronage and encouraged by the honours which his sovereign and countrymen have so readily granted—done more for the science of meteorology, and, we might add, every branch of natural history, than any other modern philosopher. But while we rejoice in the honour and success of this great man, we mourn over the neglect under which many not less gifted or aspiring minds are compelled to stifle their energies, or support a cruel oppression. The estimate which men form of the talents and capabilities of their fellow-men is not founded upon their intelligence, and the honesty and sagacity with which they pursue their object, but upon their success. Publicity is a painful condition to a man of a fearful temperament; it is only suited to the mind that can bear with the same composure the honours that are lavished upon success, and the scorn, contempt, and bitter contumely, that more certainly follow a failure. The sun itself may be eclipsed, or its radiance may be intercepted by the cloud that breeds a tempest, which desolates and lays low the noblest tree of the forest,—but the cloud is soon dissipated, and the source of light, heat, and life, pours down upon the scene of its wonted energy the fulness of its glory, dries every leaf, and gives new power to the drooping vegetation; so genius is often shadowed by the thick though fleeting atmosphere of envenomed jealousy and spite, which for a time may obscure its rays, and induce many to ask, Where is now its glory? but when the cloud is overpast, and the friends who forsake in misfortune feel again its influence and tell of its praises, as the birds sing when the sun shines, then it seeks not to destroy by the power of its ability, but to instruct and bless. A great mind is not the slave of public opinion; it appreciates the honour or the blame as it may be deserved, and if fortune frowns upon exertion, and failure attends its progress, it waits in patience for that moment when its energies may be advantageously displayed, or, if necessary, bequeaths its attempts to posterity. It cannot, however, be denied, that those who attain honours in the present day have usually a claim to them; and none of those who have attempted to climb the steep pass that leads to fame, will be unwilling to allow, that of all those who have in our own day obtained the summit and the honours as the recompense of scientific exertion, none have better deserved them than Baron Humboldt.

This eminent philosopher was led to investigate the laws of surface temperature in consequence of the phenomena which he observed during his residence on the elevated plains of South America. "Having inhabited," he says, "for a long time, the most elevated plains of the new continent, I availed myself of the advantages which they present for examining the temperature of the superincumbent strata of air, not from insulated data, the results of a few excursions to the crater of a volcano, but from the collection of a great number of observations made day after day, and month after month, in inhabited districts. In Europe, and in all the old world, the highest points of which the mean temperatures have been determined, are the convent of Peissenberg, in Bavaria, and the hospice of St. Gothard. The first of these is placed at 3264, and the second at 6808 feet above the level of the sea. In America a great number of good observations have been made at Santa Fé de Bogota, and at Quito, at altitudes of 8727 and 9544 feet. The town of Huancavelica, containing 10,000 inhabitants, and possessing all the resources of modern civilization, is situated in the Cordilleras of the southern hemisphere, at 12,310 feet of absolute elevation; and the mine of Santa Barbara, encircled with fine edifices, and placed a league to the south of Huancavelica, is a place fit for making regular observations at the height of 14,509 feet, which is double that of the hospice of St. Gothard."

The surface of the earth was once considered, in relation to its temperature, as though divided into five portions or zones,—one torrid, two frigid, and two temperate; but these are now never referred to in scientific inquiries, being superseded by a more precise arrangement. Places having the same mean temperature, have been connected by lines which are called isothermal, and by this arrangement all the places on the globe, having the same annual mean temperature, are classed together. These lines are not parallel with the equator, and their direction is by no means regular. The space included between two isothermal lines is called an isothermal zone; but it must not be supposed that two places situated upon the same line, that is, having the same mean temperature, must have necessarily the same degree of heat or cold; there may be a great difference in the intensity, and also in the duration, of seasons. Pekin, for instance, has the same mean temperature as Brittany, but its summers are much hotter, and its winters much colder.

Humboldt has divided the northern hemisphere into the six following zones:—

1.	The zone of mean temperature including all places between	32° and 41°
2.	"	41° and 50°
3.	"	50° and 59°
4.	"	59° and 68°
5.	"	68° and 77°
6.	from	77° upward.

It has been long supposed that the temperature of the southern hemisphere is not equal to that of the northern. Buffon controverted the opinion, but Œpinus defended it, and every observation that has been made tends to prove its accuracy. The small quantity of land in the southern hemisphere causes a much greater equalisation of the seasons than in the northern, while at the same time it produces a decrease of annual mean temperature. "The discoveries of Cook," says Humboldt, "made known the vast extent of ice round the south pole, but the inequalities in the temperature of the two hemispheres were then exaggerated. Le Gentil, and particularly Kirwan, have the merit of having first demonstrated that the influence of the circumpolar ice extends much less into the temperate zone than was generally admitted. The less distance of the sun from the winter solstice, and his long continuance in the northern signs, act in an opposite manner on the heat in the two hemispheres; and as the quantity of light which a planet receives from the sun increases in proportion to the true anomaly, the inequality in the temperature of the two hemispheres is not the effect of unequal radiation. The southern hemisphere receives the same quantity of light, but the accumulation of heat in it is less, on account of the emission of the radiant heat which takes place during a long winter. The hemisphere being also in a great measure covered with water, the pyramidal extremities of the continents have there an irregular climate. Summers of very low temperature are succeeded, as far as 50° of south latitude, by winters far from rigorous

The vegetable forms also of the torrid zone, the arborescent ferns, and the orchideous parasites, advance towards 38° and 42° of south latitude. The small quantity of land in the southern hemisphere, contributes not only to equalise the seasons, but also to diminish absolutely the annual temperature of that part of the globe. The cause is, I think, much more active than the small eccentricity of the earth's orbit. The continents, during summer, radiate more heat than the seas; and the ascending current, which carries the air of the equinoctial and temperate zones towards the circumpolar regions, acts less in the southern than in the northern hemisphere. That cap of ice which surrounds the pole to the 71° and 68° of south latitude, advances more towards the equator whenever it meets a free sea, that is, whenever the pyramidal extremities of the great continents are not opposite to it. There is reason to believe, that this want of dry land would produce an effect still more sensible, if the division of the continents were as unequal in the equinoctial as in the temperate zones."

TEMPERATURE OF THE SEA.

Upon this subject we must also refer to Humboldt, the almost only authority we have upon the question of surface temperature. "The sea," he says, "radiates less absolute heat than continents; the air resting upon it is cooled by the process of evaporation, and the surface is heated or cooled by the currents directed from the equator to the poles, or by the mixture of the superior and inferior strata on the sides of banks. It is from these causes combined, that, between the tropics, and perhaps as far as 30° of latitude, the mean temperatures of the air resting upon the sea, are 3° 6′ or 5° 4′ lower than that of the continental air. Under high latitudes, and in climates where the atmosphere is coolest in winter, much below the freezing point, the isothermal lines rise again towards the poles, or become convex when the continents pass below the seas."

With respect to the temperature of the ocean, we must distinguish between four very different phenomena. 1st The temperature of the water at the surface corresponding to different latitudes, the ocean being considered at rest, and destitute of shallows and currents. 2d. The decrease of heat in the superimposed strata of water. 3d. The effect of billows on the temperature of the surface water. 4th The temperature of currents which impel with an acquired velocity the waters of one zone across the immoveable waters of another zone. The region of water having the highest temperature no more coincides with the equator, than the region in which the waters reach their maximum of saltness. In passing from one hemisphere to another, we find the warmest waters between 5° 45′ of north latitude, and 6° 15′ of south latitude. Perrius found their temperature to be 82° 3′; Quevedo, 83° 5′; Cherruca, 83° 7′, and Rodman, 83° 8′. I have found them in the South Sea, to the east of the Galapagos Isles, 84° 7′. The variations and the mean results do not extend beyond 1° 3′. It is very remarkable that in the parallel of warmest waters, the temperature of the surface of the sea is from 3° 6′ to 5° 4′ higher than that of the superincumbent air. Does this difference arise from the motion of the cooled particles towards the bottom, or the absorption of light, which is not sufficiently compensated by the free emission of the radiant caloric? As we advance from the equator to the torrid zone, the influence of the seasons on the temperature of the surface of the sea becomes very sensible; but as a great mass of water follows very slowly the changes in the temperature of the air, the means of the months do not correspond at the same epochs in the ocean and in the air. Besides, the extent of the variations is less in the water than in the atmosphere, because the increase or decrease in the heat of the sea takes place in a medium of variable temperature, so that the minimum and maximum of the heat which the water reaches are modified by the atmospherical temperature of the months which follow the coldest of the warmest months of the year. It is from an analogous cause, that in springs which have a variable temperature, for example, near Upsal, the extent of the variations of temperature is only 19° 8′, while the extent of the variation in air from the month of January to August, is 39° 6′. In the parallel of the Canary Islands, Baron Von Buch found the minimum of the temperature of the water to be 68°, and the maximum 74° 8′. The temperature of the air in the warmest of the coldest months, is, in that quarter, from 64° 4′ to 75° 2′. In advancing towards the north, we find still greater differences of winter temperature between the surface of the sea and the superincumbent air. The cooled particles of water descend till their temperature reaches 39° 2′. The excess in the mean temperature of the water over that of the air attains its maximum beyond the polar circle, where the sea does not wholly freeze.

CLIMATE.

Although a number of places may have the same annual mean temperature, yet they have not necessarily the same climate. There are certain primary constituents of climate which influence every part of the earth's surface, but these are often so modified as to produce effects altogether different from those which might be anticipated. Temperature is in every case the most important constituent of climate, and this results from the form and celestial relations of the earth, such as its globular figure, the obliquity of its motion in an elliptical orbit, in regard to the plane of its equator, and its diurnal motion upon its axis. All these have a primary influence upon the production of climate; but no acquaintance, however accurate, with the circumstances resulting from these, could ever enable the philosopher to calculate the character of the climate at any place. There are many accidental causes which modify their results, and these are called the secondary constituents of climate. Such are the position of the place, its distance from the sea, its proximity to mountains, its elevation above the level of the ocean, the nature of its soil, the cultivation of the lands in its vicinity, and the direction of the winds to which it is exposed. These, and many other local phenomena, may so affect the results which would be otherwise produced by solar heat, as to prevent any hope of ascertaining a climate without experiment.

The distribution of animals and vegetables is governed by climate. The lines which mark the boundaries of temperature and peculiarities of season, are also the limits of species or genera. It is on this account that different countries contain animals and vegetables different from those which are found in neighbouring districts. This is especially marked in relation to vegetables. The plants of the tropics are rich, luxuriant, and various; interminable forests are everywhere presented to the eye of the traveller, bound closely together by the wide and gigantic arms of towering shrubs. In the arctic regions, the circle of vegetation is small and feeble: but the modest floweret that raises its head above the northern snows to blossom on the waste, has a constitution equally adapted to the circumstances in which it is placed, as the full-leaved branching trees and shrubs of the equatorial region. But the great principle of adaptation which so remarkably distinguishes all the works of the Creator, may be traced much farther than this. If all vegetable productions had been suited to one and the same temperature, but one zone of the earth's surface could have been covered with vegetation, and only that one would have been suited to maintain animal life, which is commonly supported by the productions of earth. Every zone, however, has its own vegetation, and this is invariably suited to supply the wants of those animals which are its inhabitants.

TEMPERATURE OF THE ANCIENT EARTH.

If it be true that animals and vegetables are confined to certain localities distinguished by temperature, any great change of climate should be followed by a change in the animal and vegetable products. Now it is supposed by geologists, that some such change as this has happened at several periods in the physical history of the earth. The organic remains found in the rocks of northern countries, are supposed to belong to a temperature much higher than that by which they are distinguished at the present moment. Thus, in our own climate, we find the remains of animals analogous to those which exist in tropical climes, and of plants which can only be nurtured in the hottest portions of the earth; such are those belonging to the coal measures. Now, it has been deduced from these facts, that the climate of the places in which they are imbedded must have changed, supposing that these products lived on the spots where their remains are now entombed. There are some writers, however, who object to this assumption, and imagine that they have been floated from a distant clime, and deny that the temperature of the earth has changed. Without entering upon this matter of dispute, to which reference has been already made, we may be permitted to state that too much dependance is sometimes placed upon the existence of organic remains in rocks. It is generally stated, that the fossils found in any bed give evidence as to the nature of the animals then existing upon the surface, and consequently the temperature of the place at the time. In a limited sense it may be true, but this evidence must be always received with caution, for it may mislead, in consequence of the circumstances that interfere with the results. Let us take one example. Deposites are now forming in the beds of rivers and oceans; but can it be for a moment supposed, that when they are exposed to the examination of geologists at some future age, the fossils will enable him to ascertain the temperature of the place at the time of deposition? Certainly not. Rivers bring down in their courses not only the detritus of older rocks, but also their fossils, and animal and vegetable remains from various climes; all these are mingled together in the bed that is forming, and will at some future time be its fossils, and geologists may find in them the products of many climes and many ages. We do not, however, deny the value of organic remains, as affording a means of ascertaining some facts in relation to the past history of the earth; but we may sometimes misapply their evidence, or imagine them to give more information than they are calculated to afford.

CONCLUSION.

If the explanation that has been given of the phenomena which are observed on the surface of the earth should in any degree accomplish the intention of the author, it will induce the reader to acquaint himself with the physical sciences. It must not, however, be supposed, that a knowledge of philosophical facts is all that we wish to inculcate. Knowledge, of whatever kind it may be, is only valuable as it adds to the enjoyments of life, increases the happiness of society, and gives new energy to the intellectual character of man. There would be as much wisdom in learning a language for the sake of knowing by what articulate sounds a community of men express to each other the ideas they individually entertain, as in acquiring the sciences for the purpose of knowing what has been ascertained. If wisdom consists in the knowledge of ourselves and our Maker, we must study nature with the hope of ascertaining some principles which shall enable us to gather fresh conceptions of these important elements of knowledge. God has, in not illegible characters, written his attributes on his works; and he has at the same time taught man his dependance upon his power, his wisdom, and good-ness. But at the same time we cannot withhold the statement, that however closely we may study the works of creation, we can never know what relation men bear to their Creator, or feel an entire confidence in the provisions he has made for their happiness, until we combine a knowledge of the ordinances that govern terrestrial beings, with the infinitely greater moral principles he has revealed.

INDEX.

THE END.