SCENE ON THE MOUNTAIN TOPS.

Baxter's OIL COLOUR *Printing*, — 3, *Charter-house Square.*

(From Original Paintings by W. Fowler.)

THE AIR.

BY

ROBERT MUDIE,

AUTHOR OF "THE HEAVENS," "THE EARTH,"
"NATURAL HISTORY OF BIRDS,"
&c. &c. &c.

AIR BIRD.

LONDON:
THOMAS WARD & CO., PATERNOSTER ROW.

MDCCCXXXV.

PREFACE.

Though there are perhaps, few subjects of the same extent, and the same interest, the different parts or branches of which have been treated with more scientific ability than the air, or atmospheric fluid, which surrounds our globe, and is either the field of, or one of the actors in, its most interesting operations; yet there is, perhaps, none in which it is more difficult for the unlearned to obtain any thing like a general view, which shall enable them to see at once the nature of the different parts, and their relations to each other. We find the mechanical properties of the air treated of as a distinct science, under the name of pneumatics; we find the chemical properties in the different pages of the book of chemical science; we find the relative actions of the air, in different parts of the world and at different seasons of the year, discussed as portions of physical geography; we find its relations to moisture, heat, and motion,—to the effects of which we give the general name of "the weather,"—regarded as a separate science, under the name of meteorology; and we find its use in the economy of plants and of animals forming parts of the physiology of those departments of created existence.

The list which has been given is not a short one; and yet it contains but a few of those divisions and subdivisions into which, for the purposes of accurate science, it has been found necessary to arrange the doctrine of the air. Now, though, as connected with the original obtaining of knowledge, no one would, or ought, to feel any disposition to quarrel with this, yet when we come to endeavour to put the public generally in possession of as much of this knowledge, and its results, as shall suffice for the purposes of rational conversation, and ready understanding of the varied appearances and changes of the atmosphere, and their effects upon the existing, the growing, and the living world, we feel some disadvantages—and disadvantages which are not easily overcome.

In the present volume, I do not say that I have succeeded in presenting even the most unpretending view imaginable of this most interesting fluid, which shall bring it before the reader in those broad and general features which are as "nails in sure places" in the elements of a science, and never fail to command the return of that science from even fancied oblivion in the hour of need.

It has always occurred to me, that the climbing of an extensive and difficult subject of knowledge, with profit, bears no small resemblance to the climbing of a lofty mountain, with full enjoyment. We are not to post to the summit by the straightest and most ready paths, and without ever looking back till we have gained the topmost height, and the wide horizon is at once given to our admiring eyes. Were we to do so, we should find that much were lost; we might have some notion of outlines and general forms, but we could not compare fairly with each other those places and those objects which presented themselves to us under such differences of dis-tance and of angle. If, however, we took advantage of every stage of our ascent, of each of those minor heights of which the altitude of a mountain is made up, and noted well the contents of its horizon, and the connection of each with the other, we should find the memory of those minor portions to come powerfully to our aid in understanding the whole, so that our understanding of the near and the remote would be almost upon an equality.

In endeavouring to get a general view of the atmosphere, which should be intelligible to the general reader, and, at the same time, not wholly objectionable to the very learned, I have followed some such plan as this:— I have taken first in order those properties of the atmosphere which appear to be the most simple, and the most in accordance with our common modes of thinking and of expressing ourselves; and, having done so, I have endeavoured to see how far each one would carry us in the connection with that nature, the general understanding of which is, of course, the ultimate object in all inquiries of this kind; and, if I found that recurrence to any one subject would either help to explain another, or serve to point out the general connection, I have not hesitated in making that recurrence; though, as I have not, to my knowledge, attempted a double explanation of the same phenomenon, those recurrences will not be found to have the character of repetitions.

After all the care I have taken, it is probable that the work may be faulty, even so far as it goes; and, from the limits within which, in point of mere space, I had to confine it, it must of necessity fall short of the very elements of the subject. But I believe that, in plan, and partially also in subject, it is entirely new; and, though novelty is no plea of justification for error, one does not get so smoothly or rapidly over the ground when the path is untrodden.

I shall not attempt to give any analysis of the plan of the work; because, as it is in general reduced almost to points, that would be much the same thing as repeating it over again. The contents will in some degree show the nature and order of the several parts; and it is to be hoped that the reader will find out the principal points which are wished to be established, from the line of the argument, and the bearing of the illustrations. In the execution, I have endeavoured to keep the whole system of nature before me, as much and as clearly as possible; and when the subject of itself has pointed the way to an allusion to the Great Author of nature, I have not thought it necessary to reject the mention of this conclusion for the sake of the few lines that it might occupy. In short, I have felt the difficulties of the subject; and, if any commendation is due to the sincerity of an endeavour, I have endeavoured to render them as smooth and imperceptible as possible.

ROBERT MUDIE.

Grove Cottage, Chelsea,
October 20, 1835.

ANALYSIS OF THE CONTENTS.

SECTION I.

PRELIMINARY REMARKS.

SECTION II.

STATE OF AIR.

SECTION III.

RELATION BETWEEN HEAT AND THE STATE OF BODIES, ESPECIALLY THE AIR.

SECTION VIII.

CONCLUSION.

THE AIR.

SECTION I.

PRELIMINARY REMARKS.

The air, or atmospheric fluid, may be said to be the medium not only in which all the terrestrial children of nature "live and move, and have their being," but also the medium of all terrestrial action, and of all our observation of whatever takes place. A knowledge of this fluid is therefore of the greatest use for the improvement of the mind, the advancement of the arts of life, and the promoting of that rational understanding of the system of nature and its working, which is especially requisite for duly impressing us with that reverence which we ought to feel for the Author of Nature.

In order that we may understand clearly the nature of this department of creation, whose properties and whose uses in the economy of the whole we are shortly to investigate, it may be desirable to understand the difference in signification between the two words "air" and "atmosphere," which are often used synonymously in common language.

Air relates to, or is expressive of, the state of that substance which we call the atmospheric fluid; and in its original meaning it is very nearly synonymous with " breath," or with " spirit," when that word is used in a material sense. It is proper to attend to this material sense of the word spirit, as distinguished from *immortal* spirit, or that which has none of the properties of matter, and is not in itself under any of the laws of matter, or subject to the material contingencies of change, dissolution, or death. We often use the word in this material sense: thus we say, that we are in good spirits, when all the functions of the body are going on in a healthy and vigorous manner; we speak of an animal as being spirited, when its motions are ready and rapid; and we apply the word spirited to language, when it is rapidly and strongly expressive of thought. Now, all these common uses of this word spirit—which is nearly synonymous with air, point to the grand distinction of the aëriel state from the other states of matter, and lead us, if we study them rightly, to a very clear and very correct understanding of the term. All these words, it will be observed, have reference to the readiness and vigour with which motion can be performed. If we are in good spirits, we can do our work, or perform whatever duty we may have to perform, with promptitude and vigour; if an animal is spirited, we mean that it is able and disposed to move readily and rapidly,—that, in the case of a horse for instance, he stands more in need of the rein than the spur; and when we apply the word spirited to language, or to any action or work of man, we mean that it is the product of vigorous action or motion on the part of the actor, and also, that by means of that general principle of sympathy, by which we, at once, accommodate ourselves to the subjects of our attention, so as to rejoice with the joyous or mourn with the mourner, it arouses our own faculties, and, for the time at least, imparts to us a portion of the spirit of that with which we are delighted. Now, of all possible states in which matter can exist, the state of air is that in which it has the most perfect freedom of motion; and this is the reason why we make use of the expression, "as free as air," as descriptive of that which admits of no local controul or appropriation.

So remarkable is this readiness of motion in air, and so essential does it appear to be in every kind of action which takes place upon the earth's surface, and probably as far downward both into the solid earth and into the waters as we can suppose action to extend, that there is perhaps no performance of what we may call the elementary functions of matter but in substances which pass through the state of air in the course of their action; but we shall have occasion to revert to this part of the subject, after we are in possession of some of those elements which are necessary to a right understanding of it.

There is, however, one remarkable coincidence between the action of air, and the action of many of the creatures, which tends very forcibly to show how well the name has been chosen, and to what a volume of knowledge it may, if properly understood and applied, be made the key. Every one must have observed that the times when nature is in the greatest bustle and activity are those when the air is most in motion. We do not allude to winds and storms, though there is no doubt that even these, up to a certain degree of violence, are powerful stimuli to the surfaces over which they pass; but it is matter of observation open to every body, that the months of March and April, in which vegetation in this country does more than in any other months of the year, are remarkable for atmospheric activity, for alternate wind and calm, and sun-shine and shower. When the summer sun comes to its full strength, and the atmosphere is still over the plains, nature languishes, and man is fatigued and pants for breath; but if, from any of those numerous causes which always lie ready for working in a variable climate like ours, a wind passes over, rustling the leaves and throwing the hay and corn fields into undulations like the waves of a little sea under an easy wind, it is astonishing how the spirits of man catch the freshness which this motion imparts to vegetable nature, or how much he is strengthened and exhilarated by its effects. It is well known, too, that in mountain valleys, where the air is seldom at rest, vegetation is more vigorous, more fragrant, and every way more delightful, than upon the extended flats; and, that if we are to find the barren waste, we must not seek it among the breeze-swept crags of the mountains, but upon some plain, it may only be a few feet elevated above the level of the sea. Even if we take our survey along shore, and compare the land which terminates in bold cliffs with that which has a low beach, we find that there is about the former a freshness, and, in proportion to the quantity and quality of its soil, a freedom of growth altogether unknown to the latter.

If we direct our attention to animated nature, which, as embodying a greater number of principles and of actions than matter which is without life, may be regarded as the best field for observation, we find that there is a wonderful coincidence between the activity of the different races and the extent of atmospheric action to which their nature and habits subject them. The bird which takes the top of the sky, and breasts the tempest gallantly to windward, with far more velocity than our swiftest ship can scud before its current, is all over a breathing instrument. Not only is the internal cavity of this animal fitted with tubes and cells, independently altogether of the lungs, or breathing apparatus, but every bone is hollowed out so as to be a receptacle for the atmospheric fluid; and there is not an important organ or vessel in the whole body of this fleet and buoyant creature which is not continually bathed in the breath of life. Contrast with this some of the reptile tribes, which twine in the brakes, or crawl in the mud, and we find that their breathing is as limited as their powers of action, and that very many of them doze out the winter in one unbroken and unbreathing sleep, during which they perform no action, and suffer little or no decay. Cut off, by the peculiarity of their habits, from the all-stimulating influence of the air, they remain, if the expression may be allowed, in a state of living death; so intimately is atmospheric action connected with the functions of life, and so uniformly do their intensities increase and diminish together, and in nearly the same ratio.

Nor, if we turn our attention to the waters, and examine the economy of life there, do we find the least departure from the general maxim, " the more atmospheric influence the greater activity." The finny tribes which tenant the waters are, to the extent which their nature and habits require, just as dependant upon the air as those birds which brush the sky with most elevated wing. We can readily suppose, and the reason will appear afterwards, that the water near the surface of the ocean contains more air embodied with it than the water in the depths. Corresponding with this, we find the surface fishes, which cleave the waves with as much speed as an eagle cleaves the air, so that they are able to play round and round a ship in full sail, breathing much more air than the bottom fishes, whose motions are comparatively slow. We find, also, that the swift land animals and the swift fishes very speedily expire when they are cut off from the element, the action of which renders life in them so vigorous; while the ground reptile and the bottom fish can endure to be a long time without their scanty supply. Instances have occurred of live toads found enclosed in trees; and, after small lakes have been drained, and left to dry to such a consistency as that horses could pass over the surface, some of the ground fishes and water reptiles have been turned up alive by the plough.

We have mentioned these few and familiar instances for the purpose of showing the intimate connection that there is between the air and every species of action in nature; and we have done so thus early, in order that the reader may have this connection constantly in mind when we are attempting, in our simple way, to explain some of the more remarkable properties of this highly interesting fluid, and some of the countless advantages which the system of nature derives from it. Having done so, we shall briefly advert to the meaning of the other synonyme as it stands in contra-distinction to this one.

ATMOSPHERE literally means, "the receptacle of little things." It received this name from the Greeks, on account of its apparently drinking up smoke and vapour, and being the region of clouds. The atmosphere is thus the name of the *accumulation*, while the air is the name of the *substance;* and while, considered as the atmosphere, we regard the position and distribution of air around the earth, so, as air, we consider the properties of the fluid, and its specific effects upon individual substances. But, if we distinctly understand what have now been explained as the peculiar significations of those two terms, we may then use either the one or the other, according as may be best, as expressive both of the mass or volume of the air, and of its substance: and in the more general points it is necessary to understand that we embody both meanings, whether we make use of the one term or the other.

This being understood, let us very briefly consider what it is that we require to know, or can know, respecting this atmospheric air. We have already mentioned that this fluid is the medium of all natural action, and also of all our observation of it; and thus the field for our inquiry is as wide as the utmost extent of the mind's ambition can desire. The air every where surrounds the earth to a height far exceeding that of the highest mountains, even if we were to suppose its weight the same at all elevations, which is not the case. But not only does it surround the entire globe, for it surrounds every detached piece of matter whenever that piece of matter is in any way moved, or made to change its place; and in the case of all bodies or pieces of matter, which we describe as being moveable, the air constantly surrounds them on every side. This is the case with loose stones and sand, with all animals, excepting such as grow rooted, of which there are no land species, and, in short, with every thing which merely lies supported on the surface of the earth.

Loose substances, whatever may be their nature, may thus be regarded as supported by the air as by a sort of carriage, by the help of which they can be moved from place to place with far less labour than would otherwise be required. We find this to be the fact from many experiments, as well as from daily experience in ordinary matters; and it is worthy of remark, that if the air is by any means excluded from between one piece of matter and another, it instantly changes from being a means of separation to being a means of union between them. This holds true equally between any body and the earth considered as a general mass, and between two pieces of matter, both of which are detached from the earth by an interposed stratum of air. The method by which the fact is arrived at is a matter for subsequent inquiry; but we may mention, that if a substance is detached from the earth by means of a stratum of air, however thin, then there is no more weight to be moved than the simple weight of the substance,—that is, the gravitation of the substance toward the earth is the only resistance to be overcome in removing that substance from the earth.

Thus, for instance, when a man walks along the pavement or a firm footpath, he has no weight to lift but that of his own body; and if he has been taught to walk neatly, the height to which he requires to lift this at each step is hardly perceptible, and thus he can continue a long time without being fatigued. But make him walk only half-shoe deep in tough mire, and he will feel as if each foot were loaded with a weight. This, however, is only a partial exclusion of the air from between the feet and the ground. If the air were entirely removed from below, the atmosphere would press the soles of his feet to the ground with a weight of about fifteen pounds on every square inch of the soles; and, if we suppose the surface of each sole to come in contact with the ground to an extent of eighteen square inches, then each foot would be held to the ground by a weight of two hundred and seventy pounds, or, the man standing on both feet, by a weight of five hundred and forty, so that any motion with men of the present muscular strength would be out of the question. Even to press the palm of the hand against any substance, to the exclusion of the air between them, would be to fasten the hand to the substance by a force of one hundred and eighty-five pounds, supposing the palm to contain nine square inches. This, again, would be beyond the power of any single hand to overcome, or, if the substance were not in contact with the earth in the same way, and not heavier than the hand could lift, it would stick permanently to the palm; and, but for the separating film of the atmosphere, every part of the body which came in contact with any substance would stick to that substance in consequence of the atmospheric pressure. Indeed, if it were not for the power which the atmosphere has of insinuating itself into every pore and opening, however minute, all substances would be so firmly pressed against each other, that no motion of any kind could be effected; and thus the whole action of the earth would be limited to the two motions of that planet,—on its axis, and in its orbit. The following instance will perhaps place in a more striking light the advantages which we derive, in common with all other creatures which have to exercise or to use motion, from this insinuating property of the air. A paving-stone, three feet by two, is a very small one compared with many of those of our side pavements; but if a stone of this description were so laid as that the air were absolutely excluded from under it, the atmosphere would press it down with a force of about six tons, and, as the power which overcomes any resistance must of course be greater than that resistance, a greater power than six tons would be necessary for raising the stone. In raising large stones from the ground, or quarrying them from the rock, the workmen meet with practical instances of this. If the stone is large, and has lain long, with a moderate embedment in the ground, the action of the rain gradually enfilters under it the finer particles of the soil, and it becomes nearly, but not altogether, air-tight; and, in like manner, when the beds of stone have scarcely any visible fissure between them, the air is almost, but not altogether, excluded. In both these cases the first moving of the stone is an effort which requires great strength; but, as soon as it is once "winded,"—that is, as air has been admitted under it,—

all the difficulty of moving it is overcome, its entire resistance is reduced to its mere weight as a piece of matter, and one man can deal with it as easily as twenty men could have done while there was no air under it.

In this, which may be considered as the mechanically passive use of the atmosphere in the economy of nature, we find two very remarkable, and, as they might seem at first sight, opposite effects of the same property. It is the weight of the air which presses it into all the little pores and interstices of bodies, and makes it serve as a sort of elastic cushion, or carriage, upon which every moveable thing reposes, and may be borne along from place to place; and it at the same time gives stability to every thing, and thus controuls and modifies that gravitation, by means of which, were it not for the atmosphere, things would be constantly tumbling to the ground. In order to perceive that such would be the case, we have only to consider that the atmosphere, as a fluid, must press equally in all directions—upwards, downwards, and laterally. We have mentioned that its pressure, at the level of the sea, or mean level of the earth's surface, is, under ordinary circumstances, about fifteen pounds on the square inch. Thus, if the surface of a leaf measures two square inches, such a leaf must be sustained, or held stable, by a balance consisting of thirty pounds weight upon each side of it, the two sides answering in the leaf to two equal scales, whatever may be the position in which the leaf is placed. The support given to every thing else, by the mutual pressure of the air upon all sides of it, is in proportion to the extent of surface which it presents to the air, and this altogether independently of the difference of texture of any difference of consistency or specific gravity that there may be between the different substances. Thus for instance, if we suppose a square tower to be sixty feet high, and twenty feet wide, in each of the sides, every side of such a tower will be supported by a lateral pressure of the atmosphere, equal to about twelve hundred tons, or the whole tower will be held together, and kept in its place, by a pressure of four thousand eight hundred tons, independently of the downward pressure upon the section of the tower. A support so great, so perfectly general, and applied to all bodies in proportion to the extent of their surfaces, without any reference as to whether the substances of which they are composed are of greater or less strength, or specific gravity, is of far greater advantage than those who have not reflected on the subject would be apt to suppose; and without this atmospheric support, the leaves and branches of trees, the bodies of animals, the materials of buildings, and even the cliffs of the rocks themselves, would fall to pieces, and to the earth, by their own weight. Indeed, if the atmosphere had no other property than this, no other use in nature than the support, and, at the same time, the facility of moving, or being moved—which it affords to all the working substances and structures on the face of the earth—it would be well entitled to our highest admiration; and from its nature, from the matter of which it is composed being in a state of division too fine and minute for any observation, or even any calculation, in terms of the nicest measurement, there is no conceivable portion of living, growing, or moving nature which does not, in proportion to its necessity, enjoy the benefit of this atmospheric support.

But, singularly important as this use of the atmosphere is, it is only one of its many uses, and one of the least wonderful of them, inasmuch as it depends wholly upon that fluid, as passive; and when we consider its active energies, we find that they are of still greater importance. Those active energies may be divided into two classes. In the first place, those which belong to the atmosphere generally, and do not imply any change or decomposition of its substance; and secondly, those in which the atmospheric fluid, considered as air, incorporates more or less with individual substances, becomes a portion of them, or receives the refuse and waste which they give out. It is in this manner that the air acts so very important a part in the economy of nature, and without which we could not even imagine any function of growth or of life to be carried on for one moment; and, therefore, the consideration of the atmosphere, in this point of view, involves in it some of the most important functions of the growth of plants, and of the life of animals.

The general action of the atmosphere involves in it the general principles of all surface action upon the earth; and the science of it is nearly identical with what is called *Meteorology*, or the science of the weather. This is an exceedingly important matter, not only in respect of all out-door operations, but in respect of our health and comfort, for every one is affected by the state of the weather; and this affection, in different individuals, is always in proportion to their several degrees of sentient activity; and consequently, as mankind advance in knowledge, the study of the weather becomes of greater importance. But it is not merely with regard to private interest and personal use that this is a most important branch of the phenomena of nature: there is something in the study of meteorology which is well calculated to excite, and to gratify the very highest powers of the mind. The very wind, which is the mere motion of the atmospheric fluid, has a long and a varied tale to tell; and when the western breeze sweeps over our fields, bringing fertility and health, it comes as a messenger from a far country, and its wings are loaded with information. Drawn toward that parallel of the earth where the sun is vertical at the time, it is gradually heated as it ascends, and climbs up into the higher regions of the atmosphere until it reaches a degree of cold which reacts, and again condenses it. It is stopped in its westward course by the high lands of central America; and, during great part of the year, especially during the winter, it is prevented from ascending the valley of the Mississippi; and thus it returns upon the coast of Europe, and communicates to the whole of western Europe generally, and to the British Islands in an especial manner, an uniformity of temperature throughout the year, and a consequent adaptation for culture at all seasons, which are unknown in countries much nearer the equator which have not the advantage of such a wind as this. This western breeze is warm and healthy, though it is, at the same time, loaded with humidity, and therefore disposed to precipitate frequent rains upon the western shores; the consequence is, that, on all the western side of the island, vegetation is much more constant and vigorous than it is on the eastern side. But where mountains rise near the shore, and the whole action of this Atlantic breeze is restricted to a small breadth of country, the rains are in excess, and it is impossible to ripen the usual products of the fields, which require a dry summer to bring them to maturity. In the western highlands and isles of Scotland, for instance, there are many places where no grain can be grown, save oats, because wheat or barley would sprout in the ear, and be worth nothing as food; and even the oats have to be dried within doors. But still such countries are not left without the means of human subsistence. The potato is peculiarly adapted to those dripping climates; and as the rains bring down all the richness of the hills into the hollows, the soil for the growth of this crop is renewed every year, and therefore quite inexhaustible. The same humidity of climate is equally favourable for the pasturage of stock, more especially of cattle, which in such places can find their food in the open air all the year round, as the pastures are never burnt up in summer, and the snow never lies upon the lower ones near the sea, for more than two or three days, even in the depth of winter. But when there is a general set of the wind against any shore, there is an accompanying set of the water of the ocean, not only because both fluids are affected, though differently, by the same original stimulating cause, but because a wind sweeping over the surface of the sea lays hold of that surface by friction, and moves it in the same direction, altogether independently of waves and local agitations, which take place when the natural elements of the atmosphere are disturbed.

We have mentioned this west wind as an instance of those more general motions of the volume of the atmosphere, which may be said to constitute the ordinary condition of that fluid; but when along with them we take into consideration the local disturbances, seasonal or otherwise, which produce variable winds and changeable weather, we find that we have, in the mere motions of the air, a most extensive field for inquiry, and one the knowledge of which is of the greatest use, both to a right understanding of the system and economy of nature, and of the successful performance of every occupation, whether on the land or on the ocean waters; which, while they divide the lands, and, by the peculiarity of this action, promote fertility and enjoyment, unite the inhabitants, and, as it were, bring together the most distant parts of the earth.

But it is not in the mere currents of the atmosphere—in the winds alone, that we are to seek instruction; for there is much in what they bring. Every breeze that plays, every gale that sweeps, and every storm that drives over the surface, brings with it something either for weal or for wo; and in order to determine what it brings, and for what purpose, and to what effect, we must of course know whence it comes, and wherewithal the place from which it comes has supplied it.

In these, its motions, and in the substances and the actions which the atmosphere carries along with it, we have, perhaps, the most interesting page in the whole volume of nature. The burden of the air may, in all cases, be said to be water in a state of vapour; and the action of the air, heat, in some one or other of its modifications, from the chilling blast which curdles the pools and consumes the vegetation, to the lightning's arrowy fire, which cleaves the tree or shivers the rock. In every part of the world these are phenomena of the deepest interest to the human race. In some places, and at some seasons in every place, they are mild and gentle; but there is no spot on the surface of earth at which there is not, at times, the highest sublimity in the weather. In a variable climate, such as that of the British Islands, it forms so general a topic of conversation as to follow immediately after the common salutation of courtesy when friends meet, even though they meet every day.

The very superstitions which are prevalent upon this subject, tend to show how very important it is. People are prone to believe almost any thing that can be set down as a prognostication of the weather; and perhaps there is not in the whole compass of human imposition, and that ignorance, or folly, from which imposition finds its reward, more gratuitous nonsense than is to be found in those annual publications professing to foretel the weather, which are greedily bought by tens of thousands, and sometimes by persons who really know that these oracles are lying ones. Now, wherever the ignorant have accumulated a large mass of superstition, we may rest assured that the subject of that superstition is one which will repay rational inquiry with an abundant harvest of knowledge. This is a consideration of which we should never lose sight in our endeavour to find out those subjects which are best calculated for gratifying our minds, and rewarding our inquiries; for, strange as it may seem at first sight, ignorance itself very clearly and forcibly points out to us the place where knowledge lies; and if we would attend a little more to the voice of untutored nature, and waste less of our time upon the erroneous triflings of art, we should be enabled to arrive at important truths by much shorter roads, and with much more certainty, then we do now, burdened as we are with the load and lumber of our own artificial mummeries.

This is so important, and, at the same time, so encouraging a matter, that it would require, as it certainly deserves, much more investigation than the casual glance which we are able to throw upon it. But it will not fail to occur to the reader, how many of those who have made the most splendid discoveries in the arts, and erected for themselves the noblest monuments in literature, have been self taught, or possessed of what the world has been pleased to call great natural genius. Now, it may well be doubted whether there is any difference, any original and specific difference between one *mind* and another; though, as there are differences of form and expression in the body, and different degrees of acuteness and powers in all its organs, whether of sensation or of motion, so there may be different degrees of perfection in its adaptation to the mind; so that perception and action may tell more mentally, more immediately, more vividly, and with more stirring, arousing, and onward effect in some individuals than in others. The doctrine of dulness is not, however, a wholesome doctrine to preach to any one; but, on the contrary, the maxim to be held constantly before mankind, and especially before the young, is, "Whatever is possible may be done; and the will, if hearty enough, is always certain to open up the way."

Any one who chooses to examine the history of the human race, and to view mankind in their progress from the very lowest states of savagism and ignorance, up to the highest degrees of civilization and knowledge, will not fail to observe that, in every age, and under every variety of circumstances, the steps have been made upon what may be called new ground; and that those subjects over which the uninformed minds have brought the mists of superstition most thickly have invariably been the ones from which science, properly directed, has reaped the best and most abundant reward. We have only to look at the notions which mankind of every race, to whom the light of Revelation has not come, have of the Almighty, in order to learn that superstition and error thicken the mist over those subjects which are in themselves the most fertile in the elements of true wisdom. And when we reflect upon the subject, we may readily perceive that it cannot be otherwise; and that it is the original ordinance of God, singular as it may seem, that ignorance is our tutor in the ways of wisdom. How can it be otherwise?—the spirit is in man—that breath of life which his Creator breathed into his nostrils at the first is with him, whether savage or civilized, whether left to arrive at his own conclusions by his own thinking, or drawn forward (and sometimes drawn aside) in the bands of tutorage; and therefore we may naturally suppose that there is an attraction of mind, even in its most uninformed state, toward those subjects which are most calculated to reward its noblest efforts when in the highest state of cultivation. Indeed, if we do not admit this principle, or something like this principle, we should be unable to show that the human race possess any tendency to cultivation; and thus all the steps of their improvement would be reduced to a succession of miraculous interferences of Divine power. But we cannot thus judge of our Maker; we cannot suppose that while the rest of creation is all perfect; while sun and planet, hemisphere and hemisphere, season and season, vegetable and animal, are so perfectly adapted to each other, and work so harmoniously together for the benefit of the individual and the beauty and perfection of the whole—we cannot, with this impressed upon us by every object within every horizon around the earth's girdle, imagine for a moment that, while there is all this perfection in merely material nature, man, the only being who is framed for knowing the whole—the only being to whom contemplation is pleasure, and who lives a higher and a nobler life than that which merely passes its day and generation, and then is gathered to the general mass of the dust, and blotted out for ever, not again to return,—we cannot, upon any principle of reason or philosophy imagine, that he is the exception;—that that Almighty Being, who has bestowed upon man his best blessing, should have, at the same time, accompanied that blessing with his heaviest curse, unless in cases where the perversity and the stubbornness of man's own nature may turn the honey-dew of heaven into the gall of bitterness.

But, interesting as is this subject, we must leave it, inasmuch as it is foreign to the main purpose of the present work. Incidental mention of it is, however, of much importance to every one, and in every species of inquiry, the study of which is calculated to improve the mind or to soften the heart. From the opening of life to its close, we never weary of nature. It is a subject always fresh and ever new; and it is doubtful whether the breath of spring does not blow upon us with increasing sweetness every year, whether the bloom of summer does not bring more delight to the fading eye than to the eye which has just opened upon it, whether the abundance of autumn does not impart a warmer feeling of gratitude to the heart's very last pulse than it does to the bounding tide in the youthful bosom, and whether, when the voice of winter moans through the leafless forest, or howls amidst the mountain cliffs, it does not proclaim to the aged ear more forcibly the voice of the God of nature, than it does to ears which are more open to the gaieties of early life. Now, if it be true, as it unquestionably is, that nature is a grand stimulus, a grand restorative, and a grand supporter of the human mind, amid all the vicissitudes, and reverses, and rubs which we meet with in society,—if it be true that a student of nature is invariably and without exception a person of kindly feelings and contented mind, —if it be true that the students of this noble science, in all its departments and all their branches, cheer and applaud, and bid each other "God speed!" while, on the other hand, those who devote their whole minds to some branch of merely human art, and have their understandings thereby narrowed,—glued as it were to the marble block, the patch of colour, or string of the instrument,—are tortured with jealousies, and wranglings and discords, and hatreds and persecutions of each other;—then of how much more importance must it be toward the softening of the heart and the elevation of the mind—the producing in short of that frame and temperament which are most fitted for the enjoyment of a better life, to study the highest department of terrestrial nature, our fellow creature, man, in all his conditions, and in all the stages of his progress?

The third general point of view in which we have to consider the atmospheric fluid, is that of an instrument or agent in the great system of nature's chemistry,—in the atmospheric changes that take place in the mineral or inorganic parts of the earth, in the fitting of soils for the growth of plants, in the various stages of vegetable action, germination, growth, flowering, fruiting, and final decay and decomposition, and in the development, the progress, and the general support of animal life. This branch of the subject is an exceedingly important one, so much so that we may say, with truth, that there is not one spot of the earth's surface, or one single production, of which we can rightly understand either the value and the rotations in nature, or the use in art, unless we consider it with reference to the action of the atmosphere upon it. But this is so much a matter of detail that it cannot be profitably anticipated by any introductory generalization.

There is, however, another general view of the atmosphere in which it is, if possible, of more importance to us than in any of those which we have hitherto noticed. This view is that of the air or atmosphere, considered as the medium in which all our observation takes place. We know not what might be the effect of sensation in a vacuum, or space entirely void of air, because we cannot ourselves be placed in such a situation and live; but we do know that the air is the immediate instrument of sound, and that the most sonorous body in the world would be perfectly mute, were it not for the atmosphere. So, also, the atmosphere, if not the instrument, is the vehicle of all odour, and but for it the sense of smelling would be possessed in vain. We cannot speak decidedly respecting the sense of taste, because the action of that sense is somewhat more obscure; but it is probably much more nearly allied to the sense of smelling, and more dependant on the presence of air, than we at first would be apt to suppose. It is well known that if the nostrils are held closed while drinking any liquid, the palate can take little or no cognizance of the flavour of that liquid; so that if a man drinks a glass of wine which he has not seen, and therefore formed no judgment of by the eye, he is unable, if he holds his nostrils closed, to tell what wine it is, or whether it is wine or water.

In regard to all our sensations, indeed, the presence of the air is indispensably necessary, because no organ can exist, far less perform its function, unless that organ is surrounded by the atmosphere; and, indeed, we have every reason to suppose that the presence of the atmosphere, applied to the whole surface of the body, is as essential to its general health as breathing is to the more immediate functions of life. At all events, we can form no judgment of what any sensation would be without the atmosphere as a medium between the organ of sense and the subject causing the sensation. Therefore, it may be said that all our knowledge of matter, in every variety of its forms, is knowledge derived through the medium of the atmosphere; and, such being the case, it is impossible for us satisfactorily to know any one subject in material existence, be that subject what it may, unless we take it in combination with this all-important and all-exciting fluid.

The uses of the air in our domestic and general economy are so well known to every one, that we need hardly allude to them. Man owes much of what he enjoys to fire; and, in every case of burning, the presence of air is not only necessary, but it is the air which supplies the heat and light. The motion of the air serves us as a power in various ways: it grinds at the mill, and it wafts the ship on her voyage. There is not a finer object in all the landscape than a windmill; and here there is a very striking adaptation to the necessities of man,—on those flat shores where there is no water power, the sea and land breezes render the windmill of daily use. Then, as to the ships, what would England, what would the world be, if without it? The feelings of every one who reflects but for a moment will enable him to answer the question.

Notwithstanding the many and important purposes which the air answers in the economy of nature, it appears to our sensation to be perfectly neutral and passive. It is viewless, it is silent, it is scentless, and it is tasteless, and therefore it is ready to be the vehicle of every subject of sensation with which it can be loaded. Thus, it is one of the most extraordinary works of creation, apparently perfectly simple in its nature, yet susceptible of every imaginable impression, and giving up those impressions as freely to our sensations as it receives them from objects and substances of all kinds.

We feel this in every day of our lives, for though we are unable, by even our finest instruments, to take cognizance of all changes of the atmosphere in respect of heat, of moisture, of motion, or of that more obscure condition which we call its electric state, yet it is certain that our feeling of comfort or of discomfort depends more upon the state of the atmosphere than upon any thing else; and that the same fluid which is the breath of life in our nostrils, has more to do in regulating the enjoyment of life, than any, or than all, of those possessions in the acquiring of which we toil and weary ourselves. Who that has been pent up in the closeness of the town or the city, whether in the abode of labour or in that of the most luxurious indulgence, does not feel years adding to his life, nay, almost cubits adding to his stature, when he escapes to the open fields, where the breeze of heaven plays freely around every limb? If we are weary and worn, where do we find so sweet and so speedy refreshment as when we are able to throw ourselves down on the earth's green carpet, inhale the vapourless air, and bathe our whole frame in its allinvigorating flood. Even when the pulse of life is ebbing away, when the panting lungs refuse to perform their office, and the skill of the physician has become vain, if there is even a ray of hope for the sufferer, that ray is wafted on the winds of another climate, and a simple change of atmosphere will often bring back from the gates of death, when all the arts of man have been found unavailing. All that delights the eye, all that is harmonious to the ear, all that is grateful to the scent, all that brings freshness, renovation, and health,—in short, all that we enjoy, or can enjoy, in this world,—comes to us on the wings, or in some way by the instrumentality, of the air; and the characters of nations, as well as the comforts of individuals, depend more upon it than upon any thing else. But to enumerate all the blessings which this wonderful fluid confers on nature and on man would be impossible; therefore we must pause, and consider some of its qualities.

SECTION II.

STATE OF AIR.

In order to obtain a clear and correct understanding of the numerous and varied functions which the atmospheric fluid performs in nature, it is necessary that we should have some general notion of the state of air, as distinguished from the other states in which matter presents itself to our observation. We are to understand that, though we use the term air as more peculiarly expressive of the atmospheric fluid, yet that this term, as expressing a peculiar state of bodies, is perfectly general, and that analogy leads us to suppose that there is no one substance in nature but which may, and probably in some instances does, exist in the state of air. Hence, it is desirable to have a name for this state, and also for any substance in this state, which shall not immediately suggest to us the air of the atmosphere. In the language of science, every substance, be it what it may, simple or compound, which exists in this state is called a GAS, and the state itself is called the GASEOUS state. The word gas is very nearly a synonyme with our common word, air. It is derived from a German word which signifies "spirit," in that material sense in which we have attempted to explain the term.

We need hardly mention that there are three distinct states in which matter can exist, and that they are all applicable to any and to every kind of matter; though, under ordinary circumstances, some substances are found only in one of them. These states are, the solid, the liquid, and the gaseous; but each state admits of many degrees, according to the nature of different substances, and on their confines they approach very nearly to each other. Thus, the various earths and metals, and many parts of animals and of vegetables, are seen by us constantly in the solid state, though some of them, such as the diamond, are solids of great hardness, and others, such as the leaves of trees and the flesh of animals, are comparatively soft. The most familiar instance that we have of a liquid in a state of nature, is water, though we have also natural liquids in the blood and the juices of animals, and also in the juices of plants. Of the gaseous state of air, our familiar instance is the atmosphere, though in many operations of nature and processes of art a variety of other substances are changed into this state.

Water is the substance from which we most readily get a view of those changes of state, and of the means by which they are produced. In some parts of the world we have water constantly existing in a solid state, as ice or as snow; in other places we have it as constantly liquid, and though we are not acquainted with any operation in nature by means of which water can, under ordinary circumstances, be changed into a gas, yet we find it so dissipated through the atmosphere in invisible vapour, that it is as impalpable to our senses as the air itself. We have no reason to suppose that the compound liquid which we call water can be changed into one permanent gas, though we have every reason to conclude, nay, though we are certain, that, in many of the operations, one or other of the two ingredients, oxygen and hydrogen, which form water, may be taken up into the substance of other bodies, and enter with them into new combinations, while the other one is set free in the state of gas. The power by which those component parts of water are held together is very great, and if we effect either their union or their separation, upon only a moderate scale, the results are more striking than in perhaps any other case that could be named. The intense light which is produced by the combustion of oxygen or hydrogen, in that proportion in which they form water, is well known; and it is also well known that if only a few inches of this compound were ignited at once, it would blow the strongest apparatus to atoms. Now, this burning of these gases in combination, is nothing more than the application of such a quantity of the action of heat to them, as shall make them combine and form liquid water, and after the process has begun, the immense heat and light which are produced are merely the separation of that portion of the action of heat by which the two elements of water were previously held in the state of gas. The result of the operation is nothing more than the production of a small quantity of liquid water, and in any experiment which we can perform this quantity is exceedingly small. Yet, still, we see enough in it to show us what a tremendous power nature possesses in the simple act of combining those two gaseous elements into the liquid. But it is a law of nature, that the undoing of any operation requires as much effort as the doing of it; and therefore the direct converting of liquid water into its two gaseous compounds is a process which we cannot suppose to take place, except in the extremes of nature's working. There is no doubt, however, that in the combining of the gases into liquid water, and in the separating of liquid water into the gases, nature is possessed of powers far exceeding any thing that we can even imagine, nor is there any doubt that those more mighty convulsions of the earth, the earthquake and the volcano, are intimately connected with, and, in fact, produced by the one or the other of these operations. But the investigation of this portion of the subject belongs to the natural history of the water rather than to that of the air. There is, however, something analogous to this in lightning, which is an aëriel phenomena, and of which we shall require to take some notice in the sequel, and therefore it becomes necessary that we should understand at least as much as has been stated of the composition and decomposition of water, and the great display of power by which both those operations are accompanied.

There is a farther contrast in the constitution of water and that of air which is exceedingly useful to us, not only in judging of the several operations which the system of nature presents to our notice, but in arriving at any thing like a comprehensive view of the wisdom and the power which that system displays; and it is in those contrasts of substance with substance that we most clearly see the hand of Omnipotence in all with which we are surrounded. We have stated that the constituent parts of water are held together by an affinity, or attraction for each other, which cannot be loosened without the most intense action, and that the compound liquid which they form can exist either in the liquid or the solid state under circumstances which occur in the natural succession of seasons upon the earth. We may farther remark, that there is no latitude from the equator to the pole in which there is not some portion of the earth so elevated and so cold, as that water is not, upon an average, in the solid state. The nearer that we approach the parallel of extreme heat, the more elevated are those mountain ridges which thus crystallize and retain that water which is the life of vegetation; and it is one of the most remarkable properties of air, and one of the most striking proofs of the accordance of all the parts of the system with each other, that this cold in the upper regions, which retains upon the mountain tops, against the seasons of drought in the tropical year, a portion of humidity sufficient for the supply of the vegetable, and through that of the animal kingdom, is mainly dependant upon the properties of the air; nor is it less wonderful that this same viewless messenger should carry to those elevated regions this abundant store of the drink of growing and living nature, which is ever ready to supply the wants of all that grows and lives. Considered in itself, we may say the water works constantly by gravitation. We perceive it not in mass, in any other situation than in strict obedience to this power, unless in situations where the cold is such as that it is frozen and retained in its place as a solid. When confined within boundaries, it instantly accommodates itself to the mean level of the earth, and when not so confined, we meet with it in a continual state of falling, or, which is the same thing, running downwards; and if we were not to observe or to reflect beyond this, our first knowledge of the subject, we should be inclined to imagine that the whole surface of the land was constantly in a progress of drought; and as all the operations of nature are the results of natural causes, in the action of which the grand fundamental law of gravitation is never violated, such would be the case if there were no agent but the solid earth and the liquid waters. The fountain pours out its store, the rill leaps down the mountain slope, the rivulet races onward through the meadow, and the river rolls its tide in the valley. All these go on unceasingly; and when we consider the vast quantity of water which the accumulated rivers are constantly pouring into the sea, we might well be disposed to fear that, ere the lapse of many ages, this all unsatiable element would drink up the whole moisture of the land, and leave the entire surface of the earth in a state of growthless desolation. But there is, in the limpid atmosphere, a spirit of renovation; and, just as no animal ceases to perform its functions so long as the life-inspiring atmosphere plays through that part of its organization which is fitted for the purpose of breathing, so, while this fluid plays around the globe, and performs its evaporative functions upon the ocean waters, all the land cannot be deprived of that humidity which is essential to growth and to life; and notwithstanding the dash of cataracts, the careering of currents, and the swelling tides which the seasonal overflow of the rivers pour into the sea, there is probably an equal return of water from that grand receptacle, by the silent and viewless operation of the atmospheric fluid.

Thus the consideration of air and of water forms as it were one subject; and the parts of that subject are so intimately connected, that we cannot fully understand the one without having at least some knowledge of the other. The consolidation of the water, whether permanent upon the lofty mountain tops in all regions of the world, where those ornaments and benefactors of the land are of a sufficient height, or around the poles in the alternating winters of the two hemispheres, is one of the grand securities of nature against the peril of drought; and it is especially worthy of our attention and admiration, that where a certain temperature, namely 32° of the common thermometer used in this country, is arrived at, the power of water to assume the solid state is not only constant and great, but absolutely greater than any mechanical resistance which we can imagine to be opposed to it. Any one who has been in the habit of frequenting rocky mountains at the time of the winter frosts, immediately consequent to the autumnal rains, must have heard voices among the crags scarcely less loud than that of the thunder of heaven; and at those more sublime elevations, where frosty nights invariably succeed to days which are comparatively hot by the direct action of the sun upon the bare rock, similar voices may be heard by any one who passes the night there. Now those voices, though they are occasioned by the freezing of water, are not necessary adjuncts of that operation; because, not only freezing, but every process of consolidation which takes place among all the varied substances of the earth, is performed in silence, if it can be performed freely and without resistance. Those voices are what we might call the moanings of the mountain rocks, as these are rent to pieces by the freezing of the water, which has percolated into the fissures, and which, while it arranges itself into the crystalline form, expands, not to a very great extent, but with a force which is too great for any mere resistance of matter, and the intensity of which is not measurable by the quantity of water, but seems equally great, whether that quantity is large or small.

We have mentioned these few particulars, with regard to the existence of water in the two states of liquid and solid, and the power which it possesses in itself of returning to the latter of those states whenever the temperature is sufficiently low, in order to impress upon such readers as may not have reflected much upon subjects of this kind the necessity of bearing in mind the fact, that those qualities which are inherent in the nature of any substance are just as incapable of being destroyed by the action of even the most powerful external causes as one portion of matter is incapable of annihilating, or putting wholly out of existence, any other portion. This being the case, it follows that all the materials of which our earth is composed have certain definite states, to which they have a constant tendency to return; and we may draw the general conclusion, that the ultimate state to which every part and every production of nature would speedily and certainly pass, if all action were to cease, would be a state of solidity, and of final repose; but it does not follow that any of those compound substances, of which the visible creation is made up, would return to this state in that composition in which we find it in nature; for, whether we class it with minerals, with animals, with vegetables, with water, or with the atmospheric fluid, we know of no substance, or portion of a substance, which we can with certainty pronounce to be simple and original, incapable of decomposition, or secure against being so changed by some of the varied operations of nature, as that we should be able to recognize it in its new combination. Thus in a tree, a flower, or a fruit, the substantial elements are those which compose water, together with a certain portion of charcoal, or carbon, that is, of the matter which we find in its most pure state in the diamond. But any one of these three elements may enter into combinations so numerous, and present in each combination appearances so different, and exhibit to our senses and our experiments properties so new, and so unexpected in each, that we can come to no conclusion other than this,—that there are powers in nature which have every material substance much more under their controul than the clay is under the controul of the potter; and therefore, let us carry our investigation as far and as accurately as we may, there is still a world of wonder beyond it, in which admiration must occupy the place of knowledge, and adoration must be at once the finishing and the ornament of our most scientific and most scrutinizing inquiries.

When we turn from this consideration of water to that of the air, or atmospheric fluid, we find a very striking contrast. This fluid, in its most simple form, is, as we have already said, and as we shall more completely explain in a future section, made up of two principal ingredients; but those ingredients, unlike the elements of water, appear to be mingled together, and also separable from each other, without the exertion of any thing which we can call a force. We are not acquainted with any of them as naturally existing in any other state than that of gas, or indeed, in any other state than that of union with each other, or with some other substance; we therefore conclude that, of all substances, these two constituent elements of the air mix most freely and most simply with each other; and that their separation from each other is performed with equal ease.

Thus the atmosphere is one of the most beautiful provisions that we can by possibility imagine, for carrying on the numerous and varied operations of the world, in all its phenomena of change, of growth, and of life. If any one portion of the atmosphere, whether of its own substance, or of those substances foreign to its own nature, which it is capable of holding in solution, or of that action of which it may, under various circumstances, become the storehouse, in a manner which is often much too mysterious for our ken,—if any portion of this substance, or of this action, is required, whether for great purpose, or for small, whether to sweep the land with hurricanes, and shiver the rocks with lightning, or to awaken the first rudiment of life in the atomic embryo mould upon the stone, or animalcule in the water, while yet it is all too minute for the scrutiny of the keenest eye, or the most powerful microscope,—then the atmosphere stands ever-readily prepared to administer the precise quantity, whether of substance or of action, in the very manner, and at the very time, which the necessities of the particular creature require. When we look abroad upon the world, even upon a single field—upon any field or spot in fact, in which the various agencies of nature are at work, we cannot fail in being equally overwhelmed and delighted with the accommodating powers of the atmospheric fluid; and if we had no other evidence than this of infinitely wise plan and purpose in creation, we have herein a demonstration which no candid and discerning mind can by possibility resist.

Over the extent of one single horizon, as displayed to the eye any where upon this land, it is not too much to say, in growing and in living nature, in the transfer of heat and humidity, and in the artificial labours of man, there are millions of operations constantly going on, in all of which the atmosphere is an indispensable agent, and to all of which it adapts itself with the utmost precision. The very same air which works fatigueless in the minute lungs of the gnat or the mite, supplies the ox and the elephant with the stimulating breath of life: the same air which embraces the lofty tree, in all the ramifications of its branches, and all the expansion of its leaves, bringing health to every point, and removing impurity at every pore, is just as benignant and as beneficial to the smallest moss, a thousand of which can scarcely stain the most delicate finger as it is drawn along the bark. Indeed, it is impossible to imagine a more perfect emblem of infinite bounty—a portion of matter which more powerfully suggests and more strikingly shadows forth the Almighty Creator himself, than this same atmosphere; nor is there any doubt that this reverential feeling has been natural with man from the beginning; and that it mingled in the vaguely com-

E

prehended idea of rude men, when with almost one universal voice, in all the varieties of their tongues and languages, they made the name of this most wonderful element a synonyme for that of spirit itself.

Thus while we bear in mind the universality of the service which the atmosphere renders to nature, and that it of itself tempers the kind and degree of the assistance which it affords to every creature, with a perfection which no arithmetic can number, and no tongue express, it is equally worthy of our consideration, that its state, as a gaseous compound, is perfectly independent of even the most powerful natural action with which we are acquainted. Many kinds of action, and perhaps all kinds, to a greater or less extent, are capable of appropriating, for the formation of new compounds, some one ingredient of the air; but we are aware of nothing in nature which can decompose it wholly, or even materially affect the relative proportions of its principal ingredients. The most powerful action of the vertical sun, though it tells very effectively upon the atmosphere, and enables that fluid to dispense the advantages of the solar heat far and wide over the globe, yet does not, of itself, have the least tendency to separate the constituent parts of the atmosphere, though it does dispose that fluid both for giving to the earth, and for receiving from it, according to the wants of the various productions of nature.

But as we are not acquainted, on the one hand, with any degree of heat which can finally destroy, or change the nature and constitution of this all-pervading substance, so neither are we acquainted with any degree of cold, that is, of the absence of heat, or the diminution of the action of heat, in consequence of which the atmospheric compound can be changed to the state of a solid, or even of a liquid. This, no doubt, in great part depends on the constitution of the air as a substance; and it is not a little remarkable that two ingredients, which are what we may call merely mixed mechanically with each other, or in the union of which, or in their separation, there does not appear to be any chemical action of any kind, should, in consequence of this fact of being merely mixed together, be thus capable of resisting the action of the most powerful causes. But there is no doubt that the position of the air upon the globe, and the rarety of its substance, as compared with the solid, and even the liquid parts of the planet, contribute not a little to the same result. The air is pressed by nothing but its own weight, which diminishes as we ascend, till, in the upper strata, it is probably less than any thing that we can estimate; whereas, all other substances, whether solid or liquid, are acted upon by the pressure of the whole column of the air over them; which is, at the mean level of the earth's surface, by about fifteen pounds on the square inch of each of their surfaces, in what position or direction whatever the surface may be situated.

In consequence of this, the air is left much more free and obedient to the action of any and all agents, than any other of the great constituent parts of our system. If it is powerfully affected by the beams of the sun, or by any other heating cause, it ascends, or otherwise moves away, and thus it eludes the full effect of the heating energy. So also when it is cooled beyond the average degree, at any one part of the earth, the whole of its mass sympathizes, and comes to the assistance of the position, which is thus cooled. It is obedient, to the widest extent of the earth's girdle, to whatever cause acts upon it; so that if any degree of extreme cold condenses it at one place, the whole of the surrounding mass in the upper air comes toward that place, and shares the cold with the affected portion. The air which thus comes is uniformly warmer than that over the place to which it comes; and, as it arrives, it is in part cooled and condensed. The heat which it thus parts with is not lost, however, for it is a general law of nature, that the action of matter is not more destructible than matter itself; but that when it is lost to one kind or portion of matter, it is always communicated or imparted to another, either to appear sensibly at the time, or is treasured up for some future development or display.

Thus the air is so admirably contrived, that both its state and the position which it holds upon the earth, contribute to its power of resisting the extremes both of heat and of cold; and as from the form of the earth, and the extent to which it is acted on by the sun, there may be said to be one half of its surface, and of the air over its surface, always exposed to the heating influence of the sun, while the other half is as constantly exposed to the cooling influence of the sun's absence; and farther, as these two portions, which are thus differently affected, are continually shifting in longitude by the rotatory motion, and in latitude by the oblique motion of the earth in its orbit, it follows that the natural tendency of the air to preserve its state, and maintain an uniformity of temperature, or at least an approximation to it, is powerfully seconded by the motions of the earth. This is another beautiful instance of that wisdom of design which runs so conspicuously through the whole of nature as to force itself upon every observer at every point. When we consider the local details we cannot but see that the atmospheric fluid, and the different products of the earth, are made for each other; and when we attempt to view matters on the larger scale, we have equal demonstration that the earth, in all its motions and phases, with regard to the sun, is made for the atmosphere, and that, by the most harmonious system of adaptation, the atmosphere is also made for the earth, as a whole, as well as for all its productions and inhabitants, considered in their separate and individual characters. The most remarkable part of the whole adaptation also is, that in every part of the system the working upon the great scale and the small is equally perfect; and that though there is in all the active powers energy enough for accomplishing the most successful, and, to us, the most tremendous results, the very same energy which can thus, so to speak, reach beyond the telescope in magnificence, can just as perfectly and as readily reach below the microscope in minuteness. The same power which can rend the mountains, can revive the spirits of the mite, or call the animalcula from the egg; and the very same action of heat which can burn up the fields, set the forests in a blaze, and shake the solid land with the rocking of an earthquake, and the fire and smoke, and volleyed stones and lava-flood of a volcano, can keep the life of the lichen upon the rock, and cause the lowly mosses to grow under the mantle of the polar snows. Whithersoever we turn our attention, wc find the same proofs of infinite wisdom, and the same demonstration of infinite power.

We have said that most kinds of matter are capable of existing in any or all of the three states of solid, liquid, and gas, which we have mentioned, and that there is probably no substance whatever which forms an exception to this, although we may not have seen it brought into the circumstances by which the particular state could be produced. Thus, we find water existing both as a solid and a liquid, and this within what we cannot consider as a very great range of the action of heat, while we find that the constituent parts of water can neither be separated nor combined without the most intense and powerful action. On the other hand, we have the atmospheric fluid, or air, incapable of being changed into either a solid or a liquid by any known action, however powerful; but, at the same time, we find that its constituent parts can be separated from each other by the very simplest operation of any cause in working nature; so that, maintaining its properties of air, and capable of performing all the functions which it can perform as such, it is in complete obedience, and of ready service, to all the rest of creation. If we examine the other substances, we find that there is in each, according to its kind, a different degree of adaptation to the same changes of state; and that in no two of the substances with which we are cognizant, and to which we give specific names in order to distinguish them from each other, is there exactly the same tendency to pass from the one of these three states into the other. Those different aptitudes of different substances, or differences of degree at which they yield and change their states, in obedience to the operation of external causes, are well worthy of our attention, not only in the study of nature, but in the practice of art; for all that art can do is only to bring about changes which are in themselves natural, under circumstances different from those under which nature would produce the same results.

Therefore, it is of the utmost consequence, both to our philosophical inquiry and to our practical performance, that we should understand well by what agency or agencies those different states of bodies are brought about, and how it is that the very same substance may exist in any one of these three states.

Now, whether we look upon any substance as simple or compound, whether we have been able to see the elements of it as many, or have been constrained to regard it as one whole, in which the smallest portion that we can separate agrees with the whole mass in all its general characters, (and this is all we mean, or can mean, when we speak of a simple substance,) we are led to conclude, that, in those states of substances, and in the changes from one to another, there is a conflict of at least two opposing principles,—the one inherent in the substance, and the other from without,—the one, what we may call a property of the substance, and forming part of its character as an individual production of nature—the law of its peculiar and individual being, as it were; and the other the result of external causes, which every substance, be it what it may, resists up to a certain point or degree, but to which, beyond this point or degree, every production in nature, of what form or kind soever, must give way.

We may state farther, as a principle perfectly general, that as the tendency of the whole cumulative mass of varied matters which form the body of the earth, with its ocean and atmosphere, is toward each other, in virtue of the general law—we may say the universal law—of gravitation, so every individual kind of matter has, in all its atoms, and wherever they are situated, a tendency to union and solidification, which is as true and constant to matter in its individual kinds, as gravitation is to the whole mass of matter generally.

Thus are many substances in which we have no positive effect of the operation of this principle, and we have mentioned the air as an instance of one which does not, under any circumstances, become solid, or even liquid, in its entire substance; but this is no good argument against its *tendency* to do this, and we have direct proofs that all the constituent parts of it can not only pass into the liquid or the solid state, but that they have an inherent and indestructible tendency to pass into this state, and would so pass were it not that they are prevented by the operation of causes external of themselves.

What this final state to which every kind of matter has an inherent, constant, and indestructible tendency to pass, unless hindered by something external, may be, we cannot tell with that precision which is the result of direct experiment, because we have no means of observing every different kind of substance in this state; and farther, we know that substances, even when simply or mechanically mixed, as is the case with the constituent parts of the atmosphere, can, by some singular affinity, of the operation of which we know even less than we do of the action of the parts of the same substance from each other, be restrained from combining in that intimate manner in which they would combine if uncontrolled by any thing from without, and left to the free exercise of their own properties.

To what extent the mere fact of the mixture of its constituent parts, without any effort or chemical union, may affect the atmosphere, we have not the means of ascertaining; and whether, if this simple union were dissolved, each of the two great constituent gases of which it is made up would, in the case of their separation from each other, either enter wholly into new combinations with other substances, or become solid or liquid by the force of its own principle of aggregation, we are also unable to tell. But we can see enough in the constitution of the atmosphere for enabling us to judge how beautifully the system of nature works, and with what perfection every member of the great system is adapted to whatever function it is required to perform in combination with the others.

The state of the air, when we reflect upon it with sufficient attention, shows us much more than this, by giving us an insight into the laws of nature which we might probably not be prepared to expect. Taking the atmospheric fluid as a whole, we may look upon it as a substance in which the power of aggregation is completely suspended; and that, while both its constituent parts have the faculty of entering into close and intimate union with other matters—and for aught we know with their own parts—in solids, they have, in the atmospheric fluid, a constant tendency to recede from each other, and diffuse themselves, in equal proportions of the two parts, in any space where this expansive tendency can act without restraint. Thus, for instance, when a jar is placed on the table of the common air pump, so that no air from without can enter it, and the air from within is pumped out by the action of the instrument, the small portion of air which, as a matter of course, remains after the most laborious working of the best pump, is diffused with perfect uniformity throughout all the jar, not only in respect of its quantity as matter, but in respect also of the relative proportions of its two constituent ingredients. Those ingredients, when we obtain them singly, which we can do by the direct decomposition of the air, as well as by other means, are not of the same specific gravity with each other, for the one of them is bulk for bulk heavier than the compound atmosphere at the same degree of temperature, and the other is bulk for bulk lighter than the same. They are, as we have said, simply mixed with each other without any chemical effort, and it is evident that they are so intended, in order that the very feeblest creature in nature may separate them as its necessities require; but still their different specific gravities, or weights in equal bulks, have no tendency whatever to separate this simple mechanical union; for it is vain to attempt, by any merely mechanical process—any process which shall not by a more powerful chemical affinity draw one of the constituent parts into a new compound, to separate the one from the other, or to alter their relative proportions. But, though we find that what may be considered as the power or principle of aggregation in those constituent parts of the air is completely subdued, and that there is really no nameable principle of cohesion to retain the one part in conjunction and most intimate mixture with the other part, not one jot of the gravitation of the one, the other, or both together, is in the least degree destroyed.

It is especially worthy of the notice of all who would wish to have a knowledge of the general principles and working of the system of nature, to observe which portion it is, of what we may consider as the characteristic properties of the different kinds of matter, that gives way with change of state, is most powerful when the substances are solid and as we may suppose under the full operation of their own principles, and completely suspended when they are in a state of gas. Now, from the few details which we have given, and which are founded upon facts open to every body's observation, it will be perceived that the only property in matter which remains permanent and unchanged in all states, is that single and universal property to which we give the name of gravitation. All the other qualities or tendencies, which include the whole of those which give to all the different kinds of matter their specific appearances and their varied uses, are destroyed when the substance is in the aërial state. It forms no mass, either palpable to the touch, or discernible by the eye or the microscope; and, be the substance what it may, when once it is brought into the state of air, it may be said to be perfectly passive in its form, and, considered simply as matter, entirely under the dominion of gravitation, but under that of no other law, excepting such laws as may be imposed upon it by the operation of causes from without.

Indeed, the gravitation to which a substance in the state of air is subjected is also external of itself, though it is always in proportion to its quantity, and never varies but with variations of that, or variations of distance from the centre of gravity in the mass of matter by which it is attracted. Thus, in the atmospheric air, we are not to suppose that, leaving out the influence of heat and light and that class of causes upon it, and also putting aside, for the sake of obtaining a simple view of the foundation, all those actions of individual substances of which the atmosphere is the locality, the instrument, or both, the gravitation of its whole mass toward the earth is the only property which we consider common to it all, and constant to every part of it at all times. In every other respect the air is always ready to obey any impulse whatever that may be given to it, and it is this perfect obedience, as the constituent principle of its nature, which renders it so exceedingly valuable in all that goes on upon the surface of the earth, —which enables it to yield to all actions of heat and of pressure, to give way to all substances in motion, to carry living nature, as it were, upon springs of the most perfect elasticity, and yet to preserve, amid countless thousands of actions, its equilibrium and stability at every place.

We are not warranted in saying that the particles, or portions into which the compound air as one fluid, or either of the two gases which form its constituents, is divided, are of any assignable magnitude, because no instrument, and no contrivance of man has been able, or is likely ever to be able, to take cognizance of one of those particles in a separate state. To us air seems perfectly limpid, and equally so in all the degrees of density, or quantity in equal bulks, in which we have the means of examining it. We can condense air by means of instruments, of which a common pair of bellows afford a familiar though very partial instance, which is much better exemplified in those powerful blasting cylinders that are used at our great manufactories of the metals, and of which we have direct evidence in air-guns and engines of that description, in which the air is condensed to such a degree, that the spring with which it re-acts against the common pressure of the atmosphere, when set free so to act, propels a bullet or other missile with the same velocity and force as is imparted by the ignition of gunpowder. We have also the means of rarefying or expanding air to almost any number of times its natural volume that we may desire, by enclosing it in a small quantity in a close vessel, and applying the requisite degree of heat, and also by exhausting an air tight vessel as far as we can, on the table of an air-pump, which is an instrument contrived for pumping air out of vessels, upon nearly the same principles as the common pump, used for domestic purposes, pumps water out of a pit. Between those extremes at which we arrive by experiment, though it is impossible to tell how far we may be from the ultimate extreme either way, we have an endless variety of degrees of density produced by the action of external causes. In each and all of these, however, we find the same uniformity of structure in the air, the same appearance of one simple substance, uniform in all its parts, in as far as our most accurate observation and experiment can extend; and, unless under different actions of external causes, or different distances from the earth's centre of gravity sufficiently great to occasion differences of weight or gravitation toward the earth, in the same quantity of air in one place from what there is in another (and these do not come much within the limits of contemporaneous local observation,) we have the air distributed with so much uniformity through the space which it occupies, that we cannot say, from any result of observation, that there is any pore, interstice, or opening, any where within its volume, of large dimensions when it is expanded and thereby attenuated to the utmost degree which our experiments can reach, any more than when it is under the strongest pressure, and therefore condensed or thickened to the utmost that our ingenuity can effect.

Thus, though we are perfectly sure that the atmosphere—that is, the air which forms the chief parts of the atmosphere—is made up of two separate ingredients, having very different actions upon other substances, and varying in specific gravity, when we obtain them alone and weigh them under equal degrees of heat and pressure; yet we find that with the very nicest extent of our observation, this mechanically compounded air yields equally throughout all its volume to the action of any cause which exercises equal energy upon it, whether that cause tends to condense it into smaller space or to expand it into greater.

But though this perfect uniformity of substance in all states be the only conclusion to which our observation leads us, yet we know that there must be, in reality, interstices or divisions without end in this atmospheric mass; and that, in consequence of the very fact of its existing in the state of a gas, there must not only be no cohesion, or active tendency to cohesion, between its ultimate and invisible particles, but that there must be the action of some repelling cause treasured up within its volume, which has a constant tendency to force those ultimate and invisible particles farther from each other, and would so force them, if not restrained by the operation of some opposing and counterbalancing cause. Farther, we can see that it is this cause which tends to operate separation of particle from particle, which has brought the substance of the air into the state of gas, and which keeps it in this state. Nor is it difficult, from the analogy of many other substances, or rather changes of the bulk or volume of substances, which are familiar to our every-day observation, to determine what this cause is.

But before we proceed to do this, it may not be amiss to collect together, for the purpose of more readily remembering them, the conclusions at which we have even now arrived, with regard to the several agencies which preserve the atmospheric fluid in a state of gas, under all natural circumstances with which we are acquainted.

In the first place, there is the general tendency of gravitation, by which the whole mass of the atmosphere is drawn toward the volume of the earth, which acts upon every particle of it, and which acts constantly, and would bring it to a perfectly uniform spheroid, answering to the form which the earth would assume, were it not for the operation of other causes.

Secondly, we have the attraction of cohesion, or tendency which the particles of the atmosphere have towards each other, and which, were it not opposed and suspended by the action of some other cause, would act, and make the atmosphere pass into the liquid, and then into the solid state. But as the atmosphere, in its present compound state, does not, under any circumstances with which we are acquainted, become a solid, or even a liquid, we must suppose that this *attraction of cohesion*, as we may call it, which is suspended but not destroyed, is two-fold,—a distinct degree or portion of it belonging to each of the two component parts, the *oxygen* and the *nitrogen*—of the nature of which we shall have to say something more in another section. How far the attractions of cohesion of these two substances may be modified, by the mechanical mixture of the substances with each other, we have no means of ascertaining; but we have instances in other cases in which mixture destroys cohesion. For instance, if a piece of the toughest iron is rubbed with sulphur when red hot, it becomes quite brittle; and a very small portion of tin mixed with silver destroys the cohesion of the latter metal.

The extent to which the mixture of the constituent parts of the atmosphere may effect their cohesion is unknown to us; but we do know that a mixture of the same ingredients, in different proportions, can become a liquid. Thus the constituent parts of nitric acid are the same, though not in the same proportions as those of atmospheric air; and nitric acid is a liquid, and a substance capable of exerting very powerful action. We have some reason to believe that the mixture of nitrogen diminishes the tendency to cohesion in oxygen just in the same manner as the mixture with both tends to lessen the cohesion of water when floating in the air in a state of invisible vapour; but there is difficulty as well as obscurity in this part of the subject, inasmuch as we cannot bring it to the test of experiment.

Thirdly, there is the action of that cause by which the cohesion of the air, and of its constituent parts considered singly, is suspended; and the action of this cause, whatever the cause may be, not only prevents the consolidation of the mass into one compound—in the state of a liquid or a solid, and also prevents the same result from taking place in one of the component parts without the other, but in so far counteracts the gravitation of the substance of the air, considered as mere matter, and without any reference to an attraction of cohesion which can belong to or determine the nature of any particular substance.

Thus, we may consider the compound mass of the atmosphere as being under the influence of three distinct active agencies—gravitation toward the centre of gravity of the earth, the attraction of cohesion of the particles of each of its constituent gases towards each other, and that which we may call the agency of repulsion, which counteracts the other two, and preserves the atmosphere in the state of gas. To these three, there may, in consequence of the two cohesions, be added a fourth agency, which we may call the passive one,—namely, that agency on account of which the oxygen and the nitrogen do not separate from each other. This agency may be called passive, in order to distinguish it from those tendencies to unite which form component parts into chemical compounds, that is, compounds which cannot be formed or dissolved without the action of some power.

This last, passive as it is, is very important in the structure of the atmosphere, and in the operations which that structure is one great means of bringing about. The agency to which we allude is, in all probability, that of which one particular case has got the name of *capillary attraction*,—that is, the attraction which exists between certain liquids and the internal surfaces of small tubes, as, for instance, a tube with a bore the thickness of a hair, (*capillus*.) If such a tube, open at both ends, is placed upright, with the lower extremity in a basin of water, the water will rise in the bore of the tube to the very top, if it is small enough and not too long. We are not, in the mean time, called upon to examine the particular phenomena of this capillary attraction, or to detail any of the experiments by means of which the fact of its existence has been established, and the phenomena of its action illustrated. That it is a distinct action—a proof that there is in certain substances a capacity of bringing about a result which is not the effect either of a mechanical or a chemical cause, is all that is necessary for us to show. But as this, simple though it seems, forms an exceedingly important part of the doctrine of the air, considered as the vital element of growth and life, it is necessary to have a clear perception, not only of this agency itself, but of the distinctions between it and those agencies which are either mechanical or chemical. For this purpose we may mention in two words what is meant by these two terms.

Mechanical, from a Greek word signifying what we call a "machine," means any agency which so acts upon a mass, or measurable quantity of matter, as to move it in some direction as a whole, to alter its shape, or to divide in pieces, which pieces, however they may differ in form, are yet the same in substance with the mass of which they are pieces. It is of no consequence whether the mass of matter which is acted upon mechanically be large or small, or whether it be in the state of a solid, a liquid, or a gas; for this mechanical action applies equally to all kinds of matter in every possible variety of state in which they can exist.

Chemical, from a Greek word which means "the secret," is applied to all agencies which act, not upon the mass but on the elementary particles of matter—those primary atoms which neither observation nor comprehension can reach, and yet of which it is impossible for us not to see that all matter must be made up. The evidence of this constitution of matter is complete in the very fact that every kind of matter, in its compound whole, or its constituent parts, can be changed into a viewless gas, in which no observation can discern the least distinction of parts; and in which state, therefore, we may suppose that in any substance—in atmospheric air for instance, though the volume may not be bigger than a pin's head, there are incalculably more of those mysterious little atoms than there are drops in the ocean or particles of dust in the earth. As action of this kind reaches down to elementary portions of matter, which are small beyond all means of expression and all power of comprehension, farther than the simple fact that they do and must exist, and are the real elements of all matter—in fact, substantially matter itself, it is with much propriety called "secret;" because, the foundations of it we cannot reach, though the effects both in nature and in art are of the utmost importance.

If these definitions are understood, it will also be understood what is meant by an agency, which displays its effects in matter, and which is neither mechanical nor chemical. It cannot act upon the mass of any substance, for in that case it would be mechanical; and it cannot act upon the elementary atoms as substances, because in that case it would be chemical. The question, therefore, is, what farther does there remain connected with matter upon which to act? We ask the reader to look at any thing—any substance—the paper of this page for instance, considered merely as so much material substance: what is there in it? In the first place there is the substantive mass which, taken in whole, we call a leaf of paper; then, there are all the various chemical agencies which give this paper its texture; but there is something additional—there is the *surface* of the paper, that which receives the impression of the inked types; and this brings us exactly to the subject of this which, for want of a better name, we have called a passive agency, and one case of which is capillary attraction.

When the water rises in the capillary tube, it does not rise mechanically, because the only mechanical influence which it is under is gravitation, and the action of this capillary attraction is in direct opposition to gravitation. And we have evidence that gravitation is, in the end, more powerful than this capillary attraction, for the ascent of the water is limited; even the smallest tube becomes of less and less weight as the bore of the tube is wider; and beyond a certain width, which is of course matter of experiment in the case of every kind of tube, the water does not rise at all. Thus, if the cylindrical chimney glass of a common argand lamp were placed upright, with one extremity immersed in water, the water would not rise in it, but still it would form a little elevated ring round the surface of the glass, both outside and in, and very nice observation might probably discover that the inside ring was a very little higher than the outside one; clearly proving that, though the power of capillary attraction to raise the water had been subdued in the wide tube, it had not been destroyed.

It is hardly necessary to point out by what force this capillary attraction is gradually subdued as the tube is wider, because there is no agent whatever to which it can be referred but gravitation—the tendency of the water to maintain its level; and as this increases in proportion to the increase of the section of the tube, while the capillary or surface attraction increases only as the circumference, it follows that gravitation increases as the square of the tube's diameter, while the capillary attraction increases simply as the diameter.

We are sure that the reader has anticipated not only that this fourth agency in the atmosphere, and third general kind of action throughout nature, is to be of very considerable use to us in examining the phenomena of the air, but that he has anticipated the very use which we are to make of it,—that it is this silent surface action, which is neither mechanical nor chemical, which fetches back from the sea the water which the rivers carry into that grand receptacle, spreads it viewlessly and floating lightly, in the air at every elevation, without the slightest tendency to fall to the earth so long as the state of things remains at rest and undisturbed, but ready to become dew, or rain, or hail, or snow, according to circumstances.

We shall afterwards have occasion to examine this principle more minutely, when we come to consider the natural action of the atmosphere; but as much at least as has been here stated appears to be essential to a proper understanding of the air as existing in the state of a permanent gas.

SECTION III.

RELATION BETWEEN HEAT AND THE STATE OF BODIES, ESPECIALLY THE AIR.

There is no phenomenon in nature more intimately connected with the successful performance of many of the most useful processes in the arts, with a comfortable enjoyment of life, or with a ready understanding and correct knowledge of almost every species of natural action, than that to which we give the name of heat. Consequently, there is nothing which more demands our attention, if we wish to improve that talent for acquiring knowledge which our Maker has committed to our charge, and for the manner of our employing which he himself has declared that he will most certainly call us to account. The express declaration of Him who cannot lie, is, that if even the smallest endowment of talent is hidden in the earth of ignorance and error, then it shall be taken from the sluggard who thus neglects the bounty, and given to him who has made the greatest and most profitable use of even the largest endowment. There is much in this declaration, and it is somewhat singular that though the original word rendered "talent" means a sum of money, and as such is used metaphorically, yet that we use the same word "talent," as expressive of the real meaning which is conveyed in the metaphor. No doubt that metaphor has a more extended sense than as applied to the acquiring of knowledge; but this is one sense of it, and it is the only one which properly lies within our province. And we may, in passing, remark that, in as far as the improvement and the neglect of the talent in the acquiring of knowledge is concerned, the retribution comes fully in enjoyment upon him who improves, and fearfully in retribution upon him who neglects, even in the present world. Very slight observation made in any place, or in any class of society, is sufficient to give the observer demonstration of this. Take the ranks of life, from the highest to the lowest, and say who are the men that, though they may not hold any influential situation, or issue a single word of command, yet rule and govern their class, not in matters of opinion only, but in matters of action. Society, from all its gradations, will answer with one voice, to which there is no exception, "The men who have improved their talents." We may mention as an instance,—and in so doing we would not be understood as making the slightest allusion to the world's politics or political government, which to us, in our present inquiry, are matters wholly extrinsic—that, whoever shall turn his attention to the British House of Peers, and notice who are they that take the lead there, of whatever party, or on whatever subject, will find that they are they who began the career of life as commoners, and mounted up to the peerage, not by fortune or by fawning on the great, but by the vigorous, effective, and constant improvement of their own talents.

The above remark is only incidental to our main subject, but the evidence on which it rests is so irresistibly demonstrative, and the conclusion which necessarily follows from it bears so directly upon the character, the conduct, and the comfort of man—upon all that makes the world worth living in, that we are sure every reader will pardon its interpolation. He would do this the more readily that, in whatever place of society the lines of his own lot may be cast, this principle holds out to him more encouragement, and encouragement the truth of which is the more palpable, even to the most casual glance, than can be obtained from any other nameable subject of a merely moral description. But to return to the subject of heat:—

On this, as on every other subject, the foundation of which is laid in perception by the senses, it is necessary to have a clear understanding of the term made use of, in order that that which we express in words may agree fully and perfectly with that which we mean in thought. Want of attention to this apparently very simple and obvious truth is the cause of one half of the mistakes and errors which, without any mixture of perverted intention, tend so much to the folly and the consequent misery of society; and therefore it is always well before we make extensive use of a name, as the foundation of explanation or reasoning, that we should place in as clear light as possible the reality of which we are to use that name as the symbol.

In every case of this kind, there are four distinct considerations embodied in the use of the name, and that name may be used either substantively, as expressive of the fact of existence or occurrence, or adjectively, as expressive of either, considered in the relation of a quality. First, there is the effect produced on the organ of sense, or the *sensation* as we call it; secondly, there is the *state* of the body or substance with which the organ of sense comes in contact so as to produce the sensation; thirdly, there is the *cause*, or agent, or energy, whatever it may be, that brings the body or substance into that state by which it affects the organ of sense; and fourthly, the *action* of the cause. Thus, when there is a fire burning in the grate, we put our finger upon any of the plates of metal by which the immediate receptacle of the burning fuel is supported, and we say that we feel "heat," that the metal plate is "hot," and that it has been "heated" by the "fire." These words embody all the different meanings: the first one is expressive of our sensation; the second one is expressive of the state of the substance which occasions that sensation; the third is expressive of the action of the cause; and the fourth is expressive of the cause itself.

It is obvious that when we would examine nature generally, it is to this last one, the cause, or antecedent, of the state producing the sensation, that we must direct our chief attention. Our feeling depends upon the sensibility of our own organs, and the state of our own body at the time; for a blacksmith or a glassblower can handle, with impunity, and without feeling that they are at all hot, substances which would not only strongly affect, but absolutely burn, delicate fingers. So, also, if water is just a little warmed, say to the temperature that we call milk-warm, if two persons, one of whom has been spreading out his hands close to the fire, and the other has been motionless out of doors, in the rigour of a mountain frost, shall plunge their hands at the same instant into the water, the one from the fire will pronounce it to be cold, and the one from the frosty air will pronounce it to be hot. Not only this, but one individual may, in his own person, and at the same instant, experience this double sensation. If two basons, one with cold water and the other with water as warm as the hand can bear, are taken, and a hand plunged into each, and kept there for some time, and if then the hands are changed from bason to bason, the hand from the hot water will, with difficulty, be able to endure the apparently intense cold, and that from the cold water will feel the intense heat equally unpleasant. Not only this, but if we take the well-known case of three basons, with hot, with luke-warm, and with cold water, plunge one hand into the hot, and the other into the cold, keep them there some time, and then plunge both instantaneously into the luke-warm, the hand from the hot water will be chilled, while that from the cold water will feel agreeably, or, if the water has been ice-cold, rather painfully hot.

It is necessary to understand this, to prevent us from making our own sensations the standards of absolute reality, and it is just as necessary to guard against that particular state of bodies which produces the sensation; for, as we have no knowledge of the state but by means of the sensation, the one cannot be more correctly true to the reality than the other.

It is different with the cause; that may be considered as being universal; and, as different conditions of our organs of sense give us different notions of the intensity of its action, or, which is the same thing, of the effects which that action has produced, it is of course liable to the same uncertainty, we should endeavour to obtain some means of judging of the nature of the cause, or of the general effects which it produces, without any reference to our sensations. In this way, that which we call heat, meaning thereby the cause of heating, must be supposed to have a much greater range in its action than any of which our sensations can take note. This is in strict analogy with all that we can understand of the constitution of matter. We have mentioned, and indeed the fact must be obvious to every one without any express mention in words, that every kind of matter, be it what it may, must be understood as made up of elementary particles, or atoms, which are, to our consideration, infinitely minute—it being understood that the word "infinite," in this case, means merely such a degree of smallness as stands utterly beyond all our powers and arts of observation.

Now it requires no argument to prove that if matter, in all its forms and in all its varieties, according to our notions of them, may be, indeed must be, made up of elementary particles or atoms which to us are infinitely small, action on matter, of whatever kind it may be, and the effect produced by that action, must be ultimately divisible with the same degree of minuteness; so that the effects of any cause acting upon matter must become in their smallest amounts, as it were, just as invisible to our observation as the elementary particles of matter itself. This must hold true, not of one kind of action only, but of all kinds of action; and, whether we consider it as gravitation,—which tends to bring the particles of matter nearer to each other, in proportion to their gravity, and without any reference to their kind,—the aggregation of matter, which brings the atoms of the same kind of matter into the arrangement which we call a simple substance, or two or more into that which we call a compound,—or if it be merely that tendency of surfaces to remain near each other without any chemical action, of which we have mentioned that capillary attraction is one case: And, it must hold equally true of any other action, or cause of action, whatever, which tends to separate those elementary particles farther apart, or in any way to move them from the places which they hold at the instant. This follows from the very constitution of matter; for, as matter is the only thing upon which material action is told to our comprehension, it follows that there must be just as much of the minute of action too fine for our comprehension as there is of the minute of matter; and this must be true of every kind of action, of what nature soever it may be, and of what description soever its effects, when multiplied up so that our senses or our instruments can take cognizance of them.

It matters not what is the action, or what the result when it comes to its full development. It may be the consolidation of a globe, such as the earth, out of matter so far dispersed over space and so thin that a volume of it larger than any thing which we can measure or name would not amount to the millionth part of the smallest grain of sand: and, as space is boundless, and the extent to which gravitation extends is equally so, (at least to our comprehension in both cases,) this may be the mode in which new worlds are formed out of the ruins of former ones, which have been scattered over space in an ethereal fluid, fine beyond all comprehension—beyond the ken not only of man but of the superior intelligence of the brightest spirit which is before the throne, and thus known only to Him who is All-seeing as well as All-powerful;—but here the curtain is drawn to our view, and we may not, we dare not, attempt to lift it. It may be the first formation of a little crystal, whose congregated multitude shall stand up in some giant mountain, looking athwart hundreds of miles of the land and the sea; it may be in the accumulation of the first misty drop, more fine than the lightest "rack" which floats in the upper air, but which is in due time to congregate and ripen, and condense into the mighty flood of the wide-rolling ocean; it may be the first movement of young growth in a plant—the primal impulse of that oak which is not to become even an acorn till a thousand years have passed away, and ten successive generations of the forest have mouldered in the dust; or it may be the yet more mysterious germ of animal life, which stands secure in the law of its Maker, though ten thousand generations of its race may pass away ere it comes to its final development, appears on the earth, inhales the breath of life in the air, performs its appointed functions, and then is gathered to the dust; it may be any, or it may be all of these, or any other of the countless thousands of actions which take place in nature; and yet, if we attempt to trace it backward to its rudimental beginning, it not only eludes the sense, but sets the imagination at defiance. As it is written, God created all things out of nothing; and it is a most striking confirmation of this sacred truth, that we can follow not only substantive matter, but all those actions to which the various forms and changes of matter are owing, down to the very bourne of nothingness. And there is knowledge even at the very verge,—at that mysterious boundary where the mists of oblivion begin to thicken around the mind; for here we find all matter tending to one simple elementary form, and all action of matter tending to one simple elementary effort; nor can we help being equally astonished and delighted by the extreme simplicity at which we thus arrive, and the magnificent system which has been thence produced.

It is necessary to take this elementary view of matter, and the action of matter, in order fully to understand under what circumstances the different kinds of matter which present themselves to our observation exist in particular states; and it is especially necessary to an easy and accurate understanding of the working of the atmosphere, or of those bodies which may be supposed to act upon its substance. Those actions especially which are properly styled chemical, and of which heat—that is, the cause of heating—is one, are to be understood as commencing at the elementary atom; and as, in this atom, wherever it may be situated, gravitation, being measurable by the atom, is necessarily as minute as the atom, the least force, or exertion of any cause of action upon the atom, must be sufficient to produce the first, or elementary effect. So also, as the attraction of aggregation reaches the primary atom, it must be as minute as that atom; and therefore the slightest imaginable action of any cause which works contrary to this attraction must be sufficient for producing the first, or elementary effect. Therefore, throughout all nature, in all its variable productions, we can perceive that the slightest possible variation of the action of heat—a variation so small that it would, in all probability, require to be multiplied millions of times before any sense or instrument of ours could discern its effects—must produce some change of state, as regards cohesion, and also as regards gravitation, in an equal bulk or volume of the substance. This is, of course, a part of the subject upon which we can make no experiment, because we are unable to make any observation; but still we are warranted in concluding that the very slightest increase of the action of heat upon any body or substance, be that body or substance what it may, must increase its volume; and that, on the other hand, the very slightest diminution of heat must be attended by a diminution of the volume of the substance. These changes take place without the slightest variation of the quantity of matter; and it depends upon the particular constitution of the kind of matter,—the attraction of cohesion, if to our understanding it is simple, or the attractions of combination in the several parts, and in the elementary atoms of each part jointly, in the case of any body which we have ascertained to be a compound.

The phenomena of the change of volume must depend upon the strength of this attraction of cohesion, whether we consider it as simple or as compound. If it yields without any resistance, or with a resistance lower than the least of which we take cognizance, then, how much soever the body may be expanded, and its volume augmented, there will be no display of sensible heat. But if the resistance comes within the sphere of observation, then there will be sensible heat in proportion to the degree of contest between the heating cause and the resistance; and as, from the endless variety of substances, and the endless degrees of strength of cohesion in them, and also from the unlimited variations of intensity in the action of heat, the degrees of sensible heat which substances display in their various states and various changes are beyond all powers of arithmetic to remember.

There is another consideration which it is as well to bear in mind, lest we should be betrayed into error by the use of our common language. The commencement of the effect of heat is too minute for our observation; and it follows, of necessity, that the steps of its increase must also be individually too minute for the same. We shall suppose, for example, that one of the most stubborn substances in nature, the metal *platinum* for instance, or some of the pure earths, is not only as cold as the severest temperature of a mid-winter in the polar regions of North America,—where quicksilver is a solid,—but that it is any imaginable degree colder than this; and that heat is applied to this substance until it not only gets to a red or a white heat, but till it melts into a liquid, and, after that, passes into a state of gas,—for we have every reason to believe that, under sufficient pressure and heat, every substance of nature could be melted into a liquid, and, under sufficient absence of pressure, pass into the aërial state. There must obviously be in this extreme case an immense range of the heating energy; and we can have no idea of the intensity of a heat which would turn the pure earths into limpid fluids, from any thing that we can observe taking place in the atmosphere. Of this, however, we are certain, that, whatever were the phenomena of the substance, the increase of the action of heat would be not by degrees, or step by step so to express it, but an unbroken increase. It is necessary to attend to this, because when we speak about comparative intensities of heat we always speak of them as measured in degrees; and as we thus speak of heat, there is some danger that those who do not know the extreme fineness of its progress, and the impossibility that there is of marking any definite step in that, would infer that there is some distinction in the changes of heat, between one degree and another, as indicated by the thermometer; whereas, the degrees of that instrument are merely certain definite portions of the increase in volume of the fluid which it contains, as produced by greater action of heat, or conversely of the diminution of volume produced by less action.

It is true that, when we come to particular substances, there is a great variety in the sensible results which arise from the application of the same heating cause; and almost every substance, whether simple or compound, has its range of temperature, in each of the three states, different from every other substance. This may be expected, from the different degrees of cohesion which the particles of different substances have, and which form part of their distinguishing characters, as substances. There is none which has not some power of endurance in each of the three states; and there are many which maintain one state throughout every degree of the action of heat which we can apply. Thus, for instance, there are no means by which atmospheric air, taken as a whole, can be obtained in any other state than that of gas; some earths, and other substances, cannot be obtained in any state except that of solidity by any ordinary operation to which we can have recourse; and alcohol, or pure spirit, though it readily passes into vapour, cannot be made solid by any treatment of it as one simple, unmixed, and undecomposed substance.

The general fact is, that all substances which, at natural temperatures, are solid, endure a certain degree of the action of heat, which is determinable by experiment for each particular substance, before they lose their solidity, or melt, as we term it. But the instant that the temperature answering to the melting point of the substance is arrived at, the melting takes place, and the substance, if its volume is increased in melting, becomes cooler. So also substances, which are naturally in the state of liquids, resist the action of heat, and maintain the liquid form, under greater or less variety of temperature, according to their different natures; but still, in all, or in most of those with which we are acquainted, there is a certain point—some definite degree of temperature, at which it passes into the state of gas. This change is always attended by an increase of volume, and the consequence is, that the gas is always sensibly colder than the liquid from which it is produced, indicating that a certain portion of the action of heat is required to maintain the gaseous state, and also that sensible heat, in all its degrees, and in all the different effects which it produces, is the effect of resistance to action. Hence it follows that, if there were no resistance to action, there would be no perceptible heat; and that the sensible heat produced by any heating agency upon substances, must always be in the exact proportion of the resistance which they oppose to that action. What the degree of this resistance is, in any one particular substance is a matter which must be determined by actual observation; because the natures of substances, and the degrees of cohesion by which their particles are held together, are so exceedingly various, that it is impossible to reduce the general law to any numerical formula, although, in as far as observation can be carried, we can always determine the particular case; and this is, of course, all that is necessary for practical purposes. As we find no exception to the law, in the case of any one substance which we can see changed from one of the three states to another, we have all the reason which can be obtained, in any general case of the philosophy of nature, for concluding that the principle is universal, and that there is no substance in nature to which it does not apply; nor is there any one case in which the heat which is apparent —that is, the temperature to which the body must be raised before it passes from solid to liquid, or from liquid to gas—is not an exact measure of the resistance which that body offers to the action of heat.

From what has been said, with regard to the limit of our means of observation lying far—to our comprehension, immeasurably—within that to which the minute division of matter extends; and, from the great agencies of nature—gravitation, cohesion, and the others—reaching to the elementary particle, and acting upon that, it follows that there can be no substance on the surface of the earth, or in the volume of that planet, or probably in the whole material universe, which is in the state of what may be called final and absolute cold, or upon which the action of heat exerts no influence; so on the other hand it is equally probable that there is no substance which is perfectly under the dominion of repulsive action, and has its gravitation and cohesion entirely destroyed. We can conceive, that at what we may call the cold end of the scale, the action of heat, in a substance, may be so small, as not only to be beyond the scrutiny of our instruments, but to be indefinitely and immeasurably small—to be at the very vanishing point, as it were, but not to vanish altogether. When this is the case, it is equally evident that the antagonist powers—those which tend to consolidate the substance—must be a maximum, not infinitely great, but, as one would say, on the very verge of infinitude. In like manner, at the other end of the scale, at the greatest degree of expansion which we can imagine to take place, and which we must regard as being immeasurably beyond any which we can actually observe, we can imagine the cohesive agencies to be immeasurably small, not actually reduced to nothing, but brought to the very verge of nothingness. These are the limits between which the state of every substance in nature, whatever may be its form, the function which it performs in nature, or the use to which it is applied in art, must be found. They include the whole scale of action, as affecting the state of matter, from the bottom, or, as we call it, the cold end of the scale, to the top, or the warm end, as we call it. But as is the case with every thing in nature, when we generalize it, we are able to see only a part; and how small a fraction of the whole this part may be, we have, of course, no means of ascertaining; and it is necessary for us to bear in mind that we have no such means, because this is the grand precaution which keeps us within the limits of possibility. Nor must we be at all surprised that the scale of natural action, as it affects and determines the state of bodies, should thus extend both ways immeasurably beyond our comprehension; for this is not the solitary instance; on the other hand, it is one more added to those cases of immeasurability, and extension beyond our knowledge, and our possibility of knowing, whenever we take a general view of any subject, substance, being, or agency whatever. We, for instance, speak of the meridian, or north and south line, as being extended in the direction of those points. We have an instance of a short line lying in this direction in the twelve o'clock line of a common horizontal sun-dial when it is accurately set; and we may extend this line a good many yards, and probably a few miles, along the earth's surface; but considered as pointing out the general direction of north and south, where shall we find the ultimate north, or the ultimate south, so as to be able to say that here the line ends, and can extend no farther? We cannot imagine this; for if we assume the lowest distance which numbers can express, and imagine we have arrived at this distance from our present position, we find that we are just as much at the central point of the line in our new and imagined position as we are in our observed and real one. The coincidence between the extension of space, and the variations of the state of matter, which here presents itself to us, strongly tempts our thoughts to withdraw from our own earth and its atmosphere, and look upon that mighty system of nature, in which our earth is placed, less, as compared with the whole, than the lightest mole is, as compared with the sun-beam.

We have mentioned the action of heat as the cause by which the condensing and consolidating principles in matter are counteracted, and the differences of state which we observe in matter is produced; and we have done so because, though natural action, as opposed to gravitation and cohesion, presents very different appearances in different substances, and under different circumstances, yet there seems so obvious an affinity, so complete a resemblance between the principle, in all those varieties of action, that we are warranted, not only for the sake of simplicity, but upon grounds the most philosophical, to consider the original energy as in kind one and the same in every case. Even though this should not be strictly true, there is no great error committed, because every individual case must depend upon itself, whatever theory we adopt; and simplicity is always an advantage, especially to those who are beginning the study of any subject.

Under this term, heat, we include all those kinds of natural action to which the names of expansion and its continuation to a state of the most rarefied gas, of electricity, galvanism, vegetable and animal life, and every other species of operation, by means of which gravitation and cohesion, especially the latter, are in any way counteracted or changed; and if the circumstances of any particular substance are such as to require a secondary epithet, as expressive of those particulars in which they differ from the others, then this may be considered as a modification of the general principle.

In as far as the state of substances is concerned, after they are once brought into any particular state, by the operation of this cause of general action in nature, there of course ceases to be any observed action; and though there is evidently a certain portion, so to speak, of this action remaining within the substance, and maintaining the particular state in opposition to those condensing or consolidating energies which would change the state if this action was withdrawn, yet this action is completely subdued, so that it is not discoverable by any test. It is often called the *latent heat* of the substance; and the degree of the action of heat which it requires to keep any substance in any particular state, is called its *capacity for heat*. But though this latent heat, upon which the state of the substance depends, is not sensible to any test that can be applied, so long as the state remains unaltered, it is no more destroyed than it destroys the cohesive principle in the substance. Thus, when a piece of ice is melted into liquid water, a certain degree of the action of heat is required, in order to keep the water, or substance of the water, liquid; and when the melting takes place in the free air, there is a considerable degree of heat abstracted from surrounding bodies through the medium of that; and the melting of the ice thus produces cold. This is the reason why, when it has been frost during an autumnal night, and the frost suddenly gives way in the morning, the air feels so much more cold, or raw, as we express it, than when the frost continues, and only yields gradually to the direct action of the sun. The sudden melting of the frozen portion on the surface of the earth drains the lower air of a considerable portion of that action of heat which is sensible in it, or exists there in addition to the latent heat which preserves the air constantly in the gaseous state. When the heat is thus abstracted, the lower portion of the air is no longer able to hold in vapour the same quantity of moisture. The whole air sympathizes, so to speak, with this lower stratum, and the cold feels its way upward through the whole mass of the atmosphere; or rather, the atmospheric heat, the equilibrium of which has been disturbed by the cooling of the lower stratum, restores that equilibrium; and thus the atmosphere is no longer able to support the same quantity of moisture, and the result is, the precipitation of that moisture and rain, until the equilibrium is restored, by the discharge to the earth of all that quantity of moisture which the air is unable to support. In a future section we shall have occasion to examine upon more principles, and with more detail, the general phenomena of rain; but we mention this in the meantime as an instance of the effect which is produced upon the air by the consumption, so to speak, of a certain portion of the action of heat, in the operation of turning solid ice into liquid water.

After the action of heat has changed any substance into the state of gas, there is no farther change of state open to our knowledge which it can produce; and therefore, just as solidity may be considered as the state of the least specific heat,—that is, of the least action of heat diffused through the volume, or body of the substance, and affecting the whole of its elementary atoms,—so we may consider the gaseous state as the one of the greatest action of heat—that is, the one in which this specific heat, or heat distributed through the volume of the substance and acting upon its elementary atoms, is the greatest possible. The liquid state is, of course, intermediate between them; and though some substances have a very limited range of temperature in this state, yet we must suppose that liquidity must be passed through in every change from solid to gas, or from gas to solid.

The solid state may therefore be considered as the state of cohesion, that is, the state in which bodies take their principal characters from the attraction or tendency which their own particles have towards each other. The gaseous state may be considered as that in which bodies take their principal character from the action of heat upon their elementary atoms; and the liquid state may be regarded as a sort of neuter one, in which the body has an equal tendency to obey the attraction of cohesion, or the repulsive action of heat, and become a solid, or a gas, according to circumstances. As the degree of heat at which each state is assumed is not the same in almost any two substances, an endless variety of operations are enabled to be performed at the very same instant, and by the very same cause; so that while the sun shines upon the surface of a country, the influence of his beams produces a countless number of results, and some of them, to all appearance, the very opposite of each other. Some substances are consolidated, some are melted, some are turned into vapour, and some into gas; so that, in consequence of the diversity of nature in substances, there is scarcely one imaginable operation which does not take place; and all the variety, all the beauty, and all the usefulness, which so charms us, and so ministers to our wants, on field or flood, on mountain and forest, and in every thing that lives, or grows, or exists, is all brought about by the operation of one single cause—the beams of the all-stimulating sun.

We need hardly mention—for the reader must at once perceive it—that there will be the greatest sensible heat from the action of the sun-beams, or any thing else which we can consider as a heating agent, in those bodies which have the greatest solidity; and that there will be the least in those bodies which are in the state of gas, and that the same action of the heating cause will tell less as sensible heat upon the gas the more that that gas is rarefied. This, though a very simple principle, is one of very general application, and therefore one which we should carry along with us in all our investigations of the phenomena of nature, more especially of those which belong to the nature of the air, or of which that fluid is the theatre, or the medium; for as we shall afterwards find, the action of heat, by producing more sensible effect upon the denser strata of the atmosphere than upon the rarer, and varying at all times, and in all places, with every variation of density, occasions much of that diversity of climate and weather, and, consequently, of kind and degree of vegetable and animal life, in consequence of which different elevations above the mean level are so unlike each other in their characters.

When, however, we speak of the sensible heat produced by any agent, as, for instance, by the sun-beams, being greatest where the substance is in the most solid state, or most under the influence of the consolidating energies, and least under that of heat, we must be understood as speaking generally of the state of solidity as opposed to liquid and gas, and not particularly of the specific degree of mechanical hardness which there may be in any one substance. This latter is a matter of very extensive detail, and involves all the principles of chemistry, as well as many of those of physical science; so that though what we have advanced is true of all substances in the general sense, yet in practice the same exposure to a heating cause will often make a substance which we consider as being soft to become very hot, while another one which we consider as hard will remain perfectly cold. It is impossible to lay down any specific rules for connecting those practical cases with the general principle, because we are acquainted with no case in which its action is single and simple; and therefore we have no mode of proceeding but by observing what takes place naturally, or by exposing substances to the action of which we wish to know the effects, and observing the results; but, notwithstanding this, the general principle points out the way to us in all those cases; and we invariably employ the action of heat when we want to loosen the cohesion of substances without mixing them with any foreign ingredient. Thus, for instance, when iron is in the crude state in which it is smelted from the ore, and contains so much carbon in combination that it crystallizes, and forms what is called cast-iron, we melt it, and pour it into moulds, by means of which we obtain, at a price which is next to nothing, a countless number of useful and ornamental articles, which, were it not that iron could be so melted, could not be formed by the joint labour of the whole people of Britain, or the world. So also, when, by a process which we need not describe, the carbon is removed out of the iron, and the small crystals are reduced to lengthened fibres by the operation of hammers or rollers, and the iron is brought into that tough state in which it cannot be cast, but must be hammered on the anvil, we use heat in order to facilitate the operation of hammering. If, in like manner, we were to enumerate all the working of metals, of glass, of porcelain and pottery, of all operations in the preparation of food, and in many others which will readily suggest themselves to the reader, the grand instrument, and indeed the only instrument, which we can apply, is the operation of heat. This heat, too, we do not produce artificially,—that is, we do not *make* the heat, though we are accustomed to speak about the processes of heating as being *our* operation. But, if the action of heat, even the greatest degree of heat which we can possibly obtain, is not treasured up in the substances of which we make use, then all our labour would be in vain.

We are, therefore, to understand that the action of heat influences all the elementary atoms of every portion of matter just as much as the principle of gravitation does; but that those two principles, or forces, or whatever we may call them, for we cannot call them substances, are opposed to each other in every degree of their action, and that heat is in like manner opposed to every attraction of cohesion or aggregation by which any two particles or pieces of matter are held together, or kept within a certain distance of each other.

We therefore perceive that, just as in the case of those great masses of matter of which, in the great system, the universe is made up, and of which we have one particular case, the details of which we can so far comprehend, by examining the solar system, each mass, be it sun, planet, satellite, or comet, is held always poised and balanced by the two opposing supports of gravitation on the one hand and motion on the other; just so in the minute system of nature down to the very elementary atom, which is smaller than we can even think, every thing is balanced between the forces of attraction and repulsion, the last of which we have generalized under the one name, heat. Not only so, but, just as the great bodies are left free to perform all their individual functions, exhibit all their peculiar phenomena, and support all their productions and inhabitants, without in the least disturbing, or being disturbed by, those grand general forces which sustain each and all of them as wholes; even so, when we come to the particular details, whether we take them more extendedly or more minutely, we find that they are left free to all those peculiarities of action and production which diversify the earth, and are the means of growth and life, and, in short, of every thing which goes on, at the same time that those actions never throw one single atom off the equilibrium that it has between the attractive and the repulsive action. This is a beautiful unity of the system, in which we know not whether most to admire the magnificently great or the invisibly minute. There is one law given to all planetary matter, which is yet varied to every planet; and, in like manner, there is one law given to every terrestrial substance, whether we call it solid, or liquid, or air, whether it be at rest to our observation or in motion, or whether it be living or dead; but this one law not only admits of, but in itself directly produces, all the countless productions of nature, all their phenomena, and all those properties which so beautifully fit them for the accommodation of each other and for the use of man.

So far as our observation extends, and farther we cannot speak with certainty, the tendency of heat is to distribute itself equally throughout all the productions of nature, so that each of them shall be at all times under the same influence of its sensible action,—that is, of that portion of its energy which there is over and above what is necessary for keeping the different substances in their several states of solid, liquid, and gas, and in the various degrees of those states. Were it not for this superabundant quantity of heat, it is evident that there would, or could, be no action or motion of any kind whatever among those bodies and their parts of which the earth is made up; for if we were to suppose that, at any one moment, a perfect equilibrium were established between the attractions of gravitation, cohesion, and all the others which we may call tendencies to consolidation and rest, and this antagonist power, which we have generalized under the name of heat, it is evident, that from that moment there would be an end of life, of growth, and of every species of terrestrial motion, and that the land, the waters, and the air, with all that they contain, would be in a state of stillness and of death.

But, as long as the earth revolves in its oblique orbit, and performs its daily rotation on its axis, having the beams or influence of the sun as the grand cause of heat, or rather as the action of heat, and with this action always exerted over a hemisphere differently at every different distance from the centre of this hemisphere, and with the hemisphere constantly changing at the rate of about 1000 miles an hour in longitude, and a variable quantity at every season in latitude, there is security against any arrival at this state of final equilibrium and death; and it is the air which is the grand instrument in the preventing of any such catastrophe as this, and in preserving all the local powers in those states in which they perform their functions. But though this is the case, the momentary state of every atom may be said to be a state of equilibrium; because, as the one waxes strong the antagonist power gives way to the exact difference, and if the power becomes weak, that weakness is the same in effect as so much additional strength given to its antagonist. There is, in fact, in this part of the system—which is sometimes called the corpuscular system, because it refers to the *corpusculi*, or indefinitely minute atoms or particles of bodies—a very remarkable resemblance to those compensations in the celestial system, whether with regard to the motion of the same planet in different parts of its elliptic orbit, or in the disturbing influences which different planets have upon each other, in consequence of those variations of distance, which are occasioned by the different sizes and forms of their orbits, and the different velocities of their motions, as will be found explained in our volume on THE HEAVENS. Indeed, this is a principle which runs throughout the whole of creation; and, wonderful as all the parts are, this principle is probably the most wonderful part of the whole,—the part which, when rightly understood, most forcibly impresses us with the superiority of God's working, above every thing which can be performed by man. The powers of healing in the individual, and re-production of the race in plants and in animals, are often appealed to as powerful arguments for the being and the attributes of a creating God, infinite in wisdom and in power; and, so far as they go, they are no doubt conclusive arguments, but as they include only a very small portion, a grain of dust, as it were, in the grand field of nature, they do not lead to that sublime and comprehensive conception which we obtain when we examine the whole system of nature in its more general, we may say its universal laws.

By referring to the volume above noticed, it will be seen, that in proportion as the motion of a planet round the sun becomes slower, in consequence of its receding from that luminary in moving toward its aphelion, there is involved in that very slackening of motion a proportional increase of the sun's gravitating influence upon it, which reduces the motion until the forces arising from the motion and the gravitation are equal, and the former in a state of diminishing and the latter in a state of increase; which increase throws the advantage on the side of the gravitation the instant that the point of aphelion is passed. So also, the increase of the gravitating force produces an accelerated motion in the orbit, which again reduces them to an equality in the perihelion, at which point the motive force is in a state of increase, and the force of gravitation in a state of decrease. It is exactly the same with the antagonist forces of which we are now speaking, and which, as already explained, reach material nature in every atom; and therefore, whatever change there may be in the state of any particular portion of matter, every particle of it is always balanced, as well when it is in the most rapid apparent motion, as when, to our observation, it is in a state of rest.

Such is the general constitution of the system of nature, considered in its most elementary state; and if we have correct views of it in this state, a foundation is laid upon which we can establish the knowledge of particular substances, and particular phenomena, with equal clearness and certainty.

If the effect of the action of heat in maintaining the state of bodies generally be clearly understood, there is little to be added with regard to its effect upon the atmosphere, considered as a whole. That fluid, being in the state of gas, has no cohesion to be overcome; and, therefore, the only antagonist power against which heat has to work is the mere pressure, or weight; and, from what has been already said, it will readily be understood, that the tendency of the sun-beams, as the general agent in heat, must be to produce sensible heat in the atmosphere in proportion to its density. If, from its own structure, or from the action of any external cause, it be less dense at one time or in one place than at another time or in another place, then the effect in sensibly heating it will be diminished; while, under the opposite circumstances, the sensible heat will be increased. It follows also, that where the density is the least, the same action of heat will produce greater motion, but that, under all circumstances, the perfect mobility of all parts of the atmosphere, and the freedom with which it can circulate in every direction round the globe, according as it may be rarefied or condensed in different places, must enable it very speedily to restore its equilibrium, and to be always ready for the operation of any of those causes of which it is the minister. Thus we have in the atmosphere a very ready, and, in the upper regions of it, probably a very swift, messenger; and whatever substance or action its nature adapts it for transporting or transmitting, it is always ready to receive upon its obedient wings; and, in like manner, when the burden, either of substance or of action, with which it is loaded is required for any one production of the earth, or any one operation in its economy, this burden is instantly delivered up, according to the necessity of the earth. Hence we see how beautifully this mobile atmosphere is adapted to all the wants and all the workings of those places and those things which are fixed to their localities upon the globe; and that, but for this means of general communication, the system of nature could not be carried on; for there would be parching in one place and perpetual rain in another, and each, in short, would be thrown upon its own resources,—so that the globe itself would be like "a house divided against itself," and "could not stand."

In this section we have spoken of the action of heat upon the atmosphere as affecting its state only, and preparing it and holding it ready for the performance of its office in the economy of nature. This, however, is but a very small, and, in itself, an unimportant part of the natural history of the air. The grand consideration, and that which gives this element its value, is the action of the sun-beams upon it; but the action of those beams is a complex action, not only in the active energy, but in the subject acted upon. Those rays of light which come to us across nearly a hundred millions of miles, and which come, or at least are known to us, only as energy, have many different offices to perform both in the atmosphere and on the earth; and the atmosphere itself is not only a compound of the two gases, to which allusion has been made, but it is the store-house of other substances, and the scene of other actions, in the performance of which the direct presence of the sun is not absolutely necessary, though it may be that they primarily depend on solar action. In consequence of this, it will be necessary to examine the composition of the atmosphere with regard to the different actions of the different substances which it contains, and also the several kinds, or modifications, of energy in the sun-beams, each of which will form the subject of a short section; between these it will be necessary to take a short view of the manner in which the atmosphere receives, from the more humid parts of the earth, that moisture which it distributes over those which are most fitted for its reception; and, if we shall succeed in obtaining any thing like a clear view of these, it will prepare us for understanding at least the leading principles of those atmospheric phenomena which are included in the general name of the weather.

The views that the few hints which we have in this section given of the law and the mode of natural action, on the great scale and on the small,—in the circulation of planets round their central controlling and stimulating suns, in the state of all substances considered as mere matter, and in all the changes of the state of matter and the phenomena of growth and of life,—are worthy of the most careful attention and reflection of every reader. We find that, in the whole system of nature, there is nothing left alone, and allowed to exist and act of and for itself only. If there is any power, or principle, or energy, which would, if left to itself, produce any final result, we find that there is along with it an antagonist, which, if left alone to work by itself, would produce a final result exactly the opposite of that of the former. We find that every substance is held by these, as in a balance, so that it is ready for every purpose or use to which it can be applied; farther, that this balance is never so much at rest as that the state of any one piece of matter can be inert or inactive; and still farther, that the inclination of this balance either way involves in it a return to the other,—that, to take one instance, life leads, by invariable consequences, to death, and death

I 2

as constantly back to life. But though this is displayed in matter, it is not of matter, for matter can only have the action for a limited time, and then pass into a new state. The inference is plain: The *working* of the system of nature is by the providence of Nature's Almighty Author.

SECTION IV.

COMPOSITION AND STRUCTURE OF THE AIR.

The atmospheric fluid is, as already hinted, principally composed of two gases, oxygen gas and nitrogen gas, one hundred parts of the mixture containing in measure about twenty-one parts of oxygen, and consequently seventy-nine of nitrogen; so that it will make no very great error if we say, in round numbers, that one-fifth of the whole volume of the air is composed of the first of these gases, and four-fifths of the second. If, however, we take the quantities by weight,—which is the true way of taking them, the weight being the exact measure of the quantity of matter, while the bulk or volume is not,—we have the proportion of oxygen a little greater than this, because the specific gravity of oxygen, or the weight bulk for bulk, is greater than that of nitrogen, and, consequently, the one is a little heavier than the compound mixture of the air, and the other a little lighter. Air changes its bulk so readily by every change of temperature,—that is, of the action of heat,—and its weight in equal volumes differs so much at different elevations above the mean level of the earth's surface, that to speak of measures of atmospheric air is a very indefinite mode of expression, unless it is accompanied by a statement of the degree of heat as indicated by the thermometer, and of weight or pressure of the whole atmosphere at the place of observation as indicated by the thermometer. If the thermometer stands at 60°, and the height of the column of mercury in the barometer at thirty inches, then one hundred cubic inches in measure of the atmospheric air weighs thirty-one grains, troy weight. The relative specific gravities of the three are as follows:—If a quantity of air be taken and weighed in any weight which can be expressed by the number 1000, then an equal bulk of oxygen, at the same temperature, will weigh 1093, and an equal bulk of nitrogen 978. These proportions have been determined by direct experiment, repeated many times over; and though such very nice experiments cannot be expected to agree exactly with each other, yet those which have been made by the most experienced and skilful observers do not differ much from each other; and the numbers which we have quoted are about the average. Combining the proportions of the specific gravities of the two gases with the measures contained in any volume of air, we obtain the proportions, 7743 nitrogen and 2257 oxygen in 10,000 of atmospheric air. Here, again, we shall not differ very widely from the truth if we omit the last two figures of each of the numbers, and then the remaining ones, 22 for oxygen, and 77 for nitrogen, are both divisible by 11, and therefore their proportion is exactly the same as that of 2 and 7. In thus shortening the proportion, the figures omitted in the expression for oxygen express a greater number than those for nitrogen, and they ought to have expressed a less one in the proportion of 2 to 7, so that in our short numbers the quantity of oxygen is rather small; but the difference is but a trifle, and the small numbers are so much more easily remembered that they are better for common purposes than larger and more accurate numbers, which no one can readily bear in mind, except those who are professionally engaged in investigations of this kind, and of course it is not for them that these pages are intended. This slight deviation from the more accurate numbers will appear of the less consequence when we consider that the larger numbers are not the absolute truth, but merely a little closer approximations; and that, the more figures that are used the more chance have the last ones of being incorrect, though of course the errors in them are smaller. When we apply numbers to express the results of experiments, they are merely a short method of writing down what we have observed; they cannot thus be more accurate than the observation of which they are the expression, and that observation necessarily partakes of all the imperfections both of the eye and the instrument.

Thus, we may in round numbers, and for the sake of easy remembering, state, that five parts of the atmospheric air, taken in measure, consists of one part oxygen and four parts nitrogen; and that, of nine parts taken in weight, two consist of oxygen and seven of nitrogen. So far as observation has gone, there is no variation in the proportion of these two ingredients, under any circumstances, whether of the density of the air, its temperature, the mixture of other matters with it, or any thing else. In this we have another remarkable proof of the wonderfully-accommodating power or tendency of this most important fluid. We know that, under many circumstances, a vast quantity of the oxygen is abstracted from the atmosphere, and either enters into combination with substances on the earth as solids, or forms gaseous compounds with other substances, which compounds do not diffuse themselves to any great extent through the volume of the atmosphere; but yet, unless it is in a confined place, where the communication with the great mass of the air is not free, the relative proportion of oxygen is not diminished by the greatest drain which is made upon it by terrestrial action.

Perhaps we cannot select a better instance for illustrating the great advantage which is derived from this constant tendency of the atmosphere to keep up the relative proportion of its two principal component parts than the city of London and its vicinity. In that vast accumulation of "man and his marvels," there are probably not less than a million and a half human beings constantly breathing the atmospheric air, that is, depriving it of its oxygen. Within the same compass there is probably not a less quantity consumed by the breathing of other animals; for when we consider the number of horses which are employed in heavy and in rapid draught, and the number of cattle and sheep which are driven, and the severer action to which these animals are subjected than if they were quietly grazing the meadows and downs, we can readily suppose that their consumption of oxygen must be much greater than that of an equal number of the same kind of animals in the country. When, in addition to these we consider the vast extent of combustion which is constantly going on in street lamps, and fires, and forges, and furnaces, and all the operations and apparatus of domestic accommodation and manufacturing industry in which fires are so largely used, and that all this also is supported by consuming the oxygen of the air, we may well suppose that, in very brief space, the store around and over the metropolis would be so exhausted that not a creature could breathe or a fire could burn. Nor is there any doubt that if this great accumulation of life and of industry were thrown, but for one short week, aye, even for one short day, upon its own atmosphere for the breath of life, there is no question that there would be pain and panting, and death, and extinguishment, before the sun had apparently circled the zone of the heavens.

When strangers visit this vast metropolis, and find all its markets and the houses of all its inhabitants supplied with every production of the sea and the land, which can satisfy the hungry or stimulate the luxurious, in greater abundance, of superior quality, and, generally speaking, on lower terms than the same commodities can be had even at the places where they are grown, they are apt to be astonished; and we must admit that, to those who do not see how the joint operations of mind and of money, which this mighty city puts in motion, arouse and reward the industry of men to the most distant parts of the earth,—to those who do not consider that, because of the impulse which is here given, the Chinese of the east cultivate the tea plant, the Australian in the far south shears the fleece, the Indian of the south-west toils in the mine, and the emigrant in Canada invades the forest and prepares the furrow,—they would be apt to wonder by what mysteriously attractive power the fat things of all the earth are drawn towards this city.

But, wonderful as this is while unexplained, the explanation of it not only lies within the bounds of human knowledge, but it lies near the surface, and is accessible by every one who chooses to exercise a very moderate degree of the very humblest description of thought—thought which does not require to extend beyond the plain and profitable doctrine of "turning the penny, and making it a farthing more." When, however, we look to the constant and copious supply of the atmospheric fluid,—the first and the most constant necessary of life, the suspension of which for ten minutes, or the half of that time, would consign the whole living congregation to death,—we find in it something more wonderful than in all which the industry and ingenuity of man can supply, great as are their exertions and their success.

And there is in this matter, in this constantly used necessary of life, something still more wonderful, and at the same time delightful in the contemplation. This is a matter in which the science of man would be at fault, and the hand of his workmanship altogether powerless. He can build palaces, he can furnish them with more than Oriental splendour, he can clothe himself in the most costly apparel, and he can indulge, or, which is the same, command the means of indulging in every luxury; but, not all his science could invent, not all his art could execute, and not all his wealth, were it multiplied till the line of figures extended round the earth, could bring to him one single inhalation of the breath of life; and, therefore, in the midst of all his possessions, all his power, and all his pride,—even when that pride is honest, and leads him to honourable distinction, the distinction of demonstrating by his deeds that greatness is but another name for goodness,—every throb of his pulse, every moment of his life is dependant upon this property of the atmosphere, a property which he can no more controul than he can command the sea in its tides, or the career of the earth in its orbit.

No case could, perhaps, be selected, which shows in a more striking manner the beautiful adaptation of the atmospheric fluid to every purpose in nature, and the ease with which it can be applied to all those purposes, than this silent and immediate restoration of the proportion of its elements, so immediately consequent upon any part of one of them being withdrawn, that no observable time ever elapses between the destruction of the equilibrium and its restoration. It matters not to what action the air may be subjected, whether it remain breezeless or tranquil, whether it awaken the surface of the earth with refreshened zephyrs, whether it howl in storms, or whether it sweep in the desolation of hurricanes; for, in each and in all of those states it is equally healthy, equally ready, and equally gentle and yielding to the lungs, or other breathing apparatus, of every creature; so that the gnat and the mite breathe, with the utmost ease and the most perfect safety, of that violent current of the air which uproots the forests, and lays the habitations of man level with the dust.

All this is accomplished by the perfectly yielding nature of the air, arising from the total suspension of cohesion between its elementary atoms, and its consequent instant obedience to every change of heat or of pressure. The two forces, or the two compound forces, as they probably are,—for we know not absolutely what is simple and what is compound when we speak of the constitution of substances, or of the action of agents,—by which every particle of the atmospheric fluid is exactly balanced in both its component gases, is the property by means of which this perfect adjustment of its elements, as well as the adjustment of its weight or pressure, is so readily brought about. Of those two forces, we may consider the one as an attraction, or tendency to bring together, and the other as a repulsion or tendency to drive asunder;—the first, tending towards each atom in every direction, in the same manner, though not of course to the same extent, as though the atom were the centre of gravity of the earth, or any other planet, and the force that of gravitation; and the second, exactly the reverse of this, or tending from the atom equally in all directions, as if that atom were the centre of a revolving circle,—a circle revolving in every direction, and this repulsive energy were a centrifugal force,—or rather, and it comes nearer to the reality, if it is not identically the same principle, though different in modification, as if the particle were a radiant, or light producing point, and the repulsive energy the rays of light emanating from this point, and proceeding in every direction.

As the primary atoms of matter, which are utterly lost to observation,—that is, are too minute for observation when each is loosed and separated from the other to the extent which takes place in a gas,—are the nearest approximations that we can conceive in nature to perfectly mathematical points,—that is, positions in space which do not occupy any portion of that space,—and the difference is simply this, that the mathematical point occupies no space whatever, and the elementary atom no space that can be measured, or even conceived to be of a measurable or discernible magnitude ;—so this is the case, it follows that, as regards every one of those elementary atoms, each of the agencies has its energy upon every particle, inversely as the square of the distance from that particle; that, in short, every particle may be considered as the centre of a sphere, upon which the force of attraction acts as a countless number of rays, converging upon the particle, and tending to draw towards it every thing that is around; while, on the other hand, the repulsive energy may be conceived as consisting of a countless number of rays diverging from the particle in all directions, and tending to drive from it every thing that is around. We know not, of course, what may be the absolute measure of either of those forces; but we can see, from the very nature of them, that they must both diminish as the squares of the distances; and as the number of rays which make up a sphere is indefinitely great, or, as we say in common language, infinitely great, and as those countless rays are concentrated into the nearest possible approximation to a mathematical point upon the particle itself, we have on that particle an indefinitely large, or, as we say, an infinitely large multiplier, whereby to multiply the energy of a single ray of either agency, so as to get a true estimate of its force at the particle. Now, if any quantity is to be repeated a greater number of times than we can possibly imagine, it matters not how small the single quantity may be, because, in consequence of the unlimited greatness of the multiplier, the product, or aggregate, will be in all cases indefinitely great, the greatest possible,—in short, greater than we can sum up, or even imagine. Therefore, upon the clearest and most accurate showing that can be obtained in any one matter, it follows, that if one particle were in absolute contact with another, so that there were no distance whatever between them, then those two particles would remain united by a force of cohesion indefinitely, or, as we say, infinitely great; and, as we can conceive no connection to be dissolved except by an agency more powerful than the connecting one, it would follow, as matter of necessity, that if any two particles of matter were in absolute contact with each other, it is impossible to imagine any created energy by which they could possibly be separated.

Yet from all that we can observe, either in nature or in art, we are not to conclude that, were it not for action, repulsive action, as a separating force of some kind or other, such would be the condition of every kind of matter; and this brings us to a conclusion, by which we are spared a great deal of time, and many needless and unprofitable conjectures about the origin of different kinds of motion, and motive force. For it is evident, that if the creation of this repellant, or motive energy, had not been perfectly contemporaneous with that of matter, it would have been unavailing afterwards; because all imaginable matter would have been so intimately united as to be proof against the action of all possible created force. This would have been the case, whether we consider matter as originally one and simple, and having its particles united to each other by one single and simple force of cohesion, or whether we regard it as consisting, as it does at present, of many varieties, each held together by its own cohesion, and the whole accumulated into one mass by the general attraction of gravitation; for whether there had been one force of this kind, or many forces, the effect would have been exactly the same—a union which no creative power could have dissolved.

Nor need we wonder at this view of the constitution of matter; for though we do not always think of it, it is in truth the only view which we can obtain. We indeed use the words "inert" and "inactive," as expressions of certain states of matter, or of portions of matter; but, in reality, we know of no matter which is, or which can be, in a state of inaction. The earth revolves and rotates, and, by this means, every particle in it, or its surrounding atmosphere, is in continual motion; and we have reason, too, to conclude, that every particle of it partakes, to some extent or other, of the action of heat; nor have we any idea of a perfect and absolute solid. Indeed, as we can assign no measurable magnitude to the elementary atom, we can assign no measurable magnitude to any number of those atoms, supposing them in absolute contact; and therefore, though it is a subject upon which we can *know* nothing, as a matter of experience, it is just as probable that if all the elementary parts of the earth were to be brought into absolute contact, the space which the whole would occupy would be less than a pin's head, as that it would be any larger volume. On the other hand, from the vast expansion of which the smallest possible quantity of the aërial fluid admits, it is just as probable that the very smallest imaginable quantity of water could be so dispersed by the repulsive action of particle upon particle, as that it might be extended beyond any limits which we can possibly assign. Thus, when we take the extreme cases, the powers of cohesion and the powers of repulsion—which form the balance in which every particle of matter is suspended and equipoised, and at which the particles of that atmosphere are poised so that the balance vibrates to the slightest impulse imaginable—are both vast and energetic, beyond any thing that we can estimate.

These opposing forces are exactly equal to each other, unless when a substance is in the act of expanding, or contracting; and then, though the one gains, and the other loses, in successive instants, they are still equal to each other at any one instant. It is also worthy of remark, that in proportion as the repulsive energy, the heat, is more or less required in alterations of the state of one substance,—that which is sensible in other substances goes instantly to form a supply. If air is condensed by pressure, it gives out heat in a sensible form, in proportion to the degree of pressure; if the pressure is communicated with sufficient rapidity, and to a sufficient extent, the result is a flash of fire, which is capable of kindling an inflammable substance, and is, as we shall afterwards see, intimately connected with the phenomena of thunder and lightning. On the other hand, the expansion of the air is always attended with sensible cold, or a diminution of temperature; and if it is sufficiently rapid, and not produced by the action of heat, but merely by the removal of pressure, water may be instantly frozen by it, even in the very heat of summer.

Now, the increase of sensible heat, which is produced in the case of the violent and rapid condensation of atmospheric air, is merely the resistance of the other air, or surrounding bodies, to the action of heat, which is expelled from the condensed air by the act of condensation; and it is because, when very rapidly expelled, this heat cannot immediately overcome the resistance of so large a volume of the air around, as that it can escape by silent action, that it heats a small portion in its immediate vicinity, until the oxygen of the air enters into a new combination, and the vivid light is the result. On the other hand, the cold produced in the case of expansion is merely the natural transfer of the action of heat from the portion of the air, or from surrounding substances, the temperature of which is not lowered, to raise the temperature of the cooled one, and so restore the equilibrium; and if the temperature of the body which is cooled sinks rapidly enough, and there is water in the immediate vicinity, it may happen that the water shall be frozen, in consequence of the abstraction of all that quantity of the action of heat by which it was previously maintained in a liquid state. There are some artificial mixtures, which, by melting with wonderful rapidity, produce a very intense degree of cold—a degree much greater than is usually met with under any natural circumstances; and it is worthy of remark, that in most of those mixtures, snow is an important ingredient, and that it is chiefly to the melting of the snow that the great cold is owing. Thus, if two parts of snow, or of ice reduced to fine powder, and one part of common salt, also in fine powder, be rapidly and intimately mixed, the mixture will melt, and, in the course of the melting, a degree of cold will be produced 37_0 lower than that at which water freezes. If twelve parts of snow, reduced to powder, as above, be mixed with five parts of common salt, and other five of nitrate of amonia, the melting of this mixture will be much more rapid than that of the former, and a degree of cold will be produced 57° below the cold at which water freezes under ordinary circumstances. In this case, if the finger is put into the melting mixture, or touches any substance upon which the full extent of the cooling energy has been exerted, a degree of pain will be felt, of which it will not be easy to say whether it is a sensation of cold or of heat. If a substance, which has been exposed to this mixture, and received its full cooling effect, be again exposed to another mixture, consisting of two parts of pounded snow, and three parts of muriate of lime, the temperature will be reduced to 100° of the thermometer below the freezing point of water; and any substance, at this degree of cold, would produce upon the finger the very same pain, and the very same effect, as if it were to touch a live coal, or piece of red-hot iron. Now, those which we have mentioned are all substances which may exist in the atmosphere, though not in that condensed or concentrated form in which we can obtain them for our experiments; because the atmosphere cannot support a mass of water of greater specific gravity than itself; but still the instances which we have given of substances capable of existing in whole, or in part, in the atmosphere, and of being carried by it from place to place, are sufficient to show that, while the great mass of that fluid itself is entirely passive,—is the mere medium of action,—or the obedient servant in the distribution of any effect which that action may produce, there exist in it elements sufficient for the production of all those changes of temperature which are essential to the economy of every kind of natural action, as conducive to growth, to life, and to every function of creation which goes on upon the surface of the earth.

It is this capacity of the atmospheric fluid, from the simple mixture of its component parts, and the readiness which it yields to variations, to heat and cold, and every other means of expansion and contraction, which adapts it so well for receiving and for giving out again all those substances and those energies which are necessary for carrying on growth and life, and all those other species of action which are necessary for maintaining the surface of the earth in a wholesome working state. In these respects it is not more effective in dispensing good than it is in dispensing evil.

In order to understand this latter operation, we have only to consider that just as the waste and refuse, which the atmospheric air removes from the system of an animal in the operation of breathing, would kill that animal, in a very short time, and shorter in proportion as the life of the animal is more energetic, or we may add, more valuable, if it were not remedied; even so there are countless thousands of operations which go on, both in nature and in art, the products of which, if suffered to remain at the place where they are formed, would be poison and pestilence—would kill every thing around, and the death, and the pestilent product of death, would extend on every side, till the entire surface of the forest, even the widest land, would be reduced to a charnel-house, from which there would be no resurrection—no return of a single living thing, without a new exertion of created power. Let us suppose that it were but the dead carcass of one large animal left to putrefy on the surface of the earth; and, even in the best cultivated countries, those to which man attends the most, this is not an unknown occurrence; while, in the richer uncultivated lands,—especially the tropical ones,—which are full of life, and subjected to violent alterations of seasons, this is a frequent occurrence, and not only by the violence of casualty, but in the natural course of decay. It is true that, as the system of nature is constituted, the vultures, and the eagles—which in those countries partake much of the nature of vultures, and are profitable servants, in clearing the earth of much of what would tend to produce pestilence—but still, were it not for the atmosphere, the eagle and the vulture, proof as they are against scents the most loathsome to our nostrils, have the common principle of animal life in them; and the air which they breathe must contain the same healthy ingredient as that which is breathed on the sweetest spot under the canopy of heaven. Therefore, if all the poisonous gases which the body of an animal gives out when in a state of putrid decomposition, were to accumulate and stagnate round that animal, instead of being melted and moved away by the atmosphere gradually as they are formed, an atmosphere of death would spread around the carcass, which, from the different specific gravities of the corrupting carcass, and the poisoned gas, would, in the case of not a very large animal, extend to the distance of a good many yards in every direction; while in the case of a large animal, the quantity would be sufficient to extend, not disease merely, but certain and instant death, over a whole parish. In this case, no vulture could approach near the putrifying substance, because no living animal could take into its lungs the unmixed gas given out by an animal in a state of putrefaction, and survive a single moment. We read of many melancholy instances, in which surgeons, while examining the dead body, in order to ascertain the cause of disease, and thereby contribute to the health of the living, puncturing, it may be, the tip of their finger with the point of a needle, so slightly coated with the pestilent virus of death as that its gloss is not tarnished, and the puncture is so slight that no blood flows, and no pain is felt; yet because of the extreme deadliness of this matter of corruption, this trifling puncture, given at the remotest possible distance from any part which we consider as vital, and given by an instrument which, to the observation of the eye, appears perfectly clean, shall be more certainly a death wound than the thrusting of a sword through the body, if that sword should leave untouched all those organs which are immediately essential to the carrying on of the functions of life. Now, it is easy for any one to see, that if this matter of putridity, when in the liquid state, be—even by a puncture on the finger, to which a quantity so small that it cannot be measured, or even observed,—thus fatal, we cannot imagine the same substance to be so attenuated, when in the gaseous state, as that it could be received into so delicate an apparatus as the lungs without producing death as instantaneous, and followed as immediately by corruption, as is fabled (for it is not the fact) of those who are struck down by the simoon or pestilent wind of the deserts. Nay, if a tenth and hundredth, aye a thousandth part of the volume of air which is received into the lungs during a respiration consisted of this pestilent gas, it would be fatal; and therefore, if the atmosphere did not actively carry it away, by the property which it has of distributing every substance which it receives, with the same uniformity through its whole volume as its own component parts are distributed, then there would be no enduring of any offensive thing, and death itself would, if the expression may be used, become a vital principle—that is, an extending and breeding principle, and become in itself one master-malady, which would swallow up all the rest in the rapidity of its march and the certainty of its havoc.

But it is not to be understood that even this matter of corruption, arising from the putrid decomposition of animal carcases, all-terrible as it is in its effects when applied to the living body in an unmixed state, is yet an evil in the general economy of nature. The truth is, that Nature produces no poisons, as told upon the system of her working, and those cases which have this effect in reality are always cases of misapplication, the exhibition of the substance in an improper case, or an improper quantity. We have pretty extensive evidence of this in those medicines which are most efficient in restoring the human body to health. Beyond a certain quantity, a small one in all cases, and in the case of the most active and most valuable ones exceedingly small, all medicines are poisons; and on the other hand, the most deadly poisons, in doses sufficiently small, and administered with competent knowledge of the state of the patient and the character and operation of the substance,—every poison, the most mortal that can be imagined—arsenic, hydrocyanic or prussic acid, strychnine—every thing more deadly than these, if possible, may, if the case is that which requires it, and the dose is duly apportioned, be the instrument of restoration to health, when all other human means are vain,—not only may be, but actually has been, in numerous instances, the instrument, and the only instrument, in bringing valuable life back from the very gates of death.

Even in some of those more dreadful maladies, in which there is no hope whatever from any of the ordinary means of treatment, at any stage, and especially during the last stages, those poisons, and others of the most deadly character, give at least a glimmering of hope—a faint one indeed, but still a glimmering, if skilfully applied. In *tetanus* or locked-jaw, even when the mouth cannot be opened by strong mechanical force, and when the spine is so recurved that only the back of the head and the extremities of the heels are points of support, from which the rest of the body stands up like a bow, and in that still more dreadful malady, popularly but perhaps not very accurately designated by the names of hydrophobia and canine madness, which is equally fatal as the other, and more painful both to the sufferers and to lookers on, because it is not a silent affliction, but accompanied by all the external expressions of the most direful anguish to which human nature can be subjected: even in these, when hope from medicine, and possibility of reaction in the system are utterly gone, and friends are standing round with streaming eyes to watch the last flicker of life in one dear to them—haply one upon whom all their worldly comforts depend, and who, it may be, is struck down in the prime of life, and the fulness of usefulness,—even in those last extremities of mortal wo, it may happen, and it has happened, that a skilful application of one of those mortal poisons has vanquished the disease, and, by great skill in the physician, the system of the sufferer has been made to re-act, and he has, in the end, been restored to life and to usefulness.

It is not our province to enter into the rationale of this wonderful process,—it is not required of us to show how it is possible, if the organization of the body is yet sound, to bring back to it the departed life, especially where that life has been subjected to spasmodic extinction, and if the means of reaction are applied before the angel of death has begun the work of dissolution, and ere yet corruption has stamped its final impress upon a single fibre: it is not for us to inquire into, or to attempt to explain the principle of these matters; but the fact is open to us and to every body, and it is closely connected with this wonderful power which the air has of dividing, down to the ultimate atom, every noxious, every poisonous substance, which is in any way produced on the surface of the earth, or in any case of terrestrial action; and having so divided the atoms of this matter, to scatter them far and wide, so that, within even a moderate distance of the place where the poisonous substance is naturally produced, there is probably not as much of it in a whole cubic mile as would poison an infant.

From the great activity of those substances,—from their proneness to act upon and destroy the living subject, which is, as we may say, fenced in by the constitution of its nature against the common contingencies of the region in which its lot is cast, so as that, in the average number, it shall live for the average period, with the average degree of comfort,—from this powerful action upon the living subject, notwithstanding the means of defence and cure with which life is armed by the kind provision of the Author of life, we may very reasonably, nay, most philosophically, conclude that their action upon dead matter must be still more powerful, because in such matter they have to contend only with its aggregation and its properties as matter, whereas in the other case they have to contend with all these, and with the energies and defences of the living principle in addition.

The attenuation of those substances by the atmosphere is so fine that we are unable to bring them within the scope of observation, and therefore we cannot make the details of them matters of experimental philosophy; but as there is something offensive, nay, something, if sufficiently concentrated, absolutely poisonous, given out in the putrid decomposition of every organized substance, whether animal or vegetable, when it first renders up its peculiar kind of life, and is at the time in the freshness of its structure and the fulness of its juices,—as this is universally the case, as there is no instance in which the passage from life to death, if immediate and rapid, is not attended by the evolvement or giving out of something offensive and poisonous, we cannot resist the truth of the converse of this—namely, that there is no bringing of dead matter into living action without the agency of those very deleterious substances which that matter invariably parts with when it quits the living state, and returns to the general mass of inorganic substance.

If we could but imagine the vision of the eye to be refined some thousand—some million fold, if we could find the "euphrasy and rue" wherewithal to "purge the visual nerve," truly, there is in this matter "much to see";—if we could follow as easily with the eye of observation as we can mentally trace, with the appearance, nay, the certainty of truth, the progress of those most energetic products of the wonder-working power of creation, careering from life to life upon the all-obedient wings of the viewless air, verily we should see with our eyes a displaying of the working of Almighty power, so superior to every thing which we meet with in that mechanical nature upon which, and upon which alone, it is given to the mortal eye to look, that, though we may partially feel, it is impossible for us fully to fancy how exquisite, how incalculably beyond our highest standards of presently-estimated pleasure, would be the full fruition of this mental enjoyment, or what would be the fervency of adoration which it would command in the delighted spirit. Whether this shall be part of the happiness of the redeemed of God, when the spirit shall be unclogged by the frailties of the flesh, and when the mortal shall have put on immortality, it is not for us positively to say; but this much may be felt, that herein would be found enjoyment, and adoration of the great Source of that enjoyment, in the utmost of their fulness, and trenching on the very verge of infinitude; and as the conception does not embody a single element of decay or death,—no, not of exhaustion or of pause,—the idea of perpetual duration is embodied in it, and it is at least one of the conceptions which we may form of eternal happiness. To such a conclusion are we led by the study of one of the functions of the atmosphere, a function which, except in its ending, for the beginning is so fine that we can take no note of its progress, is entirely beyond the limits of our ordinary observation, though it is as clear to our mental perception as the plainest and simplest matter which is before our eyes every day and every hour.

We may mention, merely for the purpose of drawing the attention of the reader to this most important subject, which,—as it is a subject of a purely mental character, standing in need of no apparatus, requiring no expense, and capable of being carried on contemporaneously with all the mechanical enjoyments of life—might and should afford to every one a means of escape from that vacancy of the mind which, if allowed to settle into a habit, turns round and paralyzes the hand. This is a point which we believe is not in general much attended to, and yet there are very few points which bear more directly or more largely upon the grand question of human enjoyment, and therefore it is desirable that no opportunity of impressing it upon the attention of mankind should be neglected. Indeed it will, upon examination, be found to be in those little incidental hints which do not carry with them the somewhat arrogant, and always apparently intrusive, character of direct schooling, that every one receives the most acceptable and therefore the most profitable instruction; and, consequently, he who ventures to address the public through the medium of a book, need not hesitate to notice any of those incidental hints, if they are at all apparently connected with his main subject. They are rests in that subject; and rests, judiciously placed, add to the melody and harmony of even the sweetest music. It is not necessary to say more than two words on this point:— The mind is the master, the hand only the servant: thought is the business of man, as rational and immortal; labour, of whatever kind, and how usefully soever it may be directed, is the business of man as the mortal— the organized being of clay; therefore, if the master is neglected, is unskilful and incapable, how can the servant do well?

We shall now just mention one or two of the properties of each of the great constituent parts of our atmosphere, and then hint at the small admixtures of foreign substances, that is, substances different from its principal component parts, which are usually found in it in some small quantity or other, though not in the same constant proportion as the two component parts.

Nitrogen may be considered as the principal element of the atmosphere, because it occupies, as we have already mentioned, about four fifths of the bulk, under all circumstances. Nitrogen, too, is specifically lighter than the other ingredient, and it is held in the gaseous state by a much smaller action of specific heat, that is, of that action of heat which just preserves the state of the body as a gas, without being sensible to the thermometer or any other test of heat. According to what are considered as the most accurate experiments upon this branch of the subject, the specific heat of the component parts of the atmosphere, and of the compound which they form, in the proportions in which they are mixed, estimating them from the standard of the specific heat of liquid water as 1,000, are as follows :—

Oxygen gas	47,490
Nitrogen gas	7,936
Atmospheric air	17,900

It is to be understood that these numbers do not stand for absolute quantities, which could be weighed or measured in any way, for there are no such quantities of heat; they are merely measures of proportional actions, that is, of the resistance which has to be continually opposed by the repulsive force of heat, in order that each of the simple gases, and also the compound arising from their mixture, may retain the gaseous state, without having any tendency to expansion, unless in the case of additional heating action, or any tendency to condensation, or lessening of volume, unless by the withdrawal of some portion of that action which is necessary to the maintenance of the state. When the numbers are compared, it will be perceived that, as the proportional numbers for oxygen and nitrogen are very nearly forty-eight for oyxgen, and eight for nitrogen; and dividing these by eight, we have oxygen six, nitrogen one; or, in other words, the force or action of heat which it requires to preserve oxygen in the state of gas, is about six times as much as that which is required to keep nitrogen in the same state. By farther comparison we find that the force of heat necessary for keeping the compound or atmospheric air in the state of gas, is rather more than double that which is required for producing the same effect upon nitrogen, but not very much more than one third of what is required for oxygen. We might at once infer from this, by general analogy, and without any reference to the particular facts, that oxygen must be a far more active and energetic substance than nitrogen, because it requires six times as much of the action of heat to subdue its energy of mere aggregation, and maintain it in the gaseous state.

Thus, if what has been previously said of the subdivision and distribution through the atmosphere of those still more active substances, which we find to be deadly in very moderate quantities, but which we have every reason to believe are the stimulants of life in their more minute or atomic sub-division, is borne in mind, the reader will be prepared to admit, and even to draw for himself, this inference also,—that the oxygen of the atmosphere is an active principle, which, in its pure state, would be too much for most kinds of action, especially for the actions of growth and of life, both of which are fine down to the elementary atom; and that this principle is minutely divided and diluted, by the admixture of four parts in five of nitrogen, in order that, where it is presented to the working apparatus of life in volume, as it is to the lungs of an animal in the act of breathing, it may be so reduced in its strength that it may not injure that which it is meant to serve. And here it is not necessary for us to rest the truth upon mere inference, clear and obvious as that inference is, for we have direct experience of the fact. If an animal is placed in a vessel containing pure oxygen gas, all the functions of life in the animal are awakened to greater vigour and activity: the breathing is firmer, the pulse beats more strongly, the temperature rises, the senses acquire new acuteness, and if we may so express it, the animal becomes more alive throughout its whole frame. But there is no germ of immortality in this apparent awakening of additional life in the animal. The state is an unnatural one, bearing some analogy to the unhappy condition of a human being kept constantly under the baneful influence of ardent spirits, and the increased action of the functions of life is only a proportionate and even a greater hastening of the period of death. The animal is formed for breathing the diluted oxygen which it finds in the atmosphere in its natural proportion, and if this proportion is much increased or much diminished, both changes are almost equally injurious to the animal,—the increase by working the powers of life to a degree beyond their strength, and the decrease by not working them up to that degree. In this we have no inconsiderable resemblance between the effect of oxygen, and the effect of heat upon the living structure. Up to a certain proportion they promote healthy action, and not only increase the enjoyment, but also increase, at least they do not diminish, the duration of the animal: but, if they are augmented beyond this, we find that the common law of all action applies, and that what is gained in energy is lost in time; for a life which, in the common atmospheric air, would be good for a year or for many years, would be worn out in a day, or less than a day, if the breath of life supplied to it were pure oxygen gas. Indeed, this principle is general, and applies to the action of all causes upon any one subject, and to the action of any one cause upon all subjects; so that here again, as, in every other part of nature which we can possibly examine, we find evidences of adaptation and purpose too striking to be overlooked, and too plain to be mistaken.

It is not in the functions of life and growth alone that the oxygen of the atmosphere is an important element. As the atmospheric fluid surrounds and closely invests every substance on the surface of the earth, and as it every where contains the same relative proportion of oxygen, held in solution in the nitrogen, but not held in combination with it, and thus ready to be given out upon all occasions where it is required, we might expect, and we actually find, that oxygen is one of the most prevalent ingredients in all substances, as well as one of the most energetic agents in almost every kind of action. From the number of its combinations, as well as from the nature of them, we obtain the clearest proofs of the activity of this substance; and from its being found in so many more compound bodies than nitrogen, the other and more abundant element of the atmosphere, we are led to conclude, generally, that there is some connection between the force with which the elementary particles of a substance tend toward each other, and that with which they tend toward the particles of another substance. We have stated, that the specific action of heat which is necessary to maintain oxygen in the gaseous state, is about six times as great as that which is required to keep nitrogen in the same; and if we are to judge of the tendency to combination from the number of substances with which any one substance combines, we may safely conclude, that the tendency of oxygen to combine with other substances is in proportion to that with which its own particles tend toward each other.

We have direct evidence of this in the composition and form of water and of nitric acid. Water is composed of oxygen and hydrogen gases in the following proportion, both as to weight and to bulk, though, as we cannot obtain them separately as liquids as we can obtain the component parts of the atmosphere separately as gases, it is impossible for us to compare the two proportions so as to ascertain how much of the bulk of water is made up of oxygen and how much of hydrogen. A cubic inch of water, at the temperature of 60° of the common thermometer, weighs about 252½ grains troy, and of this weight about 224½ grains consist of oxygen, and only about 28 grains of hydrogen, so that, in point of absolute quantity of matter, there is about eight times as much oxygen in water as there is hydrogen. When, however, we compare the space which these two gases would occupy if they were apart from each other, and each pure in the gaseous state, we find that, of the whole volume of 1987 cubic inches, to which the component parts of the single inch of water would be expanded, the hydrogen would occupy 1325, and the oxygen only 662, or very nearly, indeed, for all ordinary purposes, one half, of the former. In stating in round numbers the composition of water, we may therefore say, that, in bulk of gas, it consists of two volumes of hydrogen and one volume of oxygen; that it is condensed into about the two-thousandth part of the space which the gases occupy; but that when we estimate by weight, which is the test of the absolute quantity of matter, water is made up of eight parts of oxygen and only one part of hydrogen. The action of heat which is required to maintain hydrogen in a state of gas is about four times as great as that which is required so to maintain oxygen; but the tendency of the two to unite disengages as much of the action of heat from both as suffices to reduce their joint volume from about 2000 cubic inches to one cubic inch; and it is the rapid disengagement of this heat during the union of the gases in the formation of water, when they are burnt in combination, as we express it, which occasions the intense light and heat by which this operation is accompanied, and which is so much more brilliant than any other light which we can permanently obtain by artificial means, that it is used in microscopes as a substitute for the beams of the sun, and answers the purpose equally well. If, however, the mixture contains an excess of hydrogen above the proportion in which it exists in water, this hydrogen, being free, that is, not being chemically united with the oxygen, burns gradually with a feeble flame and gentle heat, because the diluted atmosphere gives it a more moderate supply of oxygen; yet, if even atmospheric air is mixed with hydrogen in a large quantity, and sufficient heat (a lighted taper, for instance,) is applied, the whole will take fire almost at once, and burn with a violent explosion,—an explosion more violent than if a taper, burning with the same low degree of heat, were applied to the gaseous components of water, in a way in which atmospheric air were entirely excluded. In this last case, we can see some advantage which the mixture of nitrogen in the atmosphere gives in the case of combustion, by separating the particles of the more active substances farther apart from each other than they would be were it not for the mixture. And in some of our artificial compounds,—gunpowder, for instance,—we find an illustration of nearly the same principle: solid gunpowder does not explode, it merely burns away; but when it is granulated, or reduced to little pieces, in the state in which it is used for fire-arms and other purposes, the air in the interstices carries the heat through its mass; and if by any artificial means we can remove the grains to a greater distance from each other than they have when they support each other, the ignition is more instantaneous, and the effect proportionably greater. Thus, in the blasting of rocks, it is found, that if the gunpowder is mixed with well-dried saw-dust of deal, the explosion, though not nearly so loud in its report, tears much more of the rock asunder than the same quantity of gunpowder would do unmixed, and probably more than would be done by as much unmixed gunpowder as the whole volume of the mixture.

In all cases of combination with oxygen, there is a tendency to condensation in the compound; and if this condensation is rapid, there is a corresponding development of the sensible action of heat. To this there is, indeed, one apparent exception—the combination of oxygen with carbon, in the formation of carbonic gas, in which the gas produced is exactly equal to the volume of oxygen consumed. This is the chief product given out in living action, in combustion by means of atmospheric air, in the growth of vegetables under certain circumstances, and in many other natural operations of frequent occurrence; but as we shall have to consider it more at large hereafter, in noticing the use of the atmosphere in life and growth, and those other operations, we shall not enter farther upon it in the meantime than to remark, that this particular product, although produced in the state of gas, does not diffuse itself so completely through the atmosphere as most other gases, and even the vapour arising from water, and from the volatile parts of various liquids and solids. It is true, that the atmosphere does contain a very small quantity of carbonic gas, and that it contains this quantity in nearly the same relative proportion at every altitude at which it has been observed; but this quantity is not greater than from one per cent. to one-half per cent. of the whole volume, so that it may be considered as a foreign substance, of which the atmospheric fluid is capable of holding in solution only a very limited quantity; yet this quantity, limited as it is, may answer the most important purposes in the economy of nature, and more especially in that of animals and vegetables. In the permanent structures of both of these, if we except the earthy matter of the bones of animals, carbon may be said to be the substantive ingredient; and it is highly probable, that vegetables especially have the power of extracting it from the air; and the small quantity which is distributed through the atmosphere, may exist in a state so attenuated by its admixture with the more abundant ingredients, as that it may be applied without injury to the most delicate organs.

It is not to be understood that this carbonic acid, though it is diffused through the air in small quantity, exists in any state of chemical combination, but that, like the oxygen and the nitrogen, it is perfectly free, and may be either communicated to the atmospheric mass, or abstracted from it, without the smallest effort, the slightest chemical action, or even the most minute variation of temperature. Its quantity is too small, and its action too delicate, for coming within the scope of our observation; but as we have evidence that this essential element of the animal and the vegetable structure is every where diffused through the atmosphere, and held there ready to obey the most minute action that we can conceive, we can discern in it the general principle of another important use of the peculiar composition of the atmospheric fluid, although we are not in a condition for so far examining the details as to be able to reduce them to calculation, or even to bring them within the limits of our knowledge.

There is another foreign substance which exists distributed through the atmosphere, in all its states, and in all places, though it is one which varies much more in quantity, under different circumstances, than either of those which we have mentioned. This substance is the vapour of water, in a state of the most minute division, when the air is transparent, and what we in common language term dry; for as this vapour of water finds its way into the atmosphere, and also out of it, without any thing that we can consider as chemical action, we must conclude that it is simply in a state of mechanical division. Indeed, both the composition and the decomposition of water are operations attended with, or rather requiring, the exertion of so much power, that it is altogether impossible for us to suppose that either of them takes place in the common receiving and distribution of humidity by the atmosphere, in that quiet manner in which these operations are usually carried on; though, in some of their more violent species of action, both in the atmosphere and in the earth, or the waters under it, there may be such operations. The consideration of the first, that is, of the more violent species of atmospheric action, belongs to the subject of the weather; and those powerful actions in the solid earth, or agitated waters, in to which the composition or the decomposition of water may be supposed to enter, and produce its violent effects, belong more to the natural history of water itself, as water must be regarded as the chief agent; and, therefore, any notice which we may be enabled to take of them can be taken with more propriety when we are considering the general phenomena of water, under the name of The Sea.

Of Nitrogen,—which, as we have said, occupies so much of the volume of the atmosphere, is held in the state of gas by so much smaller an action of heat than oxygen, and which may in some measure be regarded as the passive vehicle by which the more active substances are diluted, so that they may be meted out to the most minute and feeble creatures of nature in portions sufficiently small for their feebleness,—it is not necessary to say much. We know it chiefly by negatives, by that which it is incapable of doing; though there is no doubt, from its existence in many natural products, that it is not an inactive substance, taken on the whole, any more than oxygen, though it no doubt acts upon different substances, and in a different manner. In the grand operations of breathing, the living action of plants, and combustion, it appears that nitrogen is wholly passive, and serves no other purpose than that of diluting the oxygen which is required, so that it may not, by its concentration, and the violent action which that concentration would occasion, destroy what it is intended to foster and preserve. No animal can live in nitrogen, that is, we are acquainted with no organ of respiration to which this gas, unmixed with the requisite portion of oxygen, can be applied, and the functions of life carried on. But even in these cases we are not warranted in saying that nitrogen gas is a positive poison to animals; and this accords well with its old name of *azote*, "without the life," that is, without the means by which the energy of life is stimulated to carry on its functions; but it does not follow from this that it is in itself the direct means of death. It is true, that if we inclose an animal in a portion of atmospheric air, having no communication with the general mass of the atmosphere, the volume of the air diminishes by the consumption of the oxygen, and is replaced by carbonic acid; and if the experiment is continued until all the oxygen is exhausted, or very nearly so, the animal dies. In this case, however, we are to understand, that there is a more deleterious substance present in the carbonic acid which is formed during the process of respiration. This carbonic acid is, if we may use the expression, the ashes of the fire of life; and if this substance is returned upon the lungs of the animal, the operation is precisely the same as if a fire were extinguished by heaping upon it its own exhausted ashes. And in the case of a fire, we can have evidence of direct quenching by means of this acid in a state of gas; for, as the atmosphere takes up but a limited quantity of it, we can retain it in vessels for a long time, just as if it were water or any other liquid; and if we take and pour it on a fire in a sufficient quantity, that fire will rapidly go out, although no substance discernible to the eye is applied to it.

In the several paragraphs of this section we have endeavoured to point out the relative proportions, and some of the more remarkable properties of all the different substances which are detected as forming part of the atmospheric fluid in every direction at which it has been examined. Nitrogen gas forms by far the greater part by measure, being about four-fifths, and, to our common observation, it is very much a passive substance. Oxygen comes next in proportion, and occupies nearly the remaining fifth in bulk, is a remarkable active substance, and is held ready diluted by the nitrogen, so that it may answer an endless number of purposes in the economy of nature. Then, there is carbonic acid, of which the quantity is so small that the proportion which it bears to the whole volume of the air cannot be ascertained without the greatest nicety. It is not understood to be in itself a very active substance, although in certain operations it combines very readily with oxygen; and when the two combine and form carbonic acid gas, this gas is held in the gaseous state by an action of heat rather below that which is necessary to maintain the atmospheric compound in the same. We have, however, reason to believe that the power of aggregation in carbon, when not united with oxygen or with any other substance, is abundantly powerful, for the diamond consists, when colourless, of carbon in a state of perfect purity, and the cohesion of the diamond is greater than that of any other known substance. There is also rather a curious fact alleged of the diamond, and it is one which agrees with the philosophy of the case, and tends to shew how readily either the carbon or the oxygen of carbonic acid may be obtained out of that gas, whenever either is required for any purpose in nature. It is said that at many of the diamond mines in the East Indies, especially at those of Pannah, in the province of Allahabad in central India, the diamonds are understood to be reproduced every fourteen or fifteen years; at least, when the soil, which has been searched with the greatest diligence, has been returned to the pits, and has remained there for the period specified, it is found to be as rich in diamonds as before. The soil is a gravel, the smaller portion of which contains a considerable portion of oxide of iron, and the rationale of the process is, that the removing, searching, and returning of the gravel to the pits tend to expose new surfaces, on the small pieces of which it is made up; and that the rains, before the setting in of which the pits are always filled, carry down into the soil a considerable quantity of carbonic acid, the oxygen of which combines with the iron on the newly exposed faces of the sand and gravel, while the carbon is left free to crystallize and form diamonds, which are of what is called the first water if the carbon is perfectly pure, but which are sometimes tinged with a little oxide of iron. We mention this circumstance merely to shew that if oxygen is thus easily separated from carbon in carbonic acid, while under the earth, in the pores and insterstices of the diamond gravel, we have every reason to conclude that it will be just as easily separated for the purpose of entering into all those compounds of which we find it forming a part in nature; and thus, not only the small portion of it which is generally distributed through the atmosphere, but the larger portion which is constantly in the process of formation by so many operations of nature, must be instantly, readily, and easily available for every purpose for which it is required. The full investigation of this subject belongs, however, to the general chemistry of nature, while our more immediate object is one single, though not unimportant department—the composition and functions of the atmospheric fluid.

The last substance which we may consider as existing every where in the atmosphere, in a state of mechanical division so fine that the individual portions of it are not, under ordinary circumstances, discernible by the eye, is the vapour of water. The proportion of this varies more at different times, and under different circumstances, than that of any of the others. It is never more than one-sixtieth part, and to observation it has not been found less than about one-fifth of this, or one-three-hundredth part, but there are difficulties in determining the absolute quantity, because it is impossible to know whether we have or have not separated the whole of the moisture from a portion of the atmosphere, by any apparatus that we can employ; and when we speak of air reduced to a state of dryness, or absence of humidity, all that we mean is, that the test which we apply to it is unable to detect the presence of any more; but as to the absolute quantity we know nothing, because both the division of the water which is held suspended in the atmosphere, divided, but not decomposed, is, in its finer state, much too delicate for our perception; and so is that agency, though a mechanical one, or rather one which is neither mechanical nor chemical, by which it is held suspended. We shall, however, have occasion to return to this branch of the subject, in a future section.

When we consider the substances of which atmospheric air is composed, the simple nature of their mixture, the proportions in which they exist, the uniformity of those proportions, and the readiness with which the proportion is restored if one of them is abstracted, we cannot but admire the beautiful adaptation of this element of life to the necessities of every creature that lives—to the carrying on of every operation on the surface of the earth.

There is much in the proportion in which the component parts of the air are mixed; for we have seen that when the relative proportions are varied, the result is a substance of a very different character,—not a gentle and passive one like the limpid air, which is always ready to assist all, yet which injures none, but a substance capable of the most powerful action.

SECTION V.

WEIGHT, OR PRESSURE, AND VOLUME OF THE ATMOSPHERE.

In our preliminary remarks, in the first section of this volume, we slightly noticed the advantages which are derived from the weight or pressure of the atmospheric fluid, both in giving stability to bodies on the surface of the earth, and in enabling them to be moved. The pressure we stated as being about fifteen pounds, avoirdupois weight, on every square inch of surface, at the mean level of the sea, and under the state of mean density of the atmosphere. This pressure acts on all sides of bodies with nearly equal energy, or at least the energy differs only with difference of elevation above the level, which, in the case of any body that we can move by artificial means, is so very small that it may be left out of the estimate. It is this pressure which forces the air into every crevice and opening of the earth, in between all solids which are in contact with each other without absolutely adhering, and also which forces the air downward between the particles of all water which is freely exposed to the air, to a greater depth than, at first sight, from the superior pressure of water, we would be apt to suppose. This last is a very important part of Nature's economy. The water, which occupies by far the greater portion of the earth's surface, also contains by far the greater number of living inhabitants. Those inhabitants, though we are in the habit of saying that they breathe water by means of that fringed or fibrous apparatus to which we give the name of gills, and though none of them are perhaps capable of breathing air without its being diluted in a volume of water, are all breathers of air, as much, in principle at least—though many of them do not require nearly so much in volume—as the inhabitants of the land, or those which support themselves in the air by means of wings. Still, however, if the water does not contain air, fishes, even those which remain constantly at or near the bottom, and consequently breathe the least, cannot live in it; and it is often found that if a fish pond is completely frozen over, and the air totally excluded for even a moderate length of time, the fishes are as certainly and as completely suffocated for want of breath, as land animals would be if pent up in an air-tight apartment or vessel. We are not acquainted with any organ in the whole animal structure capable of enduring the very powerful degree of action which is necessary before oxygen can be separated from hydrogen, in that chemical union in which they exist in water; and therefore we are led to conclude that, as far down in the depths of the ocean as an animal lives, or a plant grows, be the nature of that plant or animal what it may, there must be a supply of atmospheric air adapted to its necessity. In the lower depths which are habitable, we have reason to believe that a smaller quantity of air suffices for the purposes of life, just as, on the more elevated parts of the earth, a smaller quantity of oxygen in the same volume of the rarer atmosphere there, suffices, than is required in the more dense atmosphere at the level of the sea ; but, still, without some quantity of the atmospheric fluid, however small, we can imagine no function of life or of growth to be carried on, at least after the creature has become dependant on its own organs.

When we consider these matters, and how the atmosphere is necessarily the breath of life within the waters, as well as in its own free volume above the surface, and also how it is the pressure of the atmosphere which is chiefly instrumental in sending it to maintain life in the deep, the importance of this property of the air in Nature's working, forces itself very powerfully upon our attention. When we say that the pressure of the atmosphere is thus instrumental in sending down the breath of life to the inhabitants of the waters, we make use of the word "chiefly" and not of the word "wholly," because, agreeably to the general law and purpose which runs through the whole of creation, the water is as admirably fitted for receiving this admixture of the element of life, as the atmosphere is for sending it downward.

This adaptation of the water for receiving a portion of air, undecomposed, and in mechanical mixture, not in chemical solution, is a matter well worthy of our attention, as helping to explain the reverse action by which the air takes up into its volume a portion of water intimately divided, but not more chemically dissolved than the air is which descends downward into the water. Water is the least susceptible of alteration of bulk, while it remains in the liquid state, of any substance with which we are acquainted. The severest pressure to which we can subject it condenses it but little; and so also the removal of all pressure, at least as far as we can carry that operation, expands its volume just as little. No doubt, when pressure is removed, a portion of the water passes into the state of vapour, and all the air which is in it bubbles off and escapes, thereby shewing that it was held there by pressure on the surface of the water, which, of course, can be none other, on the great scale, than the pressure of the atmosphere; but under the most effective experiments that can be made for removing pressure from water, that which remains liquid has its specific gravity, or quantity of matter in the same volume exceedingly little diminished. In like manner, if heat is applied to water, the air escapes; and if the temperature is raised to 212° of the common thermometer, under the ordinary temperature and pressure of the atmosphere at the mean level of the earth, the water passes into steam or vapour; and it passes into steam at a lower temperature if there is less pressure than the average of the atmosphere, and requires a greater degree of heat if the pressure is more than this; but still, under different degrees of heat, the changes of volume in the water are not much greater, if greater at all, than they are under variations of pressure. The fact is, that, in their effects, variations of pressure and variations of heat are very much the same, and it is also probable that their causes are not essentially very different, because, after a certain degree of change, the one invariably accompanies the other. The heat acts exactly in the same manner as the removal of mechanical pressure from the surface, only it acts as an impulse given to the atoms by the heating cause; whereas the removal of pressure enables their own expansive energy to act—which energy may, however, be always considered as the operation of the specific or latent action of heat which is treasured up insensibly in the substance.

This incompressibility of water, by means of which it preserves its pores open to a very great depth—we may almost say to any depth—leaves an open way by which the air may descend. The pressure of the air forces that fluid down into the openings thus left, and the operation is farther facilitated by that same surface action between the particles of air and the particles of water, which appears to contribute as much to the elevating of the vapour of water into the air.

Thus, in the general economy of nature, taking the most simple, but at the same time the most comprehensive view which we can take of it, the pressure of the air is of the greatest importance; and the investigation of the laws of its action is one of the most interesting inquiries to which the attention of mankind can be turned. We can consider that it is so, and very little attention must satisfy us of the fact, it seems strange that this property is but recently known to mankind.

The old doctrine was, that when the action of this pressure forced water into an empty space, in opposition to the direction in which water falls by gravitation, it arose from a certain abhorrence which nature had of a vacuum or empty space. It is not yet 250 years since the illustrious Galileo discovered the fact of atmospheric pressure, and thereby laid the first foundation of the philosophy of the air—that corner stone upon which so beautiful and so useful a structure has been raised by those who have followed in the footsteps of this truly illustrious man. It may not be amiss to mention the circumstance which led to this, perhaps the most important discovery that ever was made in natural science—because the rational understanding of the whole system of immaterial nature hinges upon it.

The use of the common pump in raising water had been known long enough before that time; but it had either so happened that no attempt had been made to raise it more than thirty-two or thirty-three feet by this means, or that, if the attempt had been made, and had failed, as it must of course have done, no notice had been taken of it. An engineer was employed to construct, for the Grand Duke of Tuscany, a pump which would raise water, to what particular height is not recorded, but certainly to a greater height than thirty-three feet. But when the pump was tried, though the water ascended readily in the bore of the pump till it reached this height above the water in the cistern, it would not rise one inch higher, for all the labour that could be exerted. The engineer, having carefully examined his pump, and found that it was well made, sound, and without a single flaw, was utterly at a loss to account for the stubbornness of the water in positively resisting every effort to raise it beyond this height. In his perplexity, he applied to Galileo, who was at that time the most able mathematician, and probably the man of most clear and enlarged views on the philosophy of matter. Galileo, somewhat equivocally, as if believing in the universally credited doctrine of nature's abhorrence of a vacuum, but at the same time throwing most pointed ridicule upon it, replied, "that the water was raised to the height of thirty-two feet on account of the horror which nature had for a vacuum, but that the horror was limited in its effects, and ceased to operate above the height of thirty-two feet." It is probable that, in giving this answer, Galileo was aware of the character of the age in which he lived, and dreaded to express more clearly that disbelief in nature's abhorrence which is really involved in his answer, through fear of those inquisitorial powers, by the interference of which he was subseqently compelled, under peril of his life, publicly to renounce the doctrines of his philosophy, after he and his disciple, Torricelli, had given to those doctrines all the force of demonstration.

But though Galileo certainly made the first discovery, and Torricelli was the first to try the weight of the air, by weighing it against a column of mercury, which he found, even in the first and rude experiment, to stand nearly at that height which was inversely to the height beyond which the water would not rise in the pump, as the specific gravity of mercury to the specific gravity of water. It followed from this, that if there was an abhorrence of a vacuum, that abhorrence varied with different substances, and in the case of the two which had been tried, the abhorrence, which extended to about 32½ feet in the water and about 27½ inches in the mercury, was measured by a constant quantity, namely, the weight of the column that was supported above the level of the cistern, supposing an equal base in both cases; and as it was known that fluids press equally upon equal portions of their bases, when the height above the base is the same, it become an easy matter to ascertain that the weight suspended in the case of water was exactly equal to that suspended in the case of mercury.

But though it was thus evident that the column of water or of mercury was as a weight in the one scale of the balance, and that it could be held in equilibrium only by an equal weight in the other scale, it remained for the illustrious Pascal to make the experimental process, and thereby establish, not only the fact that the pressure of the atmosphere admits of more easy and accurate measure than almost any thing else that we are acquainted with, but that this pressure may be employed as a means of determining the difference of the elevation of places above the mean level of the earth's surface. Pascal saw hat if the whole column of the atmosphere, taken from a place but little elevated above the level of the sea, supported a certain column of mercury, then if the mercurial column should be carried to a height—to the top of a mountain, for instance —there would be, above the mountain top, a column shorter by the elevation of the mountain, which would consequently require a shorter column of mercury to balance it; so that, if the mercurial column were carried up to such a situation, the mercury would descend in the tube. Perrier, the brother-in-law of Pascal, was entrusted with the performance of this important experiment, which he did on the 19th of September, 1648—a memorable day in the annals of natural science,—and the result was most satisfactory. The same tube was carried,—with its column of mercury, and with its lower or open extremity plunged below the surface of a quantity of the same liquid metal in a bason,—from the bottom of the mountain of Puy-de-dome, and he found as he ascended the side of the mountain that the column of mercury descended in the tube; and, when he reached the summit, the column was more than three inches shorter than it had been at the bottom. In other words, that ascending in the atmosphere to the summit of Puy-de-dome took off about a tenth part of the atmospheric pressure from the surface of the mercury in the bason, which pressure is the means whereby the column is supported in the tube. But if one tenth of the pressure was taken off, it followed, as a matter of necessary inference, that in reaching the top of Puy-de-dome, Perrier had passed through, and reached the top of, a tenth part of the mass or volume of the atmosphere as estimated at the bottom. This established not only the fact of atmospheric weight being always determinable by the quantity of mercury suspended in a perpendicular tube, closed at the upper end, entirely filled, and then plunged in a bason of mercury, until the column in the tube sunk down to a fixed level, but that differences in the length of this column would afford the means of ascertaining the different heights of the places at which those differences were apparent. Pascal himself repeated the experiment at the top and bottom of the steeple of St. Jacques-la-Boucherie, at Paris; and though that was a trifling height compared with that of the mountain on which the former experiment had been made, yet here again the result was perfectly satisfactory; and though some of the philosophers of the time continued to controvert the doctrine which those experiments had demonstrated, and others made some attempts to rob Pascal and Perrier of the merits of it, yet justice and sound philosophy triumphed, and it was not long before those who had been at first the most opposed to the doctrines, convinced themselves of the truth of it by their own experiments.

Such was the commencement of what may be considered as our rational knowledge of the atmosphere; for so long as it was supposed that there was a principle of levity in aërial matter, and in flame and smoke, and vapours of all kinds, by which they ascended in the atmosphere contrary to the well-known phenomenon by which a shower of rain, or a stone which has been thrown up, falls down, the same arguments could not be applied to the atmosphere, or to any thing floating or ascending in the atmosphere, which experience taught mankind to apply to solids and liquids on the earth; and, therefore, the philosophy of nature was broken, and, for want of the connection between matter in a state of air and matter liquid or solid, it was impossible to arrive at any correct notions of either. Indeed, there is no doubt that the agitation of this question, and the clear establishment of the fact of the air's having determinable weight, accurately expressive of the whole column over any place at any time, was one of the principal elements which led Newton to investigate the law of gravitation, and to discover and demonstrate that this law is universal in all observable matter; and that any apparent deviation there may be from it, becomes, when properly examined, an additional confirmation of its truth.

Thus was the whole mass of the atmosphere at first determined by weight, and such were the results of this most important discovery. The instrument used—consisting of the filled tube inverted with its open extremity in a bason of the same fluid which the tube contained—was called a *Barometer*, from a Greek word, which signifies "the measure of weight," but without any allusion to the atmosphere as being the substance, the weight of which is measured by this instrument. Perhaps it is as well that there is no such allusion in the name; because, though the weight of the atmosphere is that which the barometer is most generally used for determining, yet this is not the only pressure which it can be used to determine. Since the invention and improvement of the steam-engine, and the application of that greatest triumph of human science and skill to so many useful purposes, it has been found very convenient to attach an instrument, constructed on the same principle with the barometer, to measure the force of pressure in the steam which puts the engine in motion. A measure of this kind is very desirable in cases where steam at a high temperature, and consequently at a high pressure, is employed. There is a degree of temperature to which confined steam could be raised, at which it would blow to atoms not only the strongest apparatus that man can construct, but even the earth itself, and that, too, though the steam were but in a small quantity. Thus, for instance, the primary cause of an earthquake, the eruption of a volcano, or the elevation of a volcanic island through hundreds of fathoms of sea, may be nothing more than a small quantity of water, not exceeding what would fill a tea-cup or even a tea-spoon, if sufficient heat is applied to this small quantity of water, under sufficient pressure. The only evidence which a steam-engine would give of the pressure, that is, the expansive force of the steam arising from the action of heat being too great for the strength of the boiler or other containing vessel, would be the disruption of those vessels by one of those explosions, of the fatal consequences of which we but too frequently hear.

But when there is a mercurial gauge, upon the same principle as the barometer, attached to the engine, the pressure of the steam upon the surface of the mercury in the bason is always measured by the height to which the column rises in the tube; and thus the elasticity can be so regulated as that its pressure on the inch can be determined within a few pounds, and thus it cannot only be always kept below what the strength of the apparatus can bear, but the engine can be adapted to the work which it has to perform with the greatest nicety, so that no part of its energy need be lost.

In this way the barometer may be applied to determine the pressure or expansive force of any kind of vapours, or species of gaseous fluid; and thus it becomes an equally universal, accurate, and convenient measure of all power as obtainable by such substances,—in short, one of the most useful instruments for an almost countless number of purposes in the investigation of nature, and the conducting of the more useful parts of practical art. In the case of the exhaustion of vessels containing air, a similar contrivance is equally valuable for ascertaining the degree of exhaustion. It is evident, that if the bason of a mercurial gauge, constructed on the same principle as the common barometer, is introduced into the jar, or other vessel, which is placed on the table of an air-pump in order to be exhausted of air, the descent of the mercury in the tube of this gauge will indicate the degree of exhaustion; and if it is possible, by working the pump, to reduce the mercury in the tube to the same level with that in the bason, the exhaustion will be complete, or the jar will contain the same sort of vacuum as that in the top of the barometer tube over the mercury, which is called a Torricellian vacuum, after the name of its discoverer, and it is understood to be the most perfect vacuum, or absence of substantive matter, which can be obtained. It is not, generally speaking, possible to exhaust a receiver to this degree by means of any air-pump; because, even in the best constructed one, there must remain a sufficient quantity of air for raising the valves, and how finely soever these may be constructed, some force is required to raise them. But still the gauge shows to what extent the exhaustion has been carried; and, therefore, as the remaining air diffuses itself equally through the whole of any receiver of such dimensions as can be used in experiment, the gauge puts us in possession of all the information which we can obtain upon such a subject, and, indeed, of all that is necessary.

It was not long after the discovery of the pressure of air, and the invention of the barometer, that it was found that that instrument showed variations of atmospherical pressure even when it remained stationary at the same place; and this led to the desire of knowing to what circumstances those variations were owing. The immediate cause of them was understood as a matter of direct inference from the use of the barometer; because, as the height of the column of mercury was in all cases the exact measure of the atmospheric pressure, that is, of the whole weight of the mass of the air over the place, it was obvious that the changes in the height of the column were also measures of corresponding changes in the weight of the atmospheric mass; and, therefore, it only required careful attention to the other atmospheric changes which accompanied, or immediately followed, those changes of weight, to turn the barometer in so far into that which it is often properly called, "*a weather-glass.*" If the changes of the weather, or general phenomena of the atmosphere, which follow equal changes of the weight, as indicated by the variations of the mercurial column, were perfectly uniform, this part of the business would be as simple and as clearly explainable as the fact of the weight itself. But there are so many changes which take place in the atmosphere at heights too great for our observation, and arising from so many causes, of many of which we are almost necessarily quite ignorant, and of none of which have we a perfect understanding, that this part of the subject remains, and must for ever remain, in all probability, vague and imperfect. We know thus much, however, that motion of the atmosphere in a horizontal direction, that is, at right angles to, or directly across, the perpendicular direction in which its mass gravitates toward the earth, and which is the only tendency of it which tells in changes of the barometrical column, must diminish the gravitating influence, and, to the same extent, cause a fall of the mercurial column, unless the motion is attended by a resistance of the air which shall produce a condensation to compensate the diminished gravitation occasioned by the motion. It is not necessary that the motion of the air which thus affects the barometer should take place at the surface of the earth, or even at any height which observation can reach—on the summits of mountains, in air-balloons, or in any other way; because, at whatever height of the atmosphere any degree of pressure is removed or put on, the former will tell in a fall of the mercurial column, and the latter in a rise of it, in exactly the same manner and to the full extent as the change of pressure either way.

In our latitudes, the greatest height of the mercurial column at the mean level is about 31 inches, and the lowest descent at the same is about 28 inches; so that our barometrical range is thus about three inches. This is, of course, spoken of in reference to a specific level, and it applies to one very little, if any thing, above the high-water level of the sea. At the top, that is, at 31 inches, the words "set fair" are usually marked on the scale, at one side of the tube, and the words "set frost," at the other. An inch below this, or at 30 inches from the surface of the mercury in the basin, "fair" is written, on the same side with "set fair;" and "frost," on the same side with "set frost." At half an inch below this, or at 29½ inches, which is the middle of the range, the word "changeable" is written, which answers both for summer and for winter. At 29 inches, "rain" is marked on the summer side of the scale, and "snow" on the winter side; and at the bottom of the scale, or at 28 inches, the words "much rain" are written on the one side, and "very stormy," or words of similar meaning, on the other side. The scale is usually divided into parts of an inch, tenths, in common barometers; and if they are of rather superior construction, there is a sliding piece called a vernier, which contains an inch divided into eleven equal parts, and b means of this the divisions can be read to the hundredth part of an inch; or, if the divisions on the scale are more minute, and the instrument is nicely constructed, the variations in height of the column may be read to the thousandth part of an inch.

But though the names of certain kinds of weathe are thus confidently marked on the scale of the barometer, it by no means follows that the weather itself shall be that which the height of the column of mercury indicates; beçause we are not in possession, neither can we obtain possession, of all the data which are necessary to predict the result, even when the barometer shows a change of atmospheric pressure. There are, however, some general methods by which we can know what is going on in the atmosphere, although we air unable to see so far forward as to ascertain exactly what shall be the consequence of the change as told upon the earth.

If the barometer falls, that is, if the column of mercury becomes less in height, we may conclude that there is motion and disturbance in the atmospheric mass, even though that disturbance is at so great an elevation as that it is indicated to us in no other way, except, perhaps, by our general feeling of comfort, which, in persons of much sensibility, is perhaps as much influenced by those atmospheric changes as the best barometer that can be constructed. We know, also, that the tendency of motion and disturbance in the atmosphere is the precipitation of the moisture which the atmosphere holds in the state of invisible vapour; and that, if the disturbance is violent enough, and of sufficient continuance, rain or snow, according as the temperature is above or below the freezing point, is the natural consequence, in the average state of the atmosphere. But whether that consequence shall follow to the extent indicated by the barometric change, or whether, indeed, it shall follow to any extent at all, is a matter which we cannot theoretically calculate upon, but which must in a great measure be determined by the experience which we have of the general indications of the weather at the place where the observation of the barometer is made. It very often happens, that when there is sufficient motion and disturbance in the upper strata of the air for occasioning a considerable fall of the barometer, that there is in the state of the earth, and in that of the lower strata of the air, opposing tendencies sufficient to counteract the effect. We shall be better able to explain this, in so far as it is explainable in a rational manner, after we have considered the process of evaporation, and the disposing causes which make the atmosphere receive or part with humidity. But as we are speaking of the barometer, and of its uncertainty as a weather-glass, we may mention that the still air over a very dry surface may be sufficient to re-dissolve the moisture which is precipitated upon it in consequence of the disturbance of the air above, and thus not only prevent the fall of rain, but the formation of permanent clouds. It is a common saying, that "every sign of rain fails during dry weather;" and this saying has more of true philosophy in it than many others which have a great deal more of the appearance. Up to a certain point, at which the drought, like most other states in nature, when it runs to a certain length, involves in itself the means of its own termination, drought is the cause of the continuance of drought. The dry surface disposes the air to absorb moisture, instead of letting it fall; and thus, though light clouds are often formed at certain times of the day, and give promise of rain to the parched earth, in the opinion of those who have not attended much to the real indications of the weather, yet they very speedily disappear by melting into the air, and the drought becomes more severe than ever.

If we take the opposite end of the scale, that which answers to the greatest height of the mercurial column, and which, in the popular way, is marked with the words "set fair" and "set frost," we may safely conclude that, when this height is arrived at, the state of the atmosphere is one of the greatest tranquillity that it ever enjoys at the place; or, that there is less motion or disturbance of it than if the barometer were lower, even though remaining stationary at its lower range. When we speak about tranquillity in the atmosphere, we must not, however, understand that the atmospheric fluid is stagnant or wholly without motion. There are calms during which we can feel no motion of the air near the surface, neither can we detect it by any test which we can apply; but if, even in the stillest atmosphere, a balloon (which of course must be light enough to float, and consequently to obey the motion of every stratum of the air into which it passes,) is sent up to a considerable height—say that of a mile or more, it will not remain long, indeed, not for any measurable length of time, stationary over the same point, but will shift, now this way now that, apparently with a very slow course, if its elevation is great; but yet it will not be long in getting out of a pretty extended horizon, or, in other words, moving to the distance of twenty or thirty miles, or more than that, including all the flectures of its motion. These currents, which are probably never still in the upper regions of the atmosphere, and that even at what we may regard as inconsiderable elevations, as compared with those to which the volume of the atmosphere reaches, are, generally speaking, seasonal,—that is, they depend upon the rotation of the earth on its axis, and the position of that parallel of latitude over which the sun is vertical for the time. No doubt they are influenced by the different surfaces of land and water, and by the varied surface of the land, and even by the set of the tides and currents of the sea; but still there is some state of those seasonal atmospheric motions which is perfectly compatible with settled weather. Not only so, but the movement of those seasonal currents without interruption is really the cause of the settled weather; and a perfect stagnation or stoppage of those currents would as certainly be attended with a breaking of the weather, as would any other means of atmospheric disturbance. This part of the subject is, however, attended with a great deal of difficulty, more especially in countries like Britain, which, by being distant both from the equator and the pole, and placed in the middle latitudes, may be said not to be under the controlling sway, either of one character of seasons or the other. The insular situation of the country, too, and its having a wide ocean, of comparatively uniform temperature all the year round, on the west, and a continent subject to considerable seasonable varieties of temperature separated from it by only a narrow sea on the east, must, so to speak, at all seasons, abide the cross fire of that ocean and that continent, as they call and answer to each other, in consequence of the permanent state of the one, and the seasonally-varied state of the other. These, with many other local considerations, render the prediction of the weather in Britain, at least for any length of time, a matter of great uncertainty, even to those who have attended most carefully to the phenomena in their succession, which, amid so much uncertainty, is far preferable to any reasoning from theory, how plausible soever it may be, or well soever it may accord with the state of things in countries where the phenomena of the atmosphere are more uniformly obedient to general laws. We mention these circumstances, in order to warn the reader, that when we come to treat briefly of the phenomena of the weather, we are not to be understood as even attempting to lay down rules which can be applied for any length of time in variable climates, but merely as giving the most probable account which we are able, of those causes and effects in atmospheric phenomena, which follow most immediately in succession to each other.

After the fact of the weight or pressure of the atmosphere was clearly established, and the diminution of its weight or pressure with increase of elevation above the mean level of the earth's surface, which was a necessary deduction from the theory, had been established in the clearest manner, it became desirable to determine the law according to which its weight or pressure diminishes with increase of elevation. At the time when this was first attended to, the consitution of matter, and especially the nature of gases, was not so well understood as it is now that the means of converting various substances into the gaseous form are known, and the degrees of the action of heat necessary for this purpose are ascertained. When, however, we consider that the atmosphere has no cohesion, or principle of union of any kind among its particles for each other, or of its mass for the earth, but the simple fact of its gravitation, it becomes an easy matter to determine the law at which the pressure must decrease as we ascend above the mean level of the earth's surface. Every stratum, whether we consider it of greater or of less thickness,—and the only difference in this method of considering it will be, that the thinner we consider the strata, they will be the more numerous, and, on the other hand, the thicker we consider them, they will be the less numerous,—every stratum, viewed in this manner, will be pressed by the weight of all the strata above it; and as this is the only possible cause of the density, it will be the measure of that density. The strata, considered in this manner, are not to be regarded as a succession of portions of the atmosphere, each equal in density through its thickness, and having a marked change between it and the next one, but the whole proceeding gradually from greater density at the lowest stratum to less density in the highest, with a perfectly uniform or regular diminution of density with the ascent, or increase of it with the descent, so that no distinction can be marked as taking place at any single point of elevation; though between points differently elevated the difference of density will bear some proportion to the difference of elevation. The question is, what proportion, from the nature of the case, ought it to bear?

As, unless it be acted on by some external cause or agent, the atmosphere must adjust its volume and pressure exactly to each other, and as the elasticity, or tendency of the air to expand is the force by which its volume is made to occupy the larger portion of space than it occupies under greater pressure, it necessarily follows that the elasticity, or expansion, and the density are equal, or agree exactly with each other at all possible differences of elevation, whether at the mean level of the sea, where it is most dense, and the pressure about fifteen pounds on the inch, or at those greater elevations where the rarety is almost a maximum, and the pressure is a minimum, or if we could reach it there, would be insensible to any known test,—where, in short, there may not be the millionth part of a grain, or even the millionth part of that small quantity of the substance of air as matter, in ten, a hundred, a thousand, or any number of cubic miles.

Now, as the change of density, and the corresponding and equal one of elasticity, diminish as we ascend, not at the end of strata of measurable thickness, but gradually throughout the mass, it follows, that as we ascend the height in lines, the increase of volume, and the consequent decrease of density, will be as surfaces; because we may take an immeasurably thin stratum at any one elevation, and consider it as extending as a plane in every direction around any point which we choose to assume. Hence it follows, that while the elevation increases in an arithmetical proportion, or by the addition of equal measures of height, the density will diminish in a geometrical proportion, or by continual multiplication by the same factor. This relation is not an absolute one, as respects the positive density, because the density is a fact to be observed at the mean surface where the series, both of ascent in height and in diminution in density, begins. When, however, this, which we may call the maximum density, is once found by observation, the density, at all other elevations may, if we leave out the influence of heat, or any other disturbing cause, be calculated with the greatest precision.

This law of the densities at different elevations of the atmosphere being in proportion to the squares of the altitudes inversely, and the converse, that the altitudes are inversely as the square roots of the densities, follows from the simple fact of the gravitation of the atmospheric mass being the only condensing force to which it is subjected; and it holds in the case of gravitation, estimated in any other way. It must be understood, however, that the commencement of terrestrial gravitation is not to be estimated from the earth's surface, but from the earth's centre; though, in consequence of the elasticity, or tendency of the air to expand, producing an increase of volume always proportional to the decrease of density, the diminution of atmospheric pressure increases much more rapidly than the gravitation of bodies, which are not affected by this expansion. This will be readily understood by the following consideration:—Suppose a stone which has a certain weight, as estimated by some weighing instrument in which springs or other contrivances, and not weights liable to be affected by gravitation, are made use of, and that the same stone is afterwards carried to the top of a mountain, one mile in height above the former place; then the weight of the stone, as shewn by the weighing instrument, which does not act by gravitation, will appear less than it was before, in the inverse ratio of the squares of its respective distances from the centre of the earth. That is, the weight on the mile-high mountain will be to the weight at the mean level as the square of 4,000 to the square of 4,001, assuming 4,000 miles as the mean radius of the earth; if we square those numbers, that is, if we multiply each of them by itself, we have the square of 4,001 equal to 16,008,001, and the square of 4,000 equal to 16,000,000. We may leave out the last three figures of each of these numbers, because each of them amounts to more than sixteen millions, and therefore the 1 which is omitted in the first number is a very trifling part of the whole. Omitting three figures, then, we have—weight at the surface 16,008, and weight on the mountain 16,000; and dividing both these numbers by 8, which does not alter their proportion, we obtain 2,001 at the mean level, and 2,000 at the top of the mountain a mile high; and as the difference of these numbers is only the number 1, the expression of them cannot be rendered more simple. Thus, in the case of any body or substance which does not expand in consequence of the removal of pressure from it, there is a diminution of one two-thousandth part when it is raised to the height of a mile above the mean level of the earth's surface; and it would be easy to determine the diminution of weight, that is, of the force of gravitation, answering to any other elevation whatever.

In as far as the mere gravitation of atmospheric air is concerned, the diminished weight with elevation above the mean level follows exactly the same law; for the law of gravitation is constant in its nature, and common alike to all matter, under the same circumstances, if its action is not in some way modified by other causes. If, therefore, we imagine a cylindrical column of the air to stand on any circular base, that is, any round portion of the earth's surface, and consider what form this column would assume, in consequence of the elasticity expanding it in all directions, in proportion as the pressure is taken off, we shall have, perhaps, as clear a notion of the general structure of the atmosphere as can be conveyed in popular language; though causes of variation modify this at different times.

Air, at the mean level of the sea, and in average states of temperature and the other causes by which it is liable to be disturbed, is in weight, to an equal bulk of water under the same circumstances, as 1 to 827.437, or as 1 to 827 very nearly. A column of water which exactly balances the whole column of the air above the mean level, under the same circumstances, requires to be about 34 feet in height. This 34 answers to 1 in the above proportional numbers; and, therefore, if we multiply 827 by 34, we obtain 28,118 feet for the height above the mean level of the earth's surface to which the air would extend, if it were all of the same density as at the mean level, and not affected by expansion. This is very nearly five miles and nine-tenths, or about one mile and one thirty-eighth part above the top of the highest known mountain.

Upon this supposition of uniform density at all heights, a circular column of the air, standing upon a base one foot in area, would be, as has been said, 28,118 feet, or nearly five miles and one-half in height, and it would balance or be of the weight of a column of 34 feet of water on an equal base. Water weighs about 1000 ounces avoirdupois per foot; and thus the weight of a 34 feet column, or of its equal, a column of the atmosphere, would be 34,000 ounces, or 2,125 pounds, or very nearly 19 hundred weight.

Taking this, calculating the extent of the earth's surface, and making allowance for the elevation of the land above the mean level, we obtain an approximation to the absolute quantity of the atmospheric fluid. This calculation has been made, and the result has been stated in round numbers at 532,000,000,000,000 tons, that is, five hundred and thirty-two billions of tons.

This is, no doubt, an approximation to the weight, or the pressure, which is the measure of the quantity of the whole mass of the atmospheric fluid; but it must be admitted that it is a very rude approximation, for the subject is one upon which accuracy cannot be obtained. The principles are all clear enough, but the data cannot be accurately obtained. We mentioned in our volume of the EARTH, that there are difficulties in the way of getting at the exact shape and size of our planet; and, we need scarcely add, that the chances of error must increase in proportion as we have to apply more numerous and minute data to the same gigantic measures. If a line is only a few yards in length, we shall hardly find the same result if we measure it twice; how then can we expect to be very accurate with the circumference of the earth, which is at least five and twenty thousand miles, and which we must deduce from short measures? If two different surveyors measure the same small paddock of land, or if the same surveyor measure it twice in different ways—even in the same way—the results will not agree: then how can we pretend to accuracy in the case of the surface of the earth, the expression for which is the product of the diameter and circumference, both of which can be but vaguely determined? Nor is this all; for even if we could obtain the mean surface, to the fraction of a foot,—and we cannot be sure of it to within a thousand miles of the truth, or much more than that—we have still to contend with the variations of level, not only of the land, which is, to some extent at least, permanent, but of the sea, which is in continual change, on account of its own tides and currents, and also of the variable pressure of the atmosphere upon different parts, arising from causes which are exceedingly variable and temporary. Even if we could get the better of all these, how should we be able to obtain the average pressure of the atmosphere, which is not the same at perhaps any two places, or the same for two connective seconds at the same place? But, granting even all this to be capable of accomplishment, we have still the errors of our own observation, and then of the instruments which we employ; and if, as we ought certainly to do, we take all these into the account, it behoves us to speak modestly of our actual estimates of any such mighty mass as the atmosphere would be, even on the supposition that it had no elasticity, or tendency to expand, when the pressure upon it is diminished. Therefore, if we say that the pressure of the atmosphere upon one foot of the earth's surface is 19 hundred weight, that the weight of its whole mass is 500 billions of tons, and that the height of a column of it, or of the whole, would be six miles above the mean level of the surface, we obtain numbers which are easily remembered, and which are near enough to the truth for all purposes of general illustration.

Such, then, would be the weight and such the volume of the atmospheric fluid, if it were not a substance that expanded on the removal of pressure; and, as the tendency to expansion does not of itself in the least diminish the gravitation, such is its weight at the mean level in the existing state of things. Let us next examine which form the cylindrical column, upon a circular base one square foot in area, would assume, taking into account the expansion, or that the volume which the same quantity or weight of air assumes, is inversely as the pressure upon it.

At the mean level, or base of the column, the pressure is that of the whole weight, or nineteen hundred weight nearly; and at the top of the column, whatever may be the weight, the pressure is nothing, and the actual expansion is indefinitely, or, as it is usually called, infinitely, great. The word "infinite" is misapplied in these cases; because, when we come to the elevation at which the pressure of the air is 0, the air itself, of which the pressure is, in all cases, the exact measure, must also be 0, that is, there must be *no air*. In other words, when we arrive at the elevation at which the pressure is 0, we are at the upper limit of the atmosphere,—out of it, as it were.

But the pressure and the tendency to expand are the two rival, or opposing, powers by which the state, or particular degree of expansion, of the air is maintained; and if the air is in a quiescent state, that is, neither expanding nor condensing, we must suppose that these two are exactly equal to each other. At the mean level of the earth's surface, or base of the column, the tendency to expand must be equal to the whole weight or pressure of the air; at every other elevation, it must be equal to the weight or pressure at that elevation; and as the weight or pressure at the upper limit is 0, the tendency to expand must be 0 also.

We may remark, in passing, that this state of things at the upper limit of the atmosphere, where the weight and the tendency to expand are both 0, informs us of something more than the mere limit of the atmosphere, as affected by those two opposing forces. This is evidently the limit of terrestrial gravitation, beyond which nothing, in any way connected with what may be called the peculiar economy of the earth, can exist. Beyond this there can be no gravitating matter, that is, no matter of any kind which maintains its position by the influence of the earth alone. The upper part of the air is thus the limit of the whole terrestrial system; and it is a limit at which there can be no matter, and no action of any kind. The air, at its very verge, has no tendency to the earth by gravitation, and for the same reason it has no tendency from the earth by expansion, both the qualities or tendencies which maintain its state have faded into nothing, and beyond this there can be no gravitating matter till we arrive at the atmosphere of some other of the great bodies of the system; and if there be no gravitating matter, we need not add that there can be no matter at all, for gravitation is the only general, certain, and absolute test of the presence of matter.

We must therefore conclude that there is, between body and body, in the vast regions of the universe, portions which consist of what we, in common language, call empty space—that is, space which can be occupied by nothing which gravitation can affect. It is true that there are not wanting, even at the present day, men who, within the limits of atmospheric gravitation, as regards the earth, and to the very utmost range of telescopic observation, as applied to the heavens, have done honourable service in the cause of true science, who yet have contended that these intermediate spaces between body and body are filled with a "something," which, even according to their own notions of it—in so far as men ever render their notions intelligible upon a subject of which even themselves know nothing—is a "nothing," to which they give the name of "ETHER,"and which some of them have "doted and dreamed" about so far as to point out how, out of this gravitationless ether, the solid and gravitating rotundities of the earth, the other planets, and the sun, were formed. But this consideration of the state of things at the limit of our atmosphere, shows how perfectly visionary and foundationless all such speculations are. It seems, indeed, half-way to the only rational belief that we can have upon the subject, namely, "that all things have been made out of nothing"—simply, they have been made; but it involves in it this singular absurdity, that this same nothing was both the materials and the workman in the creation of worlds and all their inhabitants.

We readily allow that, in this wonderful system of things, there is something more than the mere matter of the planets and suns, and the parts of which they are substantially composed, whether living or dead, and that this supplement to mere substantive existence can come from one planet to another, or from sun to planet, athwart these empty spaces, not only as easily, but much more easily, than through those bodies which are palpable to the sense, or at least to some test of matter. Gravitation on the great scale feels its silent way, not only from the sun, but the most distant planet in the solar system. From all the conjectures, too, that we can form by analogy, for upon such a subject we have not, neither can we obtain, a single fact, we have reason to believe that those energies, which act in opposition to gravitation, come across those portions of space without being in the least disturbed or arrested in their career; that as there is not, in the portions of space to which we are alluding, any thing which the beams of light can reveal, or the force of gravitation can attract, so there is nothing that can be warmed by heat, or in any way affected by the analogous energies which we call electricity, galvanism, magnetism, and other names. The lightest meteor cannot float, the palest flicker of the aurora borealis cannot play—nothing in short can be made visible in those singular portions of the universe, for the simple reason that there is nothing to be revealed.

If this consideration of the extreme boundary of the atmosphere and the space beyond does not impart much positive information to us, it is nevertheless of value in pointing out the limit beyond which, if we go, we must of necessity fall into error and absurdity; it tells us, in language as plain as any in which truth can be conveyed, that we must not speak of *ethereal fluids*, and *electric fluids*, and *magnetic fluids*, or of *the matter of heat*, or of *light*. It reproves us if we will not blot out of the vocabulary all such unmeaning words as "imponderable substances," or of heat consisting "of particles," or of light being either an "emanation of *substance*" which passes from the radiant body to the body illuminated, or that it is the "vibrations of a *fluid*," the nature of which is far more mysterious than that of light itself.

It does this; and if we would come to the study of it in the true spirit of single-minded and candid philosophy, without any pre-conceived theory—which theory, from being our own creation, is too often more dear to us than the truths of that creation of which the contemplation is our duty, and should be our pleasure—it might do more than this; it might teach us that there are in nature two distinct subjects offered to our contemplation—substantive matter and action. The one of these is just as much above our comprehension, in respect to its origin, as the other, unless we refer both to the fiat of an Almighty Creator. For, if we look at either of the two singly, as they exist or are displayed in creation around us, we cannot, without a direct violation of every principle of reasoning, consider them as standing to each other in any relation of cause and effect. We cannot say that the substantive matter is the cause of the action, and as little can we say that the action is the cause of the matter. The earth and the other bodies which compose the solar system consist each of a certain definite and invariable mass of matter, whose quantity we can determine to almost as near a fraction of the whole as when we weigh common substances by means of a common balance; and they all perform motions, which we can determine with nearly the same relative accuracy as we can determine the motion of a coach along the road, or that of the index round the dial-plate of a clock. But we can no more say that the planet originates its motion than we can that the mere matter of the coach, or of the hand upon the dial, does the same. In the case of the coach, we have the animal power of the horses, or the power of steam, or something else in supplement to, and altogether different from, the mere mass of matter which is moved; and in the case of the hand upon the dial, we have the weight descending, or the spring uncoiling itself by its elasticity, as the immediate cause of the motion; but this, though we call it a cause, is, in truth, only an effect, and we can trace it another step,—to the winding up of the weight or the coiling up of the spring.

Follow it as we may, in either of these cases, or in any other case of action, we are never able to arrive at the original or primary source of action, any more that at the original or primary source of substantive matter. We have, therefore, no alternative but to refer the origin of material substance, and that of material action, to the same One and Almighty Creating Cause; and to consider the origin of the one as perfectly simultaneous with that of the other. Indeed, if we study the matter attentively —and there is none more worthy of our closest and best attention, we cannot even imagine the existence of matter without at the same time imagining it to be under the influence of action of some kind or other; and as the characteristic or test of the existence of substantive matter is gravitation in the mass, and the attraction of cohesion in the atoms; so the characteristic or test of the existence of action, is repulsion or refraction of one kind or another. Farther, as we can, without any violation of the strictest principles of philosophy, comprehend all substantive matter under the common appellation of "that which gravitates," so we may include all action of matter under the general appellation of "that which opposes gravitation." The gravitation, or, which is the same thing, the tendency to union, may be that which retains a planet in its path, and makes it a member of some one system of bodies in the universe, rather than a lawless wanderer over the whole; it may be that which holds in union the parts of a compound, whether the holding be chemical, as in the case of water, or simply mechanical, as in that of the air; or it may be any one of the countless thousands of modifications, to which all the substances and beings which we see around us owe their forms and their distinctions from each other; but still to what extent or by what means soever it may be modified, it is in its nature one. So, also, when we consider the opposite principle, that of separation or repulsion, it is in its more general nature one, whether it regulates the state of bodies, as solids, liquids and gases, or whether it displays itself in those changes to which we give the name of action, and qualify the name by epithets according as the action presents different appearances to our senses.

This is the grand balance in which we may consider the whole material creation suspended, in all its masses and in all its particles, down to a degree of minuteness of which it is impossible for us to have any correct notion. The fluctuations of this balance are variable without end, and we can see them only in part, because, in the direction both of the magnificent and the minute, they get beyond the scope of our organs, and all the aids by which science has enabled us to improve these; and, whether we view this balance with regard to suns and planetary systems, or with regard to those primary atoms of matter of the dimensions of which no power of observation which we possess can take cognizance, we find, that in all these, and in the whole range which lies between, and of which these are the extremities, the balancing powers are one in kind, and vary only in degree. It matters not what the substance is, whether it is a solid, a liquid, or a gas, whether it belong to the category of inorganic or dead matter, or form part of a growing plant or a living animal; for, in every possible case, it is under the one law of the two opposing forces, and the difference which it may happen to display is only a greater or less degree of cohesion, to which the repellant or separating force is always in the inverse ratio. But in the case of the greatest compactness or cohesion, as in gold or platina, which are among the most dense or weighty substances with which we are acquainted, or in diamond and oriental ruby, which are among the most difficult to separate, we cannot say that there is a complete union of particle with particle, without any repellant or separating force inhering in the substance. In like manner, in the most attenuated gas,—in atmospheric air, in hydrogen, or hydrogen expanded by the utmost intensity of heat, until a single grain, or the millionth part of a grain, would suffice to fill the whole orbit of the most distant planet, and in which the smallest member of the most tiny thing which the microscope reveals in a drop of putrid water, would not meet the least resistance,—in this, or in any case of attenuation more extreme than this, the force of aggregation does not quit even the most minute particle.

Thus the very same species of action which renders the atmospheric fluid perfectly plastic—so ready to act its part in all the operations of nature—affects, and as we may say, holds under its control, every kind and quantity of matter, influencing it, not in the mass merely, but in the atom, and in every atom, so that the whole of material nature is like a bended bow, always ready for its work. In all cases, too, the poise is so perfect, the balance so exactly on the turn, that the least addition or withdrawal of that repulsion, which we may consider as the active force, puts the whole in motion.

We, who live in a variable climate, have a beautiful instance of this, in the successions of the seasons. In the warmer parts of England, the green carpet of the earth knows no pause, but is as active in the depth of the winter flood as it is in the spring; but in places which are more cold and upland—on the slopes of the Grampians, for instance—there is a pause in that part of nature; and if winter did not benignantly throw its mantle of snow over these upper slopes, the pause would be final, so that in one year there would be an end to every growing thing. In these places, however, the very rigour of the season is a means of protection; for as soon as the surface is cooled to a certain temperature, the atmosphere comes to it on the wings of all the winds, and the condensation supplies for a time a quantity of the action of heat. While it is supplying this, it, at the same time, takes the cold, so to speak, into its own mass; and the wind from the sea, which comes to the mountain fraught with heat, and loaded with humidity in a state of invisible vapour, gives out its heat to the earth. It continues to do this until the whole atmospheric mass is below the temperature at which water ceases to be liquid, and then it deposits the whole quantity in snow. The congelation of the water produces heat and rarefication; and the wind drives with violence, until the surrounding air is drained, and the equilibrium of winter is brought about, which, in the high latitudes, is a tranquil, and far from an unpleasant time.

The snowy mantle, while it retains in the earth all the heat which is left there previous to the fall of the snow, and which is really more than is left in places that are swept by the bleak winds of winter, without any protection, reflects the heat of the sun into the air, so that, after the year has turned for some time, and the action of the sun has waxed powerful, there is a warmer atmosphere over the snow than there would be over the naked earth. In consequence of this, the general set of the spring wind is again toward the snow-clad height; and though the melting of the snow consumes or absorbs a great portion of the action of heat, it is astonishing how soon the covering of the earth gives way, and what brief time intervenes before vegetation is again in full action. So rapid are the transitions both ways, that, in very high latitudes, especially where the land can borrow its succession of atmospheres from the sea, there is hardly anything that can be called spring or autumn, and summer and winter divide the year between them. Were it not for the perfectly yielding nature of the atmospheres, these results could not be brought about, and more than half of the earth's surface would, in the course of one year, become a scene of utter and hopeless desolation.

But we have been led far, though it is hoped not altogether unprofitably, from the consideration of the atmospheric column, and the form which it would assume, on the supposition that only one such column stood on a circle of the earth's surface equal to a single square foot, every where balanced by the two opposing forces of gravitation and elasticity, or the tendency to expand, and at perfect freedom to assume that form which would naturally result from the joint action of these. As these forces are always, in the case of air, still, or at rest, exactly equal to each other, the space which the same absolute quantity or weight of air occupies at different heights must be the measure of them both,—of the expansion directly, and of the gravitation inversely,—that is, increasing with the one and diminishing with the other, so that at every imaginable height the product of the two must be a constant quantity.

It is the constancy of this product which causes the rarety or expansion of the air to increase as the squares of the heights; and from this it follows, that if we are to suppose a column of the air reaching to the height which we have stated as that which the whole atmosphere, at equal density throughout its height would occupy, and containing the same quantity or weight of air in all parts of its height, this column would assume the form of a hyperbola, on all sides spreading out with a uniform curvature, and extending indefinitely, or beyond all assignable measure, on every side, when that height at which it vanishes off into empty space were arrived at.

As every substance, emanating from the earth or the waters, and being freely diffused through the atmosphere, must assume this form, and would preserve it, were it not for the motions of the atmosphere, the full understanding of the form of this column becomes a matter of considerable interest. We shall, therefore, consider it in the opposite direction, or from the top or uppermost limit, of the atmosphere downwards. At the very top, or limit, the pressure is, of course, 0, because the expansion there has done its utmost. But if we assume any stratum, however thin, this stratum will press downwards by the whole of its own weight, but by nothing more. Take a second stratum of the same thickness with the first, and it will press downward with the whole of its own weight, and it will be compressed by the weight of this first in addition. A third will have its own weight, and will be compressed by the weight of two; a fourth will be compressed by three, and so on, each stratum being compressed by the whole thickness of one above it. Thus, whatever number of these strata we may suppose, and the number may be taken indefinitely great, as the increase of density is uniform as we descend, in proportion to the square of the heights from which we have descended, so that if we take the pressures at different heights, estimating them from the top of the atmosphere, they are directly as the squares of the distances from the top; and, consequently, if we consider them as taken from the bottom, that is, from the mean level of the earth's surface, they must be inversely as the space of these.

It is obvious that these diminished pressures, as we ascend above the mean level of the earth's surface, must tell in diminished heights of the column of mercury in the barometer; and hence, in order to turn that instrument into a very ready measurer of heights above the mean level of the earth, we have only to ascertain, by correct observation, the difference of height which answers to some given length of the column of mercury. As the mercurial column is estimated in inches, one inch is the best standard which can be taken for this purpose; and, according to the calculation of Dr. Halley, who was the first that turned his attention to this subject, 900 feet was assumed as the height of the column of air, taken near the mean level of the earth's surface, which would balance one inch of mercury. The logarithmic number answering to this is one-thirtieth part of the modules of the common system of logarithms, or ·0,144,765, which does not differ much from that assumed by Dr. Halley. This being determined, we obtain a very simple formula for the determination of heights by means of the column of mercury in the barometer, though that of course requires correction for variations of temperature. The formula is—as the number ·0,144,765 is to the difference between the logarithms of the barometric columns at the two stations, so is 900 feet to the difference of elevation, or height of the station at which the column stands lowest above that at which it stands highest.

This formula is, however, only an approximation, and the results which we obtain from it cannot be more accurate than our observations of the lengths of the barometrical column of mercury, and of the temperature at the two stations, the upper one of which has, of course, always the lowest temperature. Nor is temperature alone the only element with which we have to contend in reducing this formula to any thing like accuracy; for the atmosphere is so exceedingly sensible to all kinds of action, and to the mixture of all substances, that we must take into account every means by which its state may be affected. One of the most remarkable of these, for we cannot estimate them all—especially the electric states, is the degree of humidity in the air, and we are not in possession of elements sufficient for enabling us to determine to what extent moisture or dryness may affect the air's elasticity or expansion; and therefore, however convenient this mode of mensuration may be, it is impossible for us to determine how near the truth it may come in any particular case, although we are certain thus far, that the result which we obtain by calculation, will be at least as accurate as the data obtained by observation upon which that calculation is founded.

In the present state of science, and until some more accurate means of ascertaining the effect which all the different states of the atmosphere—as determined by the barometer, the thermometer, or measurer of heat, the hygrometer, or measurer of moisture, the electrometer, or measurer of electric state, and probably also the measurer of magnetic state, to which no name has hitherto been given—are more accurately ascertained, we may perhaps rest satisfied with the single correction arising from the effect of temperature alone. Now, if we assume as the standard, the centisimal thermometer, which is used on many parts of the Continent, and in which 100° answer to 180° of Fahrenheit, or the common thermometer used in this country, in which there are 180° between the freezing point of water and the boiling point, as estimated under the ordinary pressure of the atmosphere, as estimated at the mean level of the earth's surface, while in the centigrade, or Celsius's, thermometer, there are only 100° in the same range, we have the following formula for the determination of heights above the mean level by means of the barometer. The expansion of mercury is about one five-thousandth part of its bulk for every degree of the centisimal scale, and the expansion of air for each degree is very nearly twenty times greater than that of mercury, or about the two-hundred-and-fiftieth part of the bulks of the atmospheric fluid. Therefore, by having two thermometers, the one attached so as to show exactly the temperature of the column of mercury in the tube of the barometer, and the other detached so as to show the mean temperature of the atmosphere, and, consequently, the degree of its expansion, we have the following methods of procedure :—

First, correct the length of the column of mercury at the upper station, or height which is desired to be ascertained, by adding to it the product of its multiplication by twice the difference between the degrees on the attached thermometers at the two stations, the decimal point being shifted four places to the left.

Secondly, subtract the logarithm of this corrected length from that of the lower column, multiply by six, and move the decimal point four places to the right: the result is the approximate elevation of the one station above the other, in English feet, which, for ordinary purposes, may be regarded as sufficiently near the truth, as it will give the difference of elevation as correctly as can be obtained by any of the ordinary methods of mathematical mensuration which can be resorted to by travellers passing hastily over a country. If, however, greater accuracy is required, we may proceed—

Thirdly, by shifting the decimal point three places to the right, and multiplying by twice the sum of the degrees on the detached thermometers, and this product being added to the former, would give the true elevation very nearly. By this means, and with barometers of very nice construction, and thermometers also constructed with the greatest care, the heights of mountains, and, generally speaking, the differences of elevation of various parts of the earth's surface, can be ascertained with great ease, and with accuracy sufficient for all the common purposes of science.

There is another method by which the air may be made the means of determining elevations above the mean level of the earth's surface, and that is the temperature at which water boils or passes into the state of steam. This is not quite so precise as the determination of the same result by means of the pressure of the atmosphere estimated by the barometer, but it is a fact of the same kind, and one which it is necessary to understand, in order to have a clear notion of the use of the air in the general economy of nature. The passing of water into steam, in the common process of boiling, is inversely as the atmospheric pressure upon the surface of the water, according to a law which has not been determined with perfect accuracy, because it is one that requires much nicety of observation; but it has been ascertained that, in proportion as the atmospheric pressure is diminished, water passes into steam at a lower degree of heat; and if the pressure is increased, the temperature at which water passes into steam is higher. This is a very important fact, not merely as regards the density of the air at different elevations and under different circumstances, but as regards every operation of nature into which water enters as an element; and if we could render this portion of the theory of atmospheric pressure complete, it would enable us to determine some very interesting points in the economy of nature. From the most careful experiments which have been made, it appears that the degree of heat at which ebullition or the boiling of water takes place, diminishes by equal differences, while the pressure of the air diminishes in very nearly a geometrical progression; and the law of this progression is such, that every time the pressure or weight of the air is reduced to one half, the degree at which water boils is lowered at about 18° of the centesimal thermometer, or that thermometer which, as previously mentioned, has 100° between the freezing and the boiling points of water under the average pressure of the whole atmospheric column. Thus, in order to determine heights above the mean level, by means of the boiling of water, we have only to determine the constant multiplier which answers to the variation in this respect, and this we can do either by experiment or by observation. The experiment may be made by means of a common air pump, to which there is attached a mercurial gauge to measure the expansive force, or, which is the same thing, the pressure of the air in the receiver as it is exhausted; and by having, at the same time, a thermometer inserted in a portion of water, which shall indicate the temperature at which that water passes into the state of steam; and as by means of this apparatus we can obtain all imaginable degrees of pressure, according to the degree of exhaustion, we can determine the atmospheric pressure which answers to every temperature at which water boils or passes into the state of steam. Nor is the observation of the fact, as it occurs in nature, more difficult than this, for we have only to observe the degree of temperature required for ebullition at different heights above the mean level of the earth's surface, and this puts us in possession of the same fact, from the absolute state of things in nature, which we derive by experiment from the air pump.

Probably, one of the most careful observers who has attended to this was Saussure, who made the experiment, with as much accuracy as possible, on Mont Blanc, the most elevated summit in Europe. Saussure made use of the centigrade thermometer; and he found that when the barometer stood at 30·534, or very nearly 30½ English inches, on the plain at the bottom of the mountain, water boiled at 101°·62 of the centigrade thermometer; whereas, when the apparatus was carried to the altitude of 15,050 feet, water boiled at 86°·24 of the same thermometer. The height of mercury in the barometer, at the first station, was 30·534

English inches, and that at the second only 17·136. By comparing the two temperatures at which water boiled in these experiments with each other, we find a difference of 15·38 degrees of the centigrade thermometer, answering to a difference of elevation of 15,058 feet; and perhaps it is as near as the experiment can be made in actual practice to say, that for every thousand feet that one ascends in the atmosphere, water boils, or passes into a state of vapour, at one degree less of the centigrade thermometer. 180° of the common thermometer are equal to 100° centigrade, or 9 are equal to 5, so that it is very easy to turn our common thermometer to the same account. Thus, 555 feet difference of elevation will answer very nearly to a difference of one degree in the boiling point of water as indicated by the common thermometer.

Experiments of this kind are, however, attended with some difficulties, and can be regarded only as approximations, though they are approximations perhaps nearer to the truth than we could obtain by means of actual measurement, unless we were possessed of the very best instruments, and were capable, and had leisure, to apply them in the most skilful manner. The chief source of error in attempting to measure the pressure of the atmosphere by the boiling point of water, is the condition of the air itself with regard to heat and moisture, and chiefly with regard to the latter of these. We know that while there is scarcely any difference either in the weight of the air, as ascertained by the barometer, or in its temperature, as ascertained by the thermometer, a very considerable difference often appears in the hygrometrical state of it, or the moisture which it contains, or, more strictly speaking, the disposition which it has either to receive or to part with moisture, the cause of which disposition is certainly a complex one, and one of which we cannot be certain that we know all the elements, or how much the effect may be influenced by or depend upon those causes of which we are ignorant. We shall have to consider this part of the subject a little more at length in the next section, and, therefore, we shall close this one by just naming one or two of the uses to which the varying pressure of the atmosphere, at different heights, whether shown by the column of mercury in the barometer, or by the boiling of water, may be turned.

The principal use of both these methods of ascertaining the pressure of the atmosphere consists in finding, with much more ease and inconceivably greater rapidity, the elevation of places on the earth's surface; but as this is attended with many circumstances which relate to the practical value of those places, the question is one of far greater importance than the mere ascertaining of the form of countries. In a common map, only the outlines of countries, the courses of rivers, and the positions of mountain ridges, are laid down; the character of the latter, which is the only means whereby difference of level is in the least indicated, is left very much to the taste of the engraver, who not unfrequently seeks more to produce pictorial effect than geographical truth; and, hence, it would be a great improvement in maps, if the elevations along certain definite lines were represented, either by means of figures on different parts of the lines themselves, or by means of sections; and as actual surveying upon geometrical principles is out of the question, to the extent which is required, the measures obtained from the variations of atmospheric pressure would be highly desirable, and might indeed answer for all ordinary purposes. Some very curious results have been obtained in this way, and perhaps there is none more interesting than the set of levelings performed by Engelhardt and Parrot, between the Black Sea and the Caspian, in the year 1814. These gentlemen commenced their operations at the mouth of the Kuban on the Black Sea, and continued up the valley of that river, along the north side of the mountains of Caucasus, and down the valley of the Terek to the Caspian, a distance of more than 700 British miles, and they found that the level of the Caspian at the latter place was 334 feet lower than the common level of the ocean, or at all events than the level of the Black Sea; and not only this, but that the whole country within about 190 miles of the Caspian was below the sea level, leaving no doubt that a vast basin of water must have at one period of history existed in this part of the world, and have given to central Asia a character very different from that which it at present possesses. Similar observations, extended for long distances over those other regions which have any thing peculiar in their formation, would, no doubt, lead to results which might in time connect the detached facts of geology, and enable us to fill up the curious chasm in organic nature, between those races which are now found only in the earth, and the very different ones which are alive in the very same districts. Thus, in addition to its other advantages, the variable pressure of the atmosphere might be made the means of interpreting the darker pages in the history of the earth.

In this we have a very striking instance of the advantage which the study of general nature has over that of one department in a corner. To what perfection soever the student of the single branch might arrive, he would still be only a "division-of-labour" artisan in the workshop. In the pin manufactory he might make the pin's head; but though therein he excelled all others, the fruits of his labour would still be nothing but a pin's head. In the arts, division of labour is well, because many hands may be employed in the same work. But in matters of thought, union—grasp of subjects by the same mind—is the grand matter: if James Watt had made pins' heads, (and no doubt he would have done it to admiration,) where would have been his improvements of the steam-engine?

SECTION VI.

EVAPORATION.

Evaporation is one of the most important considerations in the whole natural history of the air, but it is, at the same time, one of the most difficult, because we are not well acquainted with that particular property by means of which the atmospheric fluid is enabled to take up moisture from the surface of water, and of all humid substances, and again to deposit this moisture in rain or snow, for the refreshment of those very plants, and the replenishing of those very waters, from which this moisture is, in the first instance, taken.

This power of taking up water in a state of so minute division as that it is perfectly invisible in the air, and does not communicate to us the least feeling of moistness, is not a peculiar property of the air, depending on the two gases of which the compound atmosphere is made up, or upon the proportions in which they are mixed together. It is a property of the aërial or gaseous state generally, apparently without any reference to the chemical or other properties of the substance which is in that state; for it is found that if they have equal heat and pressure, all gases whatever take up water in the form of vapour; and though it is impossible perfectly to establish the fact so as to connect it with what really takes place in nature, at the average elevation, and in the average state of the air, yet it has been ascertained by experiment that the nearest approximation which we can make to a perfect vacuum or empty space, in exhausting a common receiver by the air pump, is still capable of taking up the vapour of water, and, in fact, takes it up much more rapidly than denser air. Whether this circumstance would take place under the common atmospheric pressure of about fifteen pounds on the square inch, is the point necessary to be settled, before we can say positively that the action of evaporating takes place in the water or substance evaporated, and has no farther connection with, or dependance upon, any quality in the air than as the tenuity of the aërial fluid affords it scope for dispersing itself. We have no means of applying pressure to the surface of water in any approximate vacuum that we can form, and therefore it is impossible for us to say, positively, whether evaporation would or would not go on under these circumstances. The probability, is, however, that it would; for in proportion as air is rendered less dense, either naturally in the atmosphere, or artificially in our experiments, we always find evaporation more rapid.

Still, however, it should seem that there is some connection between the atmosphere and water more than there is between it and some other, if not all other, evaporable matters—volatile oils, the fumes of metals, the aroma of plants, and all those substances which the atmosphere is capable of dissipating and dispersing. The quantity of those other substances which is evaporated must be very considerable, but they are spread far and wide, so that they never return to the earth in sensible quantities, or form any thing like clouds in the sky. There seems, therefore, to be, between water and atmospheric air, a certain degree of that surface action of particle upon particle to which we alluded in a former section, and stated capillary attraction as being one particular case.

We mentioned, when formerly alluding to this subject, that the action which we may suppose thus takes place between the surfaces of the particles of the air and those of the vapour of water, is not to be considered as decidedly either a mechanical or a chemical action. Still it is an action of some kind, for the vapour is retained in the air, and requires the action of some cause for its separation; nor are we ever sure that we have been able to extract the whole of the vapour of water, so as to leave the air perfectly dry, in any experiment, notwithstanding the greatest care which can be taken in the performing of that experiment. Even here, however, there is an obvious approximation to the fact that the air and the vapour mingle, and are held mixed by the state of the air, rather than by any actual union so as to form a compound substance. In the most careful experiments which have been made upon common atmospheric air, upon oxygen, upon nitrogen, upon hydrogen, and upon carbonic-acid gas, it has been found, that when equal volumes of them were exposed to substances having strong attractions for moisture, each of them gave out so very nearly the same quantity that the difference was less than could be supposed to be the amount of error in the experiment, which is a very nice one.

Even this, however, is not decisive of the point; because, though it shows us that we can obtain equal quantities of water from equal volumes of all the component parts of the atmosphere, and also those of water, it tells us nothing respecting the quantities that *may* be left in them after the experiment has been carried to the utmost limit of human ingenuity. Nor does it appear that there are, in the present state of science, any means by which we can obtain absolute information upon this point; and, indeed, it does not seem that the information is attainable by any refinement to which we can look forward. This is the more to be regretted that the doctrine of evaporation involves in it more of the theory of atmospheric action, in life, in growth, and, generally speaking, in all that concerns the weather, than any other which can be named.

When we see such operations as water gradually diffusing itself through a lump of sugar, if a part only of that lump touches the water—a sponge taking up its load—a tree drawing juice or nourishment to its whole frame, not only from the natural organ of a root in the ground, but from a branch, the point of which is dipped in the water—we have some notion how this process of the action of surfaces goes on in substances which are porous. And when we examine these cases a little more attentively, we begin to see that there is something in the state of the surface of their pores which influences this tendency to absorb moisture. A perfectly dry sponge will not suck up water; neither will a perfectly dry piece of wood; or, at all events, the process will be exceedingly slow. In these cases we perceive that a little moistening of the surface is required in order that the capillary absorption may go on properly, though there is no perceptible change of a chemical nature in the substance which absorbs when a little moistened, and which will not absorb when absolutely dry. This points to the conclusion, that there is, in the surfaces of the elementary and invisible particles of air, and of every gas which takes up water by evaporation, something analogous in action, if not in kind, to this moistening of the pores in the sponge or the wood, but that there is no more chemical action in the one case than in the other; and that though the water is so minutely divided and so equally distributed through the air as that it is altogether invisible, yet it can be obtained without any diminution of its quantity, or any thing at all resembling chemical decomposition. There is another circumstance connected with water which may perhaps assist in throwing light upon the subject of evaporation, and also upon the fact that all substances which the air dries up or dissipates by its evaporative power, are not retained in its substance in a state of vapour, or do not form clouds, but find their way slowly, silently, and imperceptibly toward the earth. The wide oceans should, upon the ordinary theory of gravitation, be less elevated in the middle than towards the shores, especially if those shores are near high mountains, as is the case along the whole western coast of the American continent.

That the waters of the ocean are elevated not only round the shores of the great continents, but even round the small islands which rise from the deeps, above the mean level which they preserve in those deeps where there are no islands, is not only in strict accordance with the law of gravitation, but a fact proved by experiments with the pendulum, which gives a greater pressure or gravitation in such places.

Now, it is obvious that, in order to be true to the law of gravitation, all floating matters which are in any way cast upon the broad waters of the ocean should remain in the hollows, or, in other words, out at sea, unless in so far as they are acted upon by the winds and the currents of the water; and as there are no currents across some parts of those wide seas, the floating substances ought to be found there. But they are not so found: all the wreck of the sea, all the drift wood carried down by the rivers, and every other dead substance which floats, is invariably cast on shore; and drift wood especially is not dispersed in single pieces, as we might naturally expect, but always, or generally at least, in floats of some extent.

The reasons are, the sea wets all the shores, without almost a single exception; and it speedily wets, also, the surfaces of all dead substances which float on the water. When they are wetted, there is a sort of capillary attraction between the substance and the water, which gradually brings the moveable substances towards each other when they are out at sea, and ultimately brings them to the shores of the land. Substances which are not so wetted have no such tendency; and if a wetted and unwettable substance are examined as they float in water, it will be perceived that there is a small ring of water elevated round the sides of the wetted one, while round that which is not wettable, or simply which is not wet, there will be found a depression; and the two substances will, farther, have no tendency to approach each other, neither will the one upon which the water has no wetting power have any tendency to come to the side of the vessel, though the wet one will ere long be found in that situation.

In these cases, it is evident that there is no chemical action, and no action of any cause which can in strict language be called mechanical, between the substances, or between either of them and the water; and, therefore, we have only to suppose that the particles of matter in a state of gas have a capacity for being wetted, in order to understand at least something of the rationale of evaporation. In the case of the air, however, and of water, which rises by spontaneous evaporation at the ordinary temperature of the atmosphere, in a state of invisible vapour, they are all divided down to the ultimate particle, which our observation cannot reach; and thus, though we can see an exceedingly probable analogy between the action in the case of them, and that of the substances to which we have alluded in illustration, we cannot positively say that there is an absolute identity.

There is another part of the subject in which we meet with nearly the same difficulties, and that is, the different tendencies of the air to receive or to part with humidity, under the same temperature and the same degree of barometrical pressure. We do know, from observation, that there are, independently altogether of the various currents, tides, and other motions of the atmospheric mass, and independently also of the degree of heat, or of the height of the barometer, certain times when the air is what we call dry, or much disposed to take up moisture by evaporation, and other times again at which it is what we call wet, or has a tendency to deposit the moisture which it contains, rather than to take up any more. Whether that species of action which we call electric may not be connected with those differences of state, we have not the full means of ascertaining; but it is highly probable that there is a connection with this electric action, though we know too little of it to be able to say positively whether it is a cause or an effect,—that is to say, what place it holds in the succession of events which bring about peculiar changes and states of the weather; and as this is a portion of the subject which is not open to very direct observation, it is in all probability one which will keep us for ever ignorant of the real principles which regulate that most interesting subject. Even this, however, should by no means slacken our observation or damp our inquiries; for it is generally a good rule, that, when one part of a subject lies beyond our depth, we should always pay the more careful attention to that which we can reach; and this applies not merely to the productions of Nature and their phenomena, but to that Being whom they in part reveal.

There is one other fact which we may mention as affording a very strong analogical proof that the principle upon which water rises by capillary attraction, in quantity so as to be seen, and that by which it rises and diffuses itself in the air by evaporation, if not identically the same, have yet as much of similarity as that which usually suffices for the establishment of identity. We have mentioned, that the ratio in which the quantities of air, in a column of the atmosphere of the same section throughout its height, diminish as we ascend, or the expansions of the air, which are merely the converse expressions of the same fact, may be represented by a rectangular hyperbola, in which the differences from the one assymptote differ as the squares of the heights taken above the other. Now, if two plates of perfectly smooth glass, which are clean, and therefore easily wetted with water, are taken and placed on edge in coloured water, with the one end of the two in contact, and the other ends at a little distance from each other, and there kept standing vertically or upright, the surface of the water in which the under edges of the plates are immersed may be considered as the one assymptote of a rectangular hyperbola, and the upright end at which they touch each other as the other assymptote. And the coloured water will rise by capillary attraction to a considerable height at the end where the plates are in contact, and still lower and lower as they get more apart, fining off into the level line of the water, or nearly so, and forming a very perfect rectangular hyperbola, which shews that there is the most perfect coincidence in the law of this capillary ascent and the law according to which the pressure of the atmosphere diminishes as we ascend in height; nor will it be overlooked that—though the experiments are rather more nice in this case, and therefore more subject to error in the performance—the diminished temperature at which water boils, as the pressure of the atmosphere is taken off, follows so nearly the same law, that we may consider them as identical, and throw the difference upon the errors of our own observation.

Thus the whole case, in every light in which we can view it, points to a uniformity in the law of action of the evaporating air and the evaporated water; and that it is this kind of surface action, which we have mentioned as being strictly neither chemical nor mechanical, which causes the distribution of the one through the other.

We find that, under all circumstances, evaporation proceeds most rapidly when the atmosphere is warm, and also when the quantity of air exposed to the evaporating surface is in most frequent change by means of a wind or current. These two circumstances of heat and motion in the atmospheric fluid, both operate in producing the same kind of result; and therefore we may naturally conclude, that the same degree of evaporation may be produced under great varieties of the one of them, if it so happen that the other is varied to the same extent the other way. Thus, if there is a strong wind blowing, there may be great evaporation when the temperature is cold; and on the other hand, if the atmosphere is very hot, there may be strong evaporation, although the air is, to all appearance, perfectly still.

It seems, farther, that the tendency to evaporation is more a property of the water than of the air, though the state of the air no doubt gives facility in the exercise of this property. We find that it is not confined to water in a liquid state; for ice melts silently away, without leaving water in its place, when the temperature is even lower than that which produces an ordinary thaw or melting of frozen water; and we find also, that in proportion as the quantity of air in any space is diminished, the tendency to evaporation is always increased. Hence it cannot be the absolute quantity of air acting upon any chemical principle, as matter, which produces the evaporation; for if that were the case, condensed air should act more powerfully in proportion to its condensation, upon the very same principle that all chemical agents act more powerfully in proportion as they are more concentrated, that is, as more of their substance is brought within the same space or volume. It really seems, therefore, that there is in water a tendency to pass naturally or spontaneously into the state of vapour, whether the circumstances which favour its passage into this state act upon it when liquid or solid. Nor have we any difficulty in discovering what agent it is which puts this property into motion; for whenever, by the removal of pressure, the water is allowed to disperse itself in this manner, it invariably extracts heat, not only from the ground and from other solid substances, but from the air itself, which is often so far reduced in temperature by the abstraction of heat by rapid evaporation, that it is carried beyond the balancing point; and the air reacts, deprives the water of its heat, not only as vapour but as liquid, and the water falls to the earth in snow or in hail, according to circumstances.

This tendency which the vapour of water diffused through the atmosphere has to alternate with the air, in the giving and taking of the action of heat from each other, is of very extensive use in the economy of nature, and serves to explain many occurrences, of the characters of which we should otherwise be ignorant. This part of the subject is, however, so mixed up with the other actions which are constantly taking place in the atmosphere, that it is no easy matter to give even an intelligible account of it, because we would require to treat of all these subjects at once. We may mention, however, that in countries where the weather is variable, and at the variable seasons in those which have their weather running more in uniform tracks, this distribution of heat and humidity produces many powerful effects; and that those effects are always most powerful at those times of the year when the return of the sun, and what may be called the vernal season, is calling the vegetable tribes into that powerful action which they display after their annual repose, whether that repose happens to be a winter of cold, as it is in our northern climates, or a continued burning drought, as it is in tropical countries. Nor is there any doubt that it is this atmospheric variation which tends most powerfully to awaken the energies of nature. Those who attend to the variable weather which we generally have at its height in the southern part of Britain in March or in April, according to the state of the season, cannot have failed to notice, that while the winds keep blowing from all imaginable points, with all supposable degrees of velocity, and the clouds are rolling to and fro in castled masses,—now white as mountains of snow, now dark as the raven with shadow, and toward night-fall borrowing all the tints of the rainbow, as if to curtain the couch of the setting sun,—when it is rain on one field and sunshine upon another, and when violent gusts of wind, loud peals of thunder, and pelting showers of hail, tempt one to believe that the destruction of every thing that grows or lives has been decreed, and that its work has begun: when all these circumstances come blended, it is worth while to observe how the buds expand, and the grass lengthens. Nature puts on the livery of her utmost vigour, and the birds, from a feeling that the time of plenty is arriving, wing their way amid the storm, and seem to exult and give thanks on account of its very violence.

If those circumstances are thus forcible in champaign countries, where the surface of the earth is but little diversified in respect either of elevation or of covering, and where the greater part must consequently be regarded as merely atmospheric action, it is easy to see that the display must be much more striking where the varied aspect of the earth bears some proportion to the varying state of the atmosphere. In those wild districts where sea and land, mountain and valley, rock and river, dry moor and dingy morass, sheltered glen and storm-beaten peak, are all to our observation jumbled and confounded in that apparent chaos, which, after all, is the true order of natural sublimity; and when each of them performs its separate action upon the disturbed atmosphere, then is the time to study the elements of the weather,—those principles of atmospheric action, the knowledge of which is so essential in letting us know when, where, and what we should cultivate, in order that our art may be most in accordance with nature, and, consequently, the reward which the all-supporting earth shall yield to us may be the most plenteous, the most valuable, and the most readily obtained.

This is a matter which can hardly be so analyzed as that we can arrange the parts of it in any thing like a systematic order, or give them even a scientific form. They come upon us *en masse*, and each is so necessary to the explanation of every other, and the whole are in such change and disturbance, that we can do little else than admire them,—though even this admiration, simple as it may appear in itself, if not knowledge itself, is certainly the awakening of it.

The manner in which the varying heat and varying pressure of the atmosphere act upon the moisture which that fluid contains, and all of which is originally taken up by this process of evaporation, render the compound a very curious one, not merely as a compound of substances, but also as a compound of actions, and of actions of the causes of many of which we know exceedingly little.

The process of evaporation is carried on, not only at the surface of the earth, and that of every substance upon it which contains moisture, but it is also carried on in the mass of the atmosphere itself, in all probability at all times, and certainly to greater heights than that of the most lofty mountains. It is also carried on when we have no evidence of it at all palpable to the senses, or capable of being tested by any of those instruments which we make use of in ascertaining the relative dryness or moistness of the air. Those instruments, in fact, are only substances capable of receiving or of giving out the moisture of evaporation in such quantity as that it may be palpable to the senses, at times when the natural action of the atmosphere is not shown by any observable result. This follows as a matter of necessity, from the constitution both of the air itself and of the vapour of water, which is mixed with it. It is the tendency of each to expand itself in full obedience to every action of heat, and to be condensed in proportion to every lessening of that action, or every increase of cold, as we say in common language. In consequence of its greater heat, as shown sensibly by the thermometer, there is more evaporative power in the lower strata of the air; but there is less there than in the more elevated strata, in consequence of the greater density, arising from pressure by a longer column. We also state generally, that the greater the tendency of the air to display the sensible action of heat, as told upon the thermometer, or upon the senses, every kind of atmospheric action is the more intense, but, at the same time, it is confined within narrower limits in space, that is, within a smaller play in the change of volume of an equal quantity of air.

In consequence of this, there may be said to be some different disposition of the air toward evaporated moisture at every different height, and also over every different kind of surface; and all this, too, independently of any of those disturbances of the atmosphere which are occasioned by the motion of the earth, and the action of the sun and moon. So that, if we were even to suppose the earth at perfect rest, the atmospheric fluid contains in itself, and derives from the different elevations and different characters of the earth's varied surface, so many elements of internal motion and disturbance, that we may suppose it would go on attracting moisture at one place, and depositing it at another, in this state of quiescence of the solid earth.

But we cannot separate those causes, so as to assign to each the part of the labour which it performs; and as little can we follow the performing that labour down to its minutest shades. Therefore, the atmosphere, in its working phenomena, is not a subject upon which we can obtain philosophical generalization; and, consequently, we are reduced to the observation of particular cases. We see enough, however, to convince us that the action is very general; and that in proportion as the pressure of the atmospheric column is diminished, by the elevation of a place above the mean level, the general action of the atmosphere upon such a place is increased. As we ascend mountains—though there may not be so much moisture to evaporate as there is upon low and level places where water stagnates—there is really more powerful evaporative action; and, true to the general law of nature,—that if there is strong action the one way, under one class of circumstances, there is equally strong action the other way, under circumstances of an opposite nature,—we find that in the depositing of moisture, whether it falls in rain or snow, upon mountains, there is more violence than in the same process upon planes; and that this is accompanied by winds more variable and violent than on the plains and in the valleys.

Even in England—no part of which can be regarded as a very elevated country—not only the mountains and hills, but the upland heights, even though scarcely of a mountainous character, which divide the water that flows towards the valleys of the several rivers, are remarkable for the fury and the frequency of their storms, as compared with the broad and flat portions of the lower valleys; and in those districts which are elevated but little above the sea, the atmospheric disturbance, taking the average of the whole year, is only a small fraction of what it is in the hilly districts, whether we estimate it in the shiftings and various rates of motions in the winds, or in the quantity of water, frozen or unfrozen, which is precipitated on the earth by the atmosphere. At Upminster, in Essex, for instance, the diurnal quantity of rain which falls has been stated at 19½ inches in the course of the year; while at Keswick, in Cumberland, the quantity is stated at 67½ inches, which is considerably more than three times the former.

In the mountainous parts of the north of Scotland, where the elevation is greater, and where large tracks of country are still more bleak and tenantless than the coldest moors in the north of England, the violence of the storms, the falls of rain and of snow, and all kinds of atmospheric disturbance, are upon a scale of still greater magnificence. In those places of that country where the rivers lie upon a considerable slope, and have no lakes to act as regulating dams, in which the water can be in part retained till it goes off in a moderate, but long continued, swelling of the river, we often hear of very extensive devastations, produced by the autumn floods, before the frost sets in—floods, the violence of which frequently tears open new channels for the rivers, sweeps off, or covers with stones or gravel, a large portion of the cultivated land, and sometimes overturns the houses and sweeps away the crops and the cattle; while the suffering people have the greatest difficulty in saving the bare life from its fury. The vast evaporation occasioned by so much water poured on the surface of ground while it is yet comparatively warm, from the influence of the summer sun, greatly increases the cold, and hastens the setting-in of the frost. When that takes place, the deposited moisture, of course, ceases to deluge the land with overwhelming floods; for it is stored upon the mountains and elevated moors, to perform the office of a beneficial protector there during the rigour of the winter, and to refresh with streams the mountain pastures during the summer. But though it remains in peace, it comes in fury; and if one who is caught on the mountain in the violence of one of those storms, shall survive to tell the tale, that tale is, indeed, one of terror. The wind literally thunders; and one can compare it to nothing more like than the sound of heavy but unmusical hammers, thrashing the mountains and the rocks with ten-fold more than ever fancy fabled of giant force. At the same time, the snow, which comes not in flakes, falling gently to the ground, but in powder, which feels almost as sharp as pounded glass, makes a very near approximation to absolute solidity in the atmosphere; and though its colour is really of the purest white, from the minuteness of its division, and would appear so if it could be seen from the upper side, where the light of the sun falls upon it, is yet so closely compacted as the wind drives it along, that, under the cloud, there is almost the darkness of midnight; and, exposed to its fury, not even the mountain eagle herself can maintain her clutch upon the rock, but must betake herself to the shelter of some cave, or cranny, the same as the more feeble and timid animals. While this lasts, not a foot can move on the earth—not a wing can endure the sky; and so, winter, for the time, bears rule of the most despotic and unbroken character. But there is mercy even in this mighty display of atmospheric action: the duration of the storm is short, in proportion as it is violent; and when it is once over, all of wild nature in those wild places is secure, under its protection, until the return of the sun from the chambers of the south again stimulates Nature's children to the various labours of a new year.

But even the wildest places of our island are tameness itself to what takes place in regions of the world which are more sublime in their wintry desolation, whether that desolation arises from high latitude, or from lofty elevation above the mean surface of the earth. The summits of the Andes, in South America, and those of the Himalaya mountains, in Asia, have terrible tales of the winter storms to tell, in consequence of their vast elevation. Of the Himalaya, during this season, we know little, except from the memorials of ruin which are found in the elevated ghauts, or passes, after the summer has set in. But from the accumulations of uprooted trees, and masses of rock, and still greater masses of snow, which are seen lumbered together in such places, it is easy to infer, that the spirit of winter does not always slumber upon those mighty mountains.

In the Himalaya, however, there appears to be nothing but the surface productions which can tempt the cupidity of man; and as these are of course concealed during the violence of the winter, and as the inhabitants—

who move to a considerable height, through the passes, during the summer, for the purposes of grazing, and cultivating barley and some other species of grain—descend beyond the reach of the storm's violence during the winter, there is probably no observer that ever witnessed the full violence of winter upon those mountains. In the Andes the case is very different. They are rich in metals, especially silver and gold; and the richest veins of those are, in many cases, situated in the mountain-tops, at, or even above, the limit of perpetual snow. Those metals, for a long time, were almost the sole objects for which Europeans sought this part of the world, to the neglect of its vegetable, and, upon the whole, more valuable productions. Of the mines, many are situated in places so inaccessible that they are reached wtth difficulty at any season, and are unapproachable for a certain part of the year. Of course, they can be worked only by those who remain all the year round in those dreadful places, and are tempered to a degree of physical endurance greater than that of, perhaps, even the inhabitants of the extreme north. The places of their abode are not only situations where atmospheric action must be extreme, but where additional force is given to it by volcanoes and earthquakes, which necessarily still farther increase the violence. Accordingly, the snow-storms there come on so suddenly, and with so much violence, that if the poor miners are caught in them at even very short distances from their sheltering hovels, or the entrances of their mines, there is no escape for them; and they are either suffocated on the spot, or swept over the precipices by the violence of the wind.

In the polar countries, or in those which have a polar climate though placed in latitudes which would be temperate in other parts of the world, the winter storms also display very great violence. In Canada, they are severe enough, especially in the upland tracks; but from the traces of them which are left upon portions of America still farther to the north, their severity there appears to be far more intense; and though there are no winter inhabitants in the country to the southward, or rather to the eastward, of Hudson's Bay, there is every reason to believe that snow-storms of the utmost violence occur there in the early part of the winter season. There must also be very violent action of the wind and heavy falls of snow in the regions of both poles, during their alternate winters; for the icebergs, which float into comparatively warm parts of the sea, and which must diminish in their progress, both by the action of the water and by atmospheric evaporation of the ice, retain a thickness of several thousand feet, after they have journeyed to pretty long distances. How long it may require to form those icebergs to this vast size cannot be very readily determined; but, whatever may be the length of time, it can be no common action of winter by which masses so enormous are produced.

It is not necessary, however, to range the extreme parts of the globe in order to see how differently the atmosphere and the vapour which it contains are acted upon under different circumstances. We can see the action, at least, to a considerable extent, even in our own country, be our place in it wherever it may; and, along with this, we are enabled to understand a portion, at least, of the causes of this action, and to see that it is always more violent, in respect of the space over which it extends, in proportion as the pressure of the atmosphere is less. This is a very obvious consequence of the diminution of pressure, without our having recourse to any other means of explanation. Supposing the air to be affected by any cause of motion acting in a lateral direction, it is quite evident that as the pressure of the air is the only property in it by means of which it resists anything tending to move it laterally, the resistance which it offers at different elevations must be in the proportion of the densities at those elevations; so that if we suppose a certain force necessary to move the air on the surface when the height of the barometer is thirty inches, if we go to an elevation at which the height of the barometer is only fifteen inches, the same volume of air, independently of the slight diminution occasioned by its greater distance from the centre of the earth, and its greater centrifugal force, will be only half of that which is necessary to move it where the barometer is at thirty inches high. This lets us see, in part at least, how the atmosphere at different elevations is disposed with regard to the vapour which it contains, and the forces, or causes of action, to which it is subjected; and this is, at least, one step towards the understanding of all its variable phenomena.

The means of determining the relative degree of evaporation in different latitudes, at the mean temperature of those latitudes, and reducing the observations to the mean level of the earth's surface, have been investigated with a considerable degree of attention. But we can afford to state only one or two of the results, mentioning, at the same time, that the variation for equal differences of latitude is greatest a little to the southward, at the middle of the quadrant, from about 25° to about 50°; that there is least difference in the 10° nearest the pole; and that there is but little for 5° on each side of the equator. The mean temperature at the equator is taken at 85° of the common thermometer; that at 45°, or the middle of the quadrant, at 58°; and that of the pole, or termination of the quadrant, at 31°; and, corresponding to these, the proportional quantities of evaporation, as expressed in numbers, are rather more than 69 at the equator, a little less than 31 at the middle of the quadrant, and very nearly 13 at the pole; so that the annual evaporation at the middle of the quadrant is less than one-half what it is at the equator, and that at the pole less than one-fifth of the same. In the course of the year, too, there are very considerable differences of evaporative power, but they differ much with the climates and characters of countries. January is, in our latitudes, the month of least evaporation, and July the month of most, during which the relative proportion is between five and six times as much as it is during the first-named month. Places, vary so much, however, that the law of variation for each requires to be determined on its own data, ascertained by repeated and very careful observation. Under every state of the atmosphere, with regard to temperature, the quantity of moisture in it may be considered as very nearly equal to the maximum quantity which, at its temperature for the time, it is capable of holding in solution. It is obvious that if the quantity were much less than this, the air would rapidly take up more by the common process of spontaneous evaporation; and it is equally obvious that if the quantity should, in the least, exceed the maximum, the surplus would be deposited in some form or other. From this constant tendency of the air to be nearly saturated, it is evident that very slight diminution of temperature will change an apparently dry air into a moist one, and this is the reason why the air feels damper towards the evening,—why more rain falls during the night than during the day,—and also why dew forms more readily in the night, and especially in the coldest time of it, than during the day, when there is no tendency to diminution of temperature. These circumstances can, however, be explained in a more satisfactory manner afterwards.

Attempts have often been made to estimate the total quantity of water which the atmosphere holds in a state of nature, upon the average of its whole volume, for the whole year. The data for ascertaining this are much too few and rude for giving it anything more than a very rough approximation to the truth. But as the quantity is much greater than those who have not attended to the subject would be apt to suppose, it may not be amiss to mention the results which have been arrived at by the use of this imperfect data. The estimate is from some observations made long ago by Dr. Halley, that a square mile of the surface of the sea, in about latitude 18°, would furnish nearly 7000 tons of the vapour of water in the course of a day; and that the surface of the Mediterranean would evaporate daily the enormous quantity of more than five thousand millions of tons. It is impossible, however, to estimate with even approximate accuracy the quantity of evaporation, and of the reciprocal action of absorption which takes place in the leaves, and other expansions, of living vegetables. It has been attempted to estimate the whole quantity raised from the surface of the earth at something less than one hundred thousand cubic miles of water, and it will be admitted that even the half of this would be an enormous quantity. When, however, we consider the immense volumes of water which all the rivers are continually pouring into the sea, and also the quantity which must be re-evaporated from the land, we may cease to question the truth of even this amount, though it is one of the correctness of which we cannot, in the nature of things, be absolutely certain.

Though we have no reason to suppose that the vapour of water undergoes any chemical decomposition in its mixture with atmospheric air, yet all the best experiments which have been made upon the subject tend to prove that it exists there with all the mechanical properties of a gas; and that, as is the case with every other gas,—that is, with every other substance in the gaseous state,—it owes its gaseous form to the action of heat, becoming more expanded or attenuated in proportion as heat is applied to it, and condensing as heat is withdrawn, till, after a certain withdrawal, it loses the gaseous form altogether and becomes a liquid, formed into drops of greater or smaller magnitude according to circumstances.

When evaporation goes on very briskly, and the heat required for the formation of the vapour cools the surface of the ground, and the lower strata of the air, the vapour at its first ascent is not quite gaseous. Sometimes we observe the humid surface of the ground reeking in steam under the strong action of the sun, and this takes place especially upon surfaces bare of vegetation, or otherwise very susceptible to the action of heat. It may be also seen on the sea coast, especially where the beach is sand, a considerable breadth of which is left speedily bare at the ebbing of the tide. In this case there is a surface covering of water on a substance upon which the sun acts powerfully; and the whole margin of the sea may be observed reeking in steam, in the same manner as the ploughed fields do on a warm spring morning, when the moist black mould has been turned up to the sun and air. But as these natural productions of steam ascend a little way above the surface, they gradually become more attenuated, and, before any considerable height is reached, they melt invisibly into the air. The reason of this is, that the evaporation at the surface of the sand being greatest cools the lower air most, and the vapour, which is visible immediately over the surface, gradually takes more and more of the action of heat from the air, until it is so expanded as to become invisible in the volume of that substance.

There is another case in which we can observe the *action* of evaporation, though it can hardly be said that we perceive the *product* in visible vapour, even immediately on the surface. In very warm days, when there is not a breath of air stirring, if we are in the fields, where distances limiting the view cross out or cut against the clear sky, we can observe a beautiful tremulous motion, as of something ascending from the earth in columns, as those of flame, and soon gradually melting into the serene and transparent air. This apparent motion, for it seems motion rather than substance, barely obscures our observation of the smallest objects; and therefore we have in it an example of water passing into the gaseous state, and in a condition which we cannot exactly call either gas or liquid. We see it against the outlines which are at some distance, simply because there is a sufficient breadth of surface between one place of observation and the boundary to furnish a column thick enough to be visible. We do not observe it against very near objects, because the column is too thin; and if we approach the place over which it appears to be playing with the greatest activity, it fades as we near it, and when we arrive at its place it is not there.

This is an observation which may be made by any one almost any where on a fine summer-day; it has the advantage of being exceedingly delightful in the observation, because the air is never so balmy, or the breath of nature so sweet, as when this glimmering evaporation is dancing on the outline; and, as it is most conspicuous when the air is breezeless, when not a leaf stirs, when the birds which hymned in chorus to the rising sun are taking their siesta in the groves, when the cattle are lying down in the shade, and when, save the chirp of the grasshopper, there is nothing heard on the common, these unceasing operations of the atmosphere, which is one of the grand means of supplying every living thing its food and its drink, not only gives liveliness to the scene, but shows us in the most impressive manner that the Author of nature has so beautifully contrived the system, as that, at those times when the individuals need repose, the grand operations which are to support them when they again become active never cease for a single moment; and so, also, we find, that while every visible thing appears to have ceased from acting, those invisible operations of the system upon which the well being of the whole depend, never slacken a single jot. Thus, to whichever portion of nature we turn our attention, we find, that how much soever there may be to gratify the senses, and in this there is no stinted share, there is something more mysterious, but magnificently mysterious, beyond, which addresses itself only to our spiritual discernment, and points the way to a spiritual world.

The fact of the vapour of water being in the atmosphere in the state of gas, and passing into that state by the most gentle action of heat, is of itself sufficient to give us a very tolerable notion of the manner in which this portion of the atmospheric mass must be distributed in undisturbed states of the atmosphere, or when the sky is cloudless, and there is no perceptible wind or current. It is a law of gases, as nearly demonstrated by experiment as such a law can be, that any one is the same as a vacuum to any other one,—that is, that just as much of one gas will be received into any volume of another gas as would, at the same expansion of the gas received, be received into a vacuum, or empty space. At first sight this seems contrary to what we would expect; for we cannot get as much of one solid mixed with another as could be held in the space which that other occupies. But it must be borne in mind, that the atomic constitution of a gas is a very different matter from that of a solid, or even of a liquid, though the liquid is a step towards it. The gas is not a solid in a state of minute division, as if it were reduced to the most impalpable powder that could be procured by mechanical means. It is divided atom from atom, and, differences of heat and pressure excepted, those atoms are every where equally distant from each other, while each of them is individually of smaller magnitude than any thing that we can assign even in imagination. Thus the distances between those atoms must be, in respect of the magnitude of the atoms, greater than any which we can state proportionally in numbers; and, consequently, this being the state of every gas, there is of course room for two of them in the same volume of space, and this room must remain over a very wide range of expansion. Thus the humidity in the atmosphere adds just as much to the expansive force of the atmospheric mass as it does to the pressure, and hence we are not warranted to conclude that pressure of the atmosphere is either greater or less on account of the quantity of vapour which is mixed with it.

The action of heat upon this vapour is, however, very different from what it is upon the air with which the vapour is mixed. The air has no tendency whatever to become liquid, far less solid, at any known temperature that can obtain in the free atmosphere, while the vapour passes into the solid state at the temperature of 32° of Fahrenheit, though it probably requires to pass first through the liquid state as water, but it may do so in portions exceedingly minute. It is this difference of action upon the air itself, and upon the water in it, which is the immediate cause of all the applications of atmospheric moisture to the earth and its productions, whether to the surface generally as rain or snow, or to individual substances in a more delicate and imperceptible manner; and if we could fully separate the two actions, so as to understand how much depends upon the air, and how much upon the vapour, we should be in a condition for forming at least some notion of the grand action of the atmosphere in nature's economy. In the accomplishment of this, however, there are many difficulties; and, though approximate results have been obtained, the experiments have been so nice that they are liable to uncertainty.

These experiments, and the calculations founded on them, are not fit subjects for popular illustration; but we may mention at least one of the principles:—If the air is in such a state as that the smallest reduction of temperature will cause it to precipitate dew upon any surface cooler than itself, and cooling it, we may conclude that it is then exactly saturated with vapour, or contains the exact quantity which it can retain at that temperature, and under that pressure, and no more; and if the barometrical pressure, and the temperature by the thermometer are carefully observed at the same time, and the quantity of water in a given volume of the air is ascertained, we are enabled, at least in a rude way, to judge of the quantity of moisture which air under known circumstances can contain; and any temperature lower than this must make it part with its moisture in a sensible state to form dew upon the surface, if it is the stratum immediately in contact with the surface, or to form clouds in the sky if it is any more elevated strata. In this latter case, it is easy to see, from what has been already said of the more ready obedience of the upper air, in consequence of its diminished pressure and increased rarety, that clouds will form more readily in elevated portions of the air than in portions nearer the ground; but that those clouds which form at great elevations must, in consequence of the greater dispersion of the vapour, and the greater rarety of the air with which it is mixed, be of a much more light and filmy texture than those which are formed nearer the surface. But there must be a limit in elevation to the forming of any thing like a palpable cloud, on account of the great rarety both of the vapour and of the air itself, the former of which prevents the formation of any thing like a drop, and the latter would not be able to support a drop even after it had been formed. We shall have occasion, however, very shortly to notice the progress of the formation of clouds, from the lightest fleece which appears in the upper sky to the final accumulation which pours its contents upon the earth, after we have hinted at one or two of the other causes which seem to be concerned in the performance of that office.

The vapour of water in the atmosphere seems distinguished from the air with which it is mixed, not only by the greater readiness with which it obeys the action of what is usually called heat, or that action which is the general repulsive force of nature, in opposing gravitation and cohesion, and thus maintaining the state of bodies, by being the balancing antagonist to these; but it appears to be more susceptible to those other actions to which we give different names, and which produce different effects from the ordinary expansion by heat, or the production of sensible heat, or rather sensible hotness in the thing heated, to the thermometer or to the senses. Atmospheric air in itself, or even in those states which we call dry, that is, when the quantity of vapour in it is less than it is capable of receiving, appears to be a very passive substance,—except to heat, in the common sense of the word, and to the parting with one or other of its component parts in those operations of nature which require them; and in these last, it appears that that substance with which the air, or one of its component parts, combines, is the active substance, just as it is probable that water is the active substance in the case of evaporation. When air and the vapour of water are united, and the air is not saturated to the full amount of its temperature and pressure, the effect of the compound is exactly the same as if the vapour of water were not there; and from all that we can observe, it appears that the air and the water part the heat which they are under the action of between them, in nearly the same manner as the two constituent gases of the atmosphere do; and that thus, up to the point of saturation, or that at which dew would form upon any surface or substance colder than the mixture, the action of the compound is in no way different from what it would be in perfectly dry or vapourless air, under the same influence of heat and pressure. Air of this kind, together with its contained humidity, must thus be obedient only to the two forces of heat and pressure. The moment, however, that the point of saturation is reached, either by the taking up of a sufficient quantity of moisture, by a lowering of the temperature, or by any other cause which can bring about the effect, the moisture in the air becomes obedient to the operation of other causes. While, still invisible,—not only as a cloud consisting of drops, but as the lightest filmy vapour,—it may become a messenger, ready to move from place to place without a positive motion of the whole atmospheric mass; and by this means it may, and it does, perform some very important offices, and it gives rise to some very striking phenomena. Every one must have observed how much more speedily the heated vapour of water, if much above the temperature of the body, heats the body, than would be done by dry air of a much higher thermometrical temperature, and consequently, according to our judgment, under a higher degree of the action of heat. There have been many instances in which human beings have subjected themselves to dry air considerably above the boiling point of water; but we know of no instance in which any one has been able to stand boiling, or even a temperature of water considerably below it. The cause is, that the water comes from all points to deliver its excess of heat to whatever is exposed to it; whereas the dry air falls down the moment it is a little condensed, and ascends immediately it is heated, and there is no lateral motion to bring it from one place to another. On the other hand, if the air, charged with humidity to the point of saturation, above it, so as to admit of the least disposable quantity of vapour in a free state, is colder than the body, the little particles of water, even when not visible to the eye or to any instrument, come to fetch the action of heat from the body, and a degree of chillness is in consequence felt, which is not felt in dry air, even at a much lower temperature. In those states of the weather which are called raw and damp, and which mean nothing more than that the air has moisture in it up to or beyond the point of saturation, people feel more uncomfortable, and are more liable to catch disease, with a temperature considerably above the freezing point, than in perfectly dry air at freezing or below it; as far below it, indeed, as the degree of cold at which even quicksilver becomes solid. Hence, therefore, air beyond the point of saturation is always both uncomfortable and unhealthy; and, whether it is in the swamp of the warm country, or the fen in the cold one, that the body feels languid, and soon falls a victim to disease, it is not to the heat, considered as mere heat, being too great in the one case and too small in the other, that the mischief is owing; it is solely to the vapour which is disposable in the atmosphere, and which invades the body like a continual host; and if the difference of temperature between this atmosphere and the body exposed to it is sufficiently great, disease must ensue.

This is a very important consideration in the study of atmospheric humidity; because it, perhaps more than any other, affects both the comfort and duration of human life; and the knowledge of it is necessary to point out to man in what situation he should build his city, and even erect his solitary dwelling. But though this readiness in the humidity of the atmosphere to equalize in the most speedy manner the temperature as between object and object on the surface of the earth, and between all subjects and the air, is unhealthy to the human frame, we must not thence infer that it is injurious in the general economy of nature, or that in the great system it does nothing but harm. Natural objects are very many, and the means by which they are accomplished are very varied; and so, before we venture to ascribe perniciousness to any one of them, or to controvert, as has been impiously done, the benediction pronounced at the completion of the Great Work, a share in which benediction we ourselves are the only creatures that have forfeited, it behoves us to consider well of the soundness and candour of our judgment, and the extent and accuracy of the evidences upon which that judgment is founded. For, if we are not prepared to show that our knowledge is as extensive as the system itself,—if there be but one single fact, or one solitary law, in the whole range of nature of which we are ignorant, that may be the very one which, even in our own opinion, would convince us of the erroneousness of our conclusions.

The swamp and the fen, in whatever climate they may be situated, are not fit places for human habitations, and, where the objects are close-inhabiting and agriculture, let them by all means be dried. But let us not forget that they must have their uses in nature, otherwise they would not have a place. These are most assuredly not the blank pages in the great volume of Nature,—the situations in which she ministers the least to the business of life and growth. They are the pastures of the most powerful animals of the warm countries, for there the elephant, the rhinoceros, and the buffalo have their abodes; in them the python and the boa twine their voluminous folds; in them every kind of life adapted to the place is in the very excess of abundance; and in them the grasses and reeds of one year's growth rival in height our forests, which have undergone the labour of a hundred. In short, these are the spots in which the powers of life and growth are most vigorously and most continually at work; and were it not that they form re-acting barriers in the season of drought, the burning intensity might in one year turn the most fertile of the tropical lands into a desert, the state of which would be hopeless, as there would be no return to vitality.

The fens of our own country, though in former times they shook numbers of the people with ague, and are still not without some instances of that malady, must not be considered as either pestilential or unproductive in the general economy of nature. In that curious part of the history of our island which comes not within the scope of human record, when the forests were overturned and buried under the debris of the upper country, it is probable that, but for the influence of the fens in keeping up a supply of humidity during the summer, the loose and newly-exposed soil might have been swept away at the one season, and blown away at the other, till much of the land had been put beyond the possibility of culture. In the present state of things, we do not require the fen; but that is no evidence against the service which it may once have rendered. And we should a so bear in mind, that the tall and fast-growing cultivated plants have, in some measure, brought a more gentle and general action of the fen over the surface of the country, by preserving moisture during the parching winds of the early summer.

The instances which we have given, and many more must occur to every reader, will help to show the effects of an atmosphere saturated with moisture, at the surface of the earth. It is not, however, from the air being near the surface of the earth, but from its containing vapour of water up to, or what we may perhaps call incipiently beyond, the point of saturation, that this portion of the water becomes the messenger of heat, while so long as the vapour is below the point of saturation it is only the recipient,—in this latter case varying in volume and in sensible heat according to circumstances, but not having any tendency to leave the particular portion of the air through which it happens to be diffused at the time. Thus it is perfectly clear, that if there were not in the atmospheric vapour a greater susceptibility to the action of heat than there is in the air itself, so that by any means by which either the temperature were lowered or the density increased the air should become saturated beyond the portion adapted to the state of its heat and elasticity jointly, there could not possibly be a drop of rain, or a particle of the lightest haze or fog formed in any part of the atmosphere; and hence, but for this, evaporation would be vain, and the land would speedily be without moisture.

But heat, in the common acceptation of the term, in which it affects all kinds of matter in the same manner, though not to the same degree, is not the only action to which the vapour of water is more susceptible than the air, in which that vapour floats. There are various other agencies, which, though all apparently related to heat in their general action, and accompanied by the sensible display both of light and of heat when they have sufficient energy, yet affect different substances differently, and also differently from heat. Of these, the one with which we are most familiar in the atmosphere is electricity, as displayed in lightning; but it is highly probable that the aurora borealis, all luminous meteors which originate at lofty elevations, and even magnetism—the poles of which in the earth appear to be in some way connected with the points of lowest temperature, are all closely connected.

We must not be sceptical at this generalization, on account of the difference of the effects. Lightning causes air to clash against air with the voice of thunder; the aurora sports its columns and bends its arches with harmless and often with beautiful irradiance in the polar sky; and one of the effects of magnetism is, to place a steel needle, which is hung freely upon a centre, in a particular position, the discovery of which, and its application in the mariner's compass, have been of so much advantage to sailors on the waters, and to land travellers in countries where there are no roads, or known objects to guide them on their way.

These are very varied results of those different kinds, or rather modifications of natural action; and many others might be mentioned differing greatly from these, and from each other. But, in nature, difference of result does not prove an original difference of the active energy, though it may in the mode of application. Those natural energies, whether we call them by one set of names or another, have no analogy whatever to the *tools* which we use in the performance of our work. They are not substantive matter, neither are they clogged by gravitation, or by any of the properties of substance. We know them not as existences—we only observe their effects in particular cases; and nothing remains to be questioned as matter save the substances acted on in the particular case. We may, and we do, give the agent a name, but this name applies to the apparent fact, not to the agent; and we do not know, neither can we by possibility know, whether all that we have observed of one named but not understood agent includes the tenth part, or even the ten-millionth part, of all the phenomena which its energies, under circumstances which are still unknown to us, could bring about.

Even in the case of those actions with which we fancy that we are the most familiar, we meet with results as different from each other as in those which we consider quite different in their natures, and call by different names. Take common fire, for instance,—which was long looked upon as one of the *substantive elements*, of which all material things are made, and which the moderns, regarding action not as what it really is—a mere phenomenon in matter—but absolutely substan tive in its cause, called an "imponderable substance;" which, according to the literal meaning of their own words, is a "substanceless substance," and which they termed "caloric," or the *matter* of fire;—taking this common fire, whether as it appears in the sun-beam, in the grate, or any where else, there never was the least question raised about its identity in all these situations. But are the phenomena which it is acknowledged to produce every where the same? Assuredly not. One action of it causes a seed to germinate and a tree to grow; and by another action the same tree is consumed to ashes. Its action is essential to the life of all animals; for even the cold oyster, on the wave-covered rock, could not lead its slow and silent life without the action of heat. But increase the action, without in the least altering it in kind, and every living creature would be consumed. The common conversion of water into vapour, by the process of spontaneous evaporation, produces an agreeable coolness. The same conversion, performed with more rapidity, has given the world a vast working power in the steam engine. These are not one in a thousand of the known effects of heat; and yet they are as different from each other as can be named or imagined. Therefore, they should teach us caution in speaking of diversity of causes in natural action. In ruder ages, each different operation of nature was ascribed to a different *material god;* afterwards, it was the action of a different *material substance.* The names are different, but the error is the same: we observe substance, and we observe action; the cause and also the primary act of causation, is One.

Still, though it is impossible for us to lose sight of this grand beacon in the study of nature, without wandering into error, the modifications of the results of action are just as open to our observation as the varieties of the appearance of substance; and if we keep the principle steadily in view, it is impossible for us to prosecute our inquiry with too much assiduity, or beyond the limit of instruction and pleasure.

There is an analogy between the action of what we call common fire, when so powerful as to be accompanied with heat and light, and electricity, and the other modifications, when they have similar energy, (and the combustion of common fuel may be begun by them all,) which is not unworthy of attention. In common combustion, or burning, there must be a combustible and a supporter—fuel and common air in the case of a common fire; and in order to obtain a sensible display of light and heat from electric action, there must be a non-conductor and a conductor. The friction of these, in some way or other, excites the action at the first; and if the conductor is "insulated," or separated from the earth by a sufficient quantity of non-conducting substance, the electric action is treasured up in the conducting substance, and remains peaceably there till another conducting substance is brought within a certain distance of it, and then this treasured action is discharged, with violence proportional to its energy; and if, when the charged conductor and the one which is not charged, are brought sufficiently near to each other for the discharge taking place, there is between them any imperfect conductor, that is liable to be broken in pieces.

Such is a simple account of electric action, as excited by mechanical friction in the common electrical machine; and the electric action in the atmosphere—the sensible discharge of which from cloud to cloud, or from a cloud to the earth, is lightning—is not different in principle.

In the chemical method of exciting the same kind of action, by means of plates of two metals, which decompose at different rates, in the same mixture of acids with water, and in which each portion of the water and acid is exposed to one of the metals at the one end, and the other at the other, and to which the name of galvanism is given, from the discoverer, Professor Galvani, of Padua, the rationale is the same, though the process is different. But this has not any very apparent connexion with the electricity of the air when at a distance from the earth, and so it may be passed over, as foreign to our purpose. We may, however, remark, in passing, that there appears always to be some sort of electric action between any one of those substances which are called combustible, and one of those called supporters of combustion, when they are placed under proper circumstances; and, therefore, electric action *may* have more identity with the chemical operations of nature, and with growth and life, both vegetable and animal, than the present state of our knowledge admits of our stating as a demonstrated truth.

In water, hydrogen, one of the constituent parts, is one of the most combustible substances that we know; and oxygen, the other constituent part, is one of the best supporters of combustion; so that, though the investigation of it forms no part of our present plan, we can easily see how important a part water must perform in all the operations of nature. And this, again, lets us see farther the grand purpose which the atmosphere answers, in taking up this all-essential element by evaporation, and distributing it over the whole earth, for the benefit of all the children of nature. There are few substances in the mineral kingdom, and none in the vegetable or the animal, into which water, or one of the constituent parts of water, does not enter; and thus its absorption or giving out, its composition, or its decomposition, is concerned in every operation that takes place.

If we apply what has been said respecting the excitement, the treasuring up, and the communication of electric action, to the atmosphere, we shall at once perceive that it contains all the essentials of an electrical machine. Dry air, or air containing moisture below the point of saturation, is a non-conductor of electricity; but the surplus water above the point of saturation, however small its quantity, or minute the drops in which it exists as *liquid water*, is a conductor. We have a direct proof of this, in the working of the electric machine. That is always effective in proportion as the air is dry. If the air is moist, the action is feeble; and if the moisture amounts to a visible stream, the action is carried off by the particles of water as soon as it is excited, and the conductor cannot be charged. Even in dry air, if the apparatus is kept moistened, it will not act; for the water as it evaporates carries off the action. This, by the way, shows very clearly that the vapour of water is only in a state of mechanical division in the atmosphere; though, when below the point of saturation, it is divided down to the ultimate atom, and therefore has its attraction of aggregation, and all its properties, as liquid water, completely suspended. At the instant that it rises, its division must not be entirely final, because it would not, in that case, carry off the electric action, which it always does if the apparatus is moist.

The air and the surplus water after saturation are, then, the non-conductor and conductor in the atmosphere; and we have only to find the friction, or other exciting cause, in order to put the machine in motion, and have the means of lightning, if not the actual display; but before we can have a clear understanding of this, there are two or three other points to be considered.

In the first place, as the action of heat, upon which what we may call the mechanical states of all material bodies, that is, their solidity, their fluidity, or their gaseosity, and all the degrees and varieties of these, depend, is in a state of equal distribution in regard to all bodies when they are perfectly at rest, and have no tendency to change either their state or their place; so when bodies, that is, the whole substances which constitute our terrestrial orb,—land, sea, air, and all their inhabitants,—are in a state of perfect rest, and have not even a tendency to change their relations, all are in like manner in that electric state in which such may be said to be just saturated, and no more, with this kind of action. This is a state of things which, whether we regard the modification of action as heat or as electricity, or in fact as any thing else, could not exist every where in a growing and living world, and probably not in a revolving and rotating planet; but still it would be the condition of a planet like ours with all its accompaniments, not moving, but in full preparation for motion,—not living, but completely ready for the production of life,—and this is the point at which our consideration should properly begin, if we are to understand the working of the system.

In the second place, whenever any change, how slight soever, takes place in the state, or even the position of any one portion of matter, there is an increase or a deficiency of the action of heat produced by the change; and there is a tendency to the restoration of the equilibrium; and, if that which disturbs the equilibrium can battle with sufficient force against the resistance, the effect may be, the slight temperature of a growing plant, the higher one of a living animal, the pleasing warmth of a common fire, the power of a furnace, the sevenfold furnace-heat of a volcano, or even, if strong enough, the blowing of a globe a thousand times the size and strength of our earth into viewless atoms. In like manner, if there is any excitement of electric action in any one substance, in which way soever that excitement may disturb the equilibrium, there is a tendency to restore that equilibrium; and if the disturbance has been sufficiently great, and the restoration is sufficiently instantaneous, the effect of this may be as powerful as the other; and when it is powerful, it is nearly, if not altogether the same in kind with the former. We see the demonstration of it in lightning, when the disturbance has been produced in a way analogous to that in the electric machine; and we have evidence, in some of the most powerful operations which can be performed on a small scale, in the application of the galvanic battery.

In the third place, those two different modifications of action tell differently upon different substances, and it is this which forms the strongest ground for concluding that they are but modifications of one common energy. The action of heat pervades conducting substances more readily than non-conducting ones, and tells more speedily throughout their whole substance. One cannot hold an iron rod of six inches in length till the end of it is red hot, but one can hold a glass rod of the same length till the other end is melted, and a bit of dry wood until it is burnt almost to the fingers. Electric action, on the other hand, passes through the iron rod too swiftly for our measuring its velocity, but it will not pass through the glass or the wood without the assistance of water or some other conducting substance. Farther, the action of heat passes freely through dry air by radiation, or in lines from the heated substances; and if it passes upward, and the air is particularly dry, it does not sensibly heat the volume of the air. It does not appear that electric action can pass indefinitely in this manner, though it does pass through very thin strata of even the densest dry atmosphere; and though the subject is not one upon which we can obtain very satisfactory evidence, it is highly probable that it passes more readily, and therefore with less violence, through dry air, in proportion as that air is more rarefied. It is possible that in this we may have an explanation of the aurora borealis. That phenomenon appears to come from the region of the pole, and it displays itself chiefly in the winter. At that season, the polar snow and ice are below 0° of Fahrenheit's or the common thermometer; and from the rate at which the temperature becomes lower as we ascend above the mean level of the surface, we are certain that there is an elevation—not more than six miles, and therefore not much above one-seventh of that at which the air is dense enough for sending down the sun's rays in twilight—at which the temperature must be constantly below 0°. Water becomes ice or snow at 32°, and at 0° these cease to be conductors. Therefore, any electric action which is produced in the regions of the pole, at a temperature below 0°, cannot be received into the earth or the waters; and it *may* stream toward the warmer parts of the globe, and be lost by dispersion as the latitude becomes less, and the circumference of the parallel becomes larger.

In the fourth place, it is probable that, while heat acts upon the solid or mass of bodies, and equally upon all their particles, electricity is merely a surface action. This is rendered probable, though not absolutely demonstrated, by the fact that when electric action is communicated to a metallic ball, having a perforation through the centre, the centre shows no electric action, while the surface does. It has been mentioned that the action by means of which the vapour of water is held in mixture with atmospheric air is also a surface action, and therefore we may suppose that every change of the capacity of any portion of air for vapour must alter the electric state; though, in the case of there being no surplus water above that which is required for saturation, there may, from the absence of any conductor in which it can accumulate, be no sensible display of this electric action. If, however, there is water free, and thus in the state of a conductor, this may accumulate even the most minute excitements of electricity, till the sum shall amount, not merely to a perceptible, but to a very powerful display.

Every change of the capacity of the air for moisture, either in the way of heat or of elasticity, may convert the air into an electric machine, having as many conductors as there are incipient drops in the case of the capacity being diminished, and losing as many conductors as there are drops re-evaporated in the case of the capacity being increased. It is of no consequence how small these drops may be in the initial stage of the process, provided they are greater than the ultimate atom; for if there are only two of these atoms in contact, so far as to form a first union of liquid water, then those almost indefinitely small drops must have all the properties of liquid water, and that of being conductors of electric action among the rest. Not only this, but if the quantity of water is the same, there may be the more electric action the smaller the drops are. Electricity is, as we have said, a surface action; and the more drops there are in the same quantity of water, there is the more surface, and consequently the more scope for this action.

These observations bring us very near to the formation of clouds, the production of lightning, and the fall of humidity, either liquid or frozen; and we shall consider the other causes in the next section.

SECTION VII.

SEPARATION OF MOISTURE FROM THE AIR.

The subject of this section is exactly the converse of that of the preceding one, and we have chosen for it the above short title instead of the names of the various phenomena which it comprises. In a practical point of view, it is by far the most important that relates to the atmosphere, inasmuch as it comprehends all those appearances and changes of appearance to which we give the general name of the weather, and upon which the agreeableness and value of every region of the world, in a very great measure, depend. Under it are included the winds, or mere motions of the atmospheric mass, by whatever causes they may be produced; the formation of atmospheric vapour into clouds within the atmospheric volume, or into dew on the surface of the ground; the various appearances of those clouds, and their repeated production and disappearance, without the fall of any rain; the charging of clouds with electric action, and the discharge of that action, from cloud to cloud, or from a cloud to the earth, with or without the sound of thunder; and the fall of the matter of clouds in rain, or hail, or snow, according to circumstances.

The phenomena, of which this is a short enumeration, are very different in their characters, from the means by which moisture is elevated into the air, and by which it is affected previous to the formation of a visible cloud. They are all palpable to the senses, and some of them are among the most striking phenomena of nature, while those of which we endeavoured to give a popular notice in the preceding section are, generally speaking, veiled from our observation, though we can trace them in their effects: as, for instance, we know that the atmosphere drinks up moisture, because it soon dries the ground; whereas, if we cover a portion of the said ground with an inverted vessel, that portion remains wet, and, under particular circumstances, apparently becomes more humid than before. Indeed, the surface does so in reality, for such is the tendency of water to mix with air in the process of evaporation that it will come from a great depth in the ground; and it has been ascertained, by actual observation, that when the surface appears quite parched and moistureless, and is rent into champs and fissures, no less a quantity of water than 1,600 gallons an acre has been evaporated from this ground, appearing absolutely dry, in the course of twenty-four hours. Indeed, the greater the drought and evaporation, the more will a covered portion of the surface become moistened; and this is the reason why it is so beneficial to cover delicate plants with glasses or inverted garden pots during the day, when the weather is very hot. It is exceedingly doubtful whether this conversion of the general evaporation from the dry ground into a sort of well-spring for small portions of it, is duly attended to, or indeed rightly understood, though it might be the means of saving many a choice vegetable from the destruction of our very dry seasons.

We mention this incidentally, and shall proceed to the proper topics of the section; remarking that the most conspicuous of the phenomena alluded to are connected in their origin with the obscure subject of evaporation and the state of vapour in the air, or with other subjects equally obscure.

WIND, in the common acceptation of the term, signifies motion, and not matter; and thus, even in common language, there is a distinction between the two. The word is derived from the old English verb "wend," which we still retain as expressive of motion, in conjunction with the verb "go." Every motion of the air is therefore a wind, and every thing which can put any portion of the air into motion is the cause of a wind. In our volume, "THE EARTH," there will be found some notice of those more general winds which arise from the motions of the earth, and the various action of the sun upon it at different times; and these will be found accompanied by some hints as to how those general motions are modified by the distribution of sea and land, and by the varied character of the latter.

Those winds which blow constantly from the north and the south of east upon the broad oceans, and which shift with the varying declination of the sun, are called *Trade Winds;* and when one gets fully into their current, they are more steady and also more gentle than the more variable winds; on which account they conduce not a little to the ease of crossing the broad waters in the direction towards which they blow.

The winds which blow seasonally, part of the year in one direction and another part in the opposite direction, from the way in which the hemispheres and different parts of the hemispheres reciprocally affect each other at different seasons, are called *Monsoons*, from a Persian word which signifies "season," or "seasonal." Each monsoon is tolerably regular to its direction during the greater part of its season, but the times of the changes are times of great atmospheric disturbance.

Where the surface of the land is of such a nature as to become greatly heated, and the latitude or the season such that the sun acts powerfully upon it during the day, there are alternate winds from the sea to the land at one time of the twenty-four hours, and from the land to the sea at another. These are called, *Sea and Land Breezes*. They vary much in different countries, and in some they are not known. If there are lofty mountains near the shore, they do not occur, neither are they sensibly felt in the high latitudes, or during the winter in temperate climates; and during the fall of the rains, or at the turn of monsoons, they do not blow even in tropical countries. But in the rainless season, the sea breeze is very refreshing on the shores of those countries, while the land breeze is serviceable in carrying ships out to sea.

These breezes are the same as the monsoons, only they are on a limited scale, both in extent and duration. The temperature of the sea varies little during the twenty-four hours; but in dry and hot weather that of the land varies a great deal, and thus it is alternately higher and lower than that of the sea. The difference is very considerable, and may occasion a sea wind at the rate of twenty-six miles, and a land one at the rate of twenty miles an hour.

The times of shifting in these winds are calm; and they are very often accompanied by fogs on the shore, when the currents of different temperatures meet there and neither of them has much strength; but when either breeze begins to blow decidedly, the fog disappears. The formation of this fog, and indeed of all ground fogs, is precisely the same in principle as the first formation of a cloud, the nature of which will be explained in another paragraph. It is astonishing how small a portion of water suffices for the play of those winds, especially of the stronger one, or that from the water, if there is no general wind over a breadth of the country to obliterate their effects. A lake of moderate dimensions, a river, a mill-pond, nay even a grove of trees, or a field of green corn, is sufficient to stir the air around it on a hot and calm day.

The *variable winds*, which are not affected by the alternate play of land and water, but which sweep over both with nearly the same velocity, can hardly be reduced to any thing like system; because they depend upon the relative situation of places on the globe, with regard to the general currents of the atmosphere as depending on the sun and the earth's motions, and also upon the particular nature of the larger divisions of the earth's surface. The susceptibility of the surface to the action of the sun, and the degree to which that action affects it, are jointly the cause of all surface winds, that is, of all winds which have their origin at the earth's surface. The *general* surface current is toward the parallel of the sun's greatest action for the time, southward to the north of that parallel, and northward to the south of it; but as both those currents advance, they come into regions where, in consequence of the increase of the parallels, the motion of the earth eastward is faster than that of the air, and thus they are both turned in the direction of westward, till they come to the parallel of greatest heat, where they ascend in the general mass of the atmosphere, cooling in proportion to their ascent. Thence the motion of both is reversed. But, in the tropical regions, the reversed currents are in the upper part of the atmosphere, and therefore they are not observed. As they advance from the parallel of greatest heat, they come into places where, because the parallel is smaller, they have greater motion in circulation than that parallel, and the consequence is, that they get before the surface of the land and sea, in eastward rotation, and become winds—one blowing from the south-west, in the northern hemisphere, and the other blowing from the north-west, in the southern. In fact, they are exactly the reverse of those currents which occasion the trade winds, only of course they do not reach the surface till beyond the latitudes in which the trade winds are felt; for there cannot be two winds in opposite directions, blowing over the same surface, at the same time. But when the tropic is passed to some distance, they begin to be felt, and are very perceptible in the north and south parts of the Atlantic, as a westerly wind, blowing against the shores of Europe, in the former, and another blowing in the same way in the direction of the Cape of Good Hope, though, a little to the south of that, a general current, which sweeps round the whole uninterrupted girdle of the Antartic Ocean. In the temperate latitudes of Europe, or, generally speaking, of the northern hemisphere, if a very strong wind should come from the region of the pole, in the winter season, when the air there is very cold and much condensed, the motion of such a wind southward would turn it into a wind blowing from the east of north, and more easterly as it advances. The facts verify this; for all our most violent snow-storms, and most intensely cold gales, are from the north-east; while the winds from the opposite quarter, which are composed of that general current of the air which is returning from its visit to the equator, are of a milder character.

The north-east wind, too, comes as an expanding wind, because it comes into warmer latitudes; and, therefore, unless it has been loaded with humidity before its arrival on our shores, it becomes a parching and drying wind. The westerly winds again, by coming from warmer latitudes, come as condensing winds, and in a state which disposes them to part with a certain quantity of their humidity. This is the reason why so much more rain falls on the western shores of the British Islands than on the eastern; and also why the temperature is lower on the western shores for the average of the year, though the wind which comes to them is warmer.

In the southern hemisphere the circumstances are reversed; and the most violent winds, and those which bring the greatest drought, are from the south-east. Every one has at least heard of a south-easter off the Cape of Good Hope; but this south-easter, though it comes the whole way from the south pole over the sea, with great velocity, and agitating the water, so that its quantity of moisture must be a maximum, is yet not merely a drying wind in the country of the Cape, but one which speedily withers all vegetation ; the dust is raised in columns, the very heavens seem disturbed and the stars in their courses to dance to the terrible music of the south-easter. Such are some of the principal winds, the details of which, even briefly told, would fill many volumes.

CLOUDS, in their primary state, bear some resemblance to DEW, only they are formed entirely in the air, while, in the case of dew, there is another substance concerned—namely, the one on which the dew forms. We shall first advert to the dew, because it is the simpler process, and the one which is the more open to our observation.

Dew forms most copiously in warm climates, in warm weather, and when the sky is cloudless ; while it much more rarely forms in cold weather, under a sky covered with clouds, or when the surface of the ground is swept by a wind of moderate briskness. It also forms more copiously on low-lying places than on those which are elevated, provided their surfaces are nearly of the same character. These facts are of themselves sufficient to explain to us the rationale of its formation. The surface of the ground is, during the day, hotter—or, at least, not colder—than the air immediately over it ; but when the influence of the sun is withdrawn, it cools much more rapidly, because its heat radiates upward to a considerable height through the atmosphere, without raising the temperature of the air, or disturbing the quantity of humidity. Thus in brief space—briefer in proportion as the heat of the earth has been greater than that of the air—the earth becomes the colder of the two, and cools the lower stratum of the air, thereby diminishing its capacity for moisture; and if the state of previous saturation has been such as that this diminution of temperature shall reduce the capacity below the contained vapour, there is no alternative but that the quantity of liquid water thus set free shall descend; and, as it is very near the surface of the earth, the incipient drops, though perhaps not even microscopic singly, fall to the ground, or rather, perhaps we should say, are taken out of the air by the cold surface. That dew does not form during wind is easily understood, because the lateral motion of the almost gravitationless drops cuts off their tendency to the surface. That it does not form during clear nights, is perhaps the most satisfactory proof of the manner of its formation. There is no doubt that, the lower and the more dense the clouds are, there is the less tendency to the formation of dew; but still, if there is a canopy of visible cloud, the formation will be prevented; and more than this, if it happens to be cloudy during the night, but becomes clear in the morning, a morning dew may form, though the ground is quite dry during the greater part of the night. From this, it is evident that the heat which radiates from the earth, after the action of the sun is withdrawn, reaches to a much greater height in the atmosphere than that at which any canopy of cloud forms; and, comparing settled clouds in the sky with the height of the mountains, we may assign, at least some of them, an elevation of between two and three miles. The clouds must, generally speaking, though not always, be of less compact structure the higher they are, because the atmosphere there is incapable of supporting so much weight; but yet it is proved by the observed fact, that the most elevated, and therefore, generally speaking, the least compact, canopy of clouds, can check the radiation farther upward, and most probably can radiate back again downwards. Thus the cloud of night, when it covers the sky, is a sort of protecting mantle which prevents the earth from becoming so cold as it otherwise would be. It does even something more than this; for the dew has to be disposed of after sunrise. This must be done by evaporation; and the evaporation is a source of greater cold than the formation of the dew; and if the temperature has been low enough to convert the dew into hoar-frost, which is often simply frozen dew, the cold produced by the double process of thawing and evaporating, and the more rapidly it is done the worse, is often highly injurious to delicate vegetation.

In this matter of dew we may discover a very beautiful portion of nature's economy. In such countries as our own, the spring nights are generally cloudy, and the winds are then seldom at rest. It is the awakening of the season; and as all the powers of nature work together, both the earth and the atmosphere are stirring. Hence, during spring nights, there is comparatively little dew, nor does it commence, in most situations, till the summer is in so far advanced; but spring is also the time when the bud, the blade, and the blossom, are both tender and energetic in their growth; and therefore, if they were to be frequently dewed upon, and especially if that dew were to be turned into hoar-frost, which it would be because the spring nights are often cold, they would be destroyed. If a single hoar-frost comes at this season, and a hot sun speedily dissolves it, the choicer fruit crop is a failure and many of the most ornamental shrubs and plants are in ruins.

In autumn, on the other hand, nature reposes before the winter sets in—the flowers are over, the fruits are gathered, the buds are muffled up for the winter, the leaves of the deciduous trees have performed their annual function, and the action of cold is wanted to heal them off, so that the places to which they adhere may be cicatrized. It is astonishing how soon this operation is performed in some trees: to day, the mulberry on the lawn shall be in all the apparent greenness of its foliage; a dew shall fall at a freezing temperature during the night, the warm sun shall beat strong upon it in the morning, and, before the dew of the following evening, the whole of its foliage shall be lying under it in a heap. But examine it, and there shall not be a lacerated wound in a single twig, but the whole shall be already skinned over. Is there not purpose in this, and purpose which works beautifully for nature—and for man?

The readiness with which dew forms into drops, and frozen dew, or hoar-frost, into spiculæ, shews us something of the way in which rain forms into drops, snow into flakes, and hailstones into masses. We have reason to believe—nay, we are sure—from the fact of their being formed so close to the surface dewed upon, that the individual portions, as they are formed, must be very minute; but they accumulate into pearly drops, which are, generally speaking, large in proportion to the length of time that the dew continues forming. We must from this conclude, that the smallest imaginable portions of water in the atmosphere, as soon as one particle has come into contact with another and the liquid type has begun, have an attraction for each other, which brings them together, and that the magnitude of the acumulations must be in proportion to the time during which this attraction of accumulation acts. The force of this attraction must be in proportion to the quantity already accumulated; and therefore a larger drop falling through a mass of smaller ones must attract them just as a snow-ball licks up the snow over which it is rolled, or as the dew-drop, which has already acquired some size upon the blade of grass, draws toward it the smaller portions which are in the act of forming. So also, when the temperature is as low as freezing, even at the very surface, and when no visible spiculæ of ice can be perceived at the distance of an inch, or half an inch, from the portion already formed, they find their way to that portion, so as to form little bristling points of the most beautiful arrangement. There is one very peculiar and very beautiful appearance of this frozen dew, which will be readily understood by any one who chooses to notice into how large globules water will form itself during rain, upon a cabbage-leaf, or any other surface which is not wetted by it. Spiders' threads possess this quality of not being readily wetted; and thus, on those mornings of gentle dew when many surfaces are merely moist, the web of a field-spider will be found thinly studded with rather large and exceedingly beautiful globules of water; and when everything else is covered with spicular hoar-frost, the larger threads of the great garden-spider's web, which are strong, and thus remain many weeks after the spiders themselves disappear, are found with the frozen moisture upon them in small round globules, the whole resembling strings of little pearls. There is a surface repulsion between water and those substances which are not wetted by it something similar to the repulsion which takes place between two conducting substances, both charged with electric action; and this, as we shall see more at large afterwards, explains why, during thunder storms, rain should fall in large drops.

That the portion of the atmosphere out of which dew forms is very thin, or, at least, confined to within a very small distance of the surface dewed upon, appears from the fact that a temperature so low as that of freezing, even at the height of two or three feet, is not necessary in the formation of hoar-frost. The surface cold is, no doubt, greatly promoted by a partial evaporation which the radiating heat produces; but this only causes a mixture of thin strata at different temperatures, which increases the depositation of moisture and the cold of the surface. In this way the climate of Britain and that of Greenland may be brought within a few feet of each other, all over the country; for it must be 32° when the hoar-frost forms, and in such cases the thermometer, a few feet up, may stand between 40° and 50°. If the sky over head is clear enough, the hoar-frost may proceed to such an extent as to freeze the surface, and cover the little pools of shallow water with ice.

It has sometimes been said that this cooling of the surface in clear nights is occasioned by "cold pulses shot down from the sky." But this cannot be—cold is merely the absence of the action of heat, and surely the absence of action cannot *act?* If one vessel were full and another empty, and if the contents of the full one were transferred to the empty, it would be quite correct to say that the contents had been poured out of the full vessel, and into the empty one, but nobody would think of saying that the emptiness of the empty vessel had been poured into the full one; and yet this is a case exactly parallel to that which supposes the surface of the earth, in clear nights, to be cooled by cold pulses shot down from the sky. Perhaps the extreme case of cooling—at all events the most melancholy one—of which we have any knowledge, is that in which an iceberg from the polar sea grounds upon the shore of one of our northern isles. The iceberg so grounded melts away; partly by the direct action of the sun upon it, as melting it into liquid water, but more as turning it into vapour; and the production of cold—that is, the abstraction of heat—both from the land and the atmosphere, for many miles round, is so great, and the quantity of moisture floating in the cold and condensed atmosphere is so excessive, that vegetation vanishes, the cattle die, and disease carries off the wretched inhabitants. But, dismal as are the effects thus produced by the grounded iceberg, that iceberg is no more an active agent in the desolation which it occasions than if it had remained rooted on the cliffy shores of Greenland or Spitzbergen. The evil is really produced by the warmth of the place into which it comes, and the iceberg itself is passive to that action of heat which assails it on every side, and in the end consumes it.

In shortly noticing the phenomena of CLOUDS, we shall take the description of the leading classes, and the modes of their formation and various appearances, in conjunction with each other, as this will shorten our notice, and perhaps also render it a little plainer. It is unnecessary to tell any one living under a British sky what we, generally speaking, mean by a cloud.

The general principle of the first formation of a cloud is nearly the same, in whatever part of the atmosphere that cloud may happen to be formed; but if it is formed immediately on the surface of the earth, then the earth must have some influence in its formation. On the other hand, if it is formed at a great elevation in the air, it must be the result of atmospheric causes only; and from what was remarked in the preceding section, its initial formation must be only mechanical, and not dependant in any way upon any species of electric action; because the cloudless air is a non-conductor of electric action, and therefore it is not easy to see, or rather it is impossible to believe, that it could be the means of disturbing its own equilibrium; because that would be endowing it with a faculty of action, and before there can be any material action there must be at least two parties —an actor, and an object whereon to act. Let us inquire which is likely to be the proximate source of this action, which disturbs the equilibrium of the atmosphere, and forms cloud.

That, in consequence of the permanent winds, and the local and seasonal ones, the mass of the atmosphere is, in different portions of it, in continual motion, in a countless variety of directions, is quite evident. There are also other motions, which arise from the action of the sun and moon. Thus, for instance, the air on the hemisphere turned to the sun is more heated, and therefore must be more expanded than that which is turned from the sun. Hence, as day and night alternate at any place, the air over that place must, so to speak, be raised up during the day, and it must sink down again during the night; and this daily rise and nightly fall must be a little increased, or at least affected, in the morning and evening, by the gravitation, though the equilibrium, in as far as this is concerned, will be restored at midnight. But these disturbances are not attended with any great cause of lateral motion in the atmosphere.

The moon may be said to exert no rarefying effect upon the atmosphere, for the moon beams are cold; but the tidal influence of the moon must be greater than that of the sun, for reasons which we will endeavour to explain when we come to consider the phenomena of the Sea, in a volume on that subject; and, just as is the case with the sea, those lunar tides of the atmosphere must be joined with the solar ones at the times of new and full moon, and opposed to them at the quarters. Here again, however, there is very little cause of lateral motion, though when these monthly occurrences are taken in connection with the daily ones, and also with the seasonal ones, which shift the light and dark hemispheres according to the sun's declination, a considerable degree of upward and downward motion must be produced in the atmospheric mass, and as this is in the cross direction to all the lateral motions, it must tend so far to mingle the strata, and partially confound them with each other; and from the complication of all these motions, one portion of the atmosphere must always be running against another portion, in some place or other.

The higher regions of the atmosphere are removed from terrestrial action, so that they can be but little disturbed by the causes of the surface winds. We have a confirmation of this even in our own country, where none of the mountains are quite a mile above the level of the sea. On their summits, we find the upper current from the south-west blowing with little variation, at least for all that portion of the year during which it is pleasant or even safe to visit such places, and if we could get a little higher than this, we may presume that the upper current would be steady all the year round. Of course it would be the same in other latitudes, only higher in the direction of the trade winds, and perhaps lower in the regions of the poles, though there the equatorial action of the sun is of course the least possible. Thus we may assume that, in the higher atmosphere, all over the globe, there is a current constantly moving obliquely from the west of south in the northern hemisphere, and from the west of north in the southern one. In this place, that is, at this elevation, the atmosphere is rare, and therefore light, compared with what it is on the surface; but, rare as it is, it may be considered that these upper currents form a sort of shell, within which, though its limits must vary with seasons, and other circumstances, the working of the clouds, and all the accompanying phenomena, is carried on; and as these currents are uniform in their directions, every counter current which sets in a different direction must so far mingle with them, and each must arrest the progress of a part of the other, at the line of their junction, wherever that line may be situated. It is to be borne in mind, too, that this more elevated shell of the atmosphere consists of air, which is continually raised up by the action of the sun from countries where evaporation is a maximum; and that, consequently, unless where it is heated by very warm and nearly quiescent air under it, it must always be at or very near the point of saturation in respect of humidity,—in other words, it must be always so circumstanced as to form a cloud whenever its equilibrium is in the least disturbed, though, on account of its own rarety, this cloud can be but a light and filmy one. We shall see what it is and how it operates by and by, but in the meantime, it will be as well to bear in mind that such is the general condition of the upper air.

We cannot go with a line to measure what the general elevation of this may be above the surface of the earth, and we are able to make observations at so few of the 790,000,000,000,000,000 square inches, which is about the average measure of the earth's surface, to say nothing of the increased surface of the upper air, that it would be unwise to speak positively on the subject; and, indeed, the stratum or shell of which we are speaking is of very great and indefinite thickness, for it extends as far upwards as the atmosphere is capable of motion, which is probably not less than twilight height—forty or fifty miles above the mean level. The conjecture is, that, at the poles, the height of the portion of this shell in which light clouds are most apt to be formed is rather less than two miles, and that it gradually increases till it is nearly five at the equator, though clouds must form at a much greater height than this, at least in the equatorial regions, otherwise snow could not fall on the summits of the Himalaya and the Andes, the loftiest of which are very little below five miles.

This elevation is every where greater than that of perpetual frost, at least as ascertained on the surface of the earth,—for we can tell very little about it in the free atmosphere, especially over the lower-lying places. From the explanation given of dew, however, there is every reason to conclude that, in the warm and tropical countries especially, where the radiation of heat from the earth is very great, and the sky is generally clear, the height of the line of frost is very much greater than it is on the surface of the elevated lands, though it is impossible for us to state in numbers what its height may be. It is probable, however, that the same difference, with regard to the height at which water freezes, extends, proportionally to circumstances, to every latitude; and that while the earth is bound up in ice and snow, and the temperature of the lower air sufficient to freeze mercury, there may be an elevation at which water may remain liquid, and absolutely have to descend before it is turned into snow. This, however, is contrary to the assumed theories—and they are merely assumed, and therefore we do not state it as any thing else than a mere conjectural hint, the working out of which might lead to something; and it is certainly encouraging when we reflect upon that which we can observe: for if we have more than ten degrees higher temperature at four feet or less above the hoar-frost of Britain, why may not the air be temperate, or even hotter than that, a mile above the snows of Sorate or Dhawalaghiri? On this subject we strongly suspect that the most confident of our theorists have much to learn—and not a little to forget.

Thus there is, in the higher regions of this atmosphere, a quantity of the mass constantly in motion, and always near the point of saturation; there are abundance of currents under it, in all possible directions, meeting, opposing, and mingling with each other, and there are the elevations and depressions occasioned by the sun and moon farther to disturb the whole. In order, therefore, that we may have at least some notion how a cloud *may* form in the air, we have only to find out by what means these currents, when they mingle, can be made to part with, or set free in the liquid state, a portion of that water which they hold in the state of gaseous vapour.

At first sight, it might seem that there could not be, in the mere mingling of two currents of air, even supposing them both completely saturated with vapour, any tendency to set any portion of that vapour free as liquid water; and if the currents were exactly of the same temperature and the same density, there is no doubt that this would be the case. But, were it so, there would really not be any current, because the currents are produced by differences of temperature, and the densities are always, under the same pressure, that is, at the same part of the atmosphere, inversely as these. Now, it is not only in accordance with theory, but it has been proved by direct experiment, that if two portions of air, at different temperatures, are mixed together, their capacity for moisture, that is, the quantity of water which they can sustain in a state of gaseous vapour, is less in the compound than in the two component parts separately; and that, if the difference of temperature is considerable, the union of the two portions will not be able to retain the whole quantity which they did separately, even though one or both of them is below the point of saturation. For instance, it has been ascertained, by correct experiments—at least as correct as the subject will admit of—that if equal portions of air, within 1° of the hygrometer, or measurer of moisture, of saturation, and the one at 30°, and the other at 50° of the common thermometer, be mixed together, the mixture will be unable to maintain in the state of vapour the quantity of moisture in both. The mean temperature is of course 40°, the half sum of 30° and 50°; and 1,000,000 cubic inches of air at the temperature of 40° is saturated with 1,782 grains of water. But the same number of inches at 50°, one hygrometric degree below saturation, holds 2,389 grains in saturation; the same quantity at 30° holds 1,235; the sum of these is 3,624, and the half of that which remains to be held by the half volume of the mixture at 40° is 1,812 grains. Comparing this with the 1,782 grains which this volume at 40° can hold when saturated, we find that there are 30 grains above saturation, for the difference of 1812 and 1782 is 30. Therefore, in the mixture which we have been considering, upon the supposition that each part of it is 1° below the point of saturation, there would be 60 grains of water set free. The extent of air, namely, the million of cubic inches which we have been considering, is but a small measure of the atmosphere,—it is only a cube of 8⅓ feet in the side; so that the two together, which yield the 60 grains of disposable water, would not fill even a small room; and this is nothing compared to the extent over which any two currents of the atmosphere must extend in their meeting with each other. At even this rate, the quantity of water set free from a cubic mile of the atmosphere, which is no great extent in the formation of clouds, would amount, in round numbers, to about 450 tons; and there are many circumstances where the saturation of both strata may be complete, the difference of temperature as great as has been stated, and the extent many hundreds of cubic miles; so that what may appear to us, comparing it with the whole volume of the atmosphere, a very local and even insignificant disturbance, may be sufficient to set free a sufficient quantity of water for an abundant shower of rain. According to a rude calculation, founded upon this estimate, and it is not an over-strained one, a fall of rain to the depth of one inch, or about one-twenty-fourth part of what falls in Britain, on the average of the year, over one square mile of the surface, could be obtained from a stratum of air, one hundred miles long, fifteen broad, and one in thickness; and as twenty miles an hour is a very moderate rate of motion in the upper air, and but a moderate breeze in the lower, the whole of this quantity of rain might be formed, and might fall to the ground in the course of a few hours. Such is the power which the atmosphere has to form clouds from the mere union of currents of different temperatures, and without reference to electric action, or any other occult cause, real or imaginary, the operation of which we do not understand, and consequently cannot explain. Having thus seen that there is a power of action in the atmosphere, by which clouds may be formed, we shall now, very briefly, enumerate the leading kinds of them, and their more remarkable appearances.

In the more modern nomenclature of clouds, there are four simple or original names made use of,—*Cirrus*, which implies that the cloud consists of long and generally wavy fibres, having some resemblance to locks of hair; *Stratus*, which means that the cloud is broad and flat, extending in the horizontal direction; *Cumulus*, which means that the cloud is accumulated, or made up by the addition of smaller clouds; and *Nimbus*, which means that the cloud consists of drops of rain, which are either in the act of falling or may be expected to fall to the ground. Every cloud which meets the ground, or any one passing through its mass, is not, however, a nimbus; for the mountain-fog cloud, sometimes called a "Scotch mist," will very speedily wet one to the skin, or cover one with hoar-frost if the weather is cold, and yet there is no decided falling of drops to the ground.

Besides these simple or original names, there are others which are compounded of them, because the clouds to which they are applied have a mixed character, or partake partly of the appearance of one of the simple classes, and partly of that of another. These compound names are,—*Cirrocumulus*, which means an accumulation of cirri; *Cirrostratus*, which means a stratum or table of cirri, extended horizontally, and when low in the sky, and even at some distance, it appears a long line or bar; and *Cumulostratus*, which means an aggregation of stratus, generally in the progress of passing into cumulus.

With the exception of stratus, which has reference chiefly to the earth, and does not of itself in any way indicate a fall of rain from the sky, or necessarily any change in the weather, all the rest are rain clouds; and they form a series, from cirrus to nimbus, in nearly the following order: cirrus, the first or uppermost cloud that appears in the sky; cirrocumulus which is the next in elevation, and forms what is sometimes called a "dappled," or mackerel sky; cirrostratus, which is the third, and never very low in its real situation, though it may seem so if even near the horizon; cumulus, which often forms in the horizon in large and very dense masses, which appear like snowy mountains when in the light of the sun, and when near the place of the sun their mass is often very dark, and their edges as brilliant, especially when the sun is near the horizon; nimbus, which is usually the lowest of all clouds at the time, and, if in large volume, the darkest of them all. Though rain does not fall until after nimbus forms, and though cirrus is the first cloud, it does not follow that they come in regular succession within the same horizon, or rain during the same storm. Cirrus may appear in one place, and pass through all the stages in different places, becoming nimbus at the distance of many miles from the place at which it first appears. Nimbus may also march alone into a sky which has been cloudless for weeks, or more frequently cumulus comes in this way, and is changed into nimbus probably by electric action,—at least, such clouds usually march for a considerable way before they break. They occur chiefly in warm weather, and are usually accompanied with forky lightning and loud thunder. When on a very large scale, so as to cover almost half the canopy, and ultimately cover the whole of it, they are among the most splendid displays of the summer sky. There is also a sort of ready-made nimbus, which is not an air-formed cloud at all, but a product of the sea, raised up by a water-spout, the proper consideration of which belongs to the SEA. As a phenomenon in the air, it is often, however, very splendid; it is especially so to those who, with the sea not in view, see it for the first time, without knowing what it is. The upper part of the water-spout consists of water in large drops, raised, separated from each other, and supported, by the revolving motion of a whirlwind; and while the base of this travels over the surface of the water, continuing the supply, the upper part may be carried for many miles inland, at a considerable height, by the sea breezes. But when the point at which the breeze ends is arrived at, the forward march is stopped, though the whirling may continue; and then, to an observer under it, it appears as if a long rope of cloud, rising from one part of the horizon, were in the act of being coiled into a ball in the zenith. We had once an opportunity of witnessing a display of this kind on the afternoon of an otherwise very warm and bright summer day; and, we may add, that we beheld it with no small consternation, for it was long ago, and the place was lonely. A circular cloud was whirling round and round a little to the south of the zenith, and an ascending beam of cloud connected it with the eastern part of the horizon: at first it was very pretty, but it broadened and blackened, and by the time that it had covered the sky there was twilight darkness. The small rim of light at the horizon was very striking for a time, but when all became dark it was rather dismal. In the midst of the darkness, gleam went the one mighty flash of lightning, as if the heavens had taken fire; and instantly after, crash went the thunder, as if heavens and earth had been hurtled into one common ruin. There likely was "another roar," but that was unheard, for the rain was in a moment rattling on the earth like bullets. The shelter of an old fortalice, in a little grove of dark pines, bordered with laburnums in full flower, was made for, despite some superstitions which caused it to be rather avoided in common cases. Very soon the sun was out again, there was a lovely rainbow in the east, the level plain lay in lakes, and the large drops, which had been dashed upon every leaf and spray, outlustred all the caskets upon earth. But the rainbow:—"And it shall come to pass, when I bring a cloud upon the earth, that the bow shall be set in the cloud: and I will remember my covenant, which is between me and you, and every living creature of all flesh; and the waters shall no more become a flood to destroy all flesh."—The reader will perhaps pardon this little digression, which is as literal as memory can make it.

The fact of this water-spout being attended with one very powerful display of electric action, and with no more than one, which one was almost instantly followed by the precipitation of the whole mass of water upon the earth, may, perhaps, throw a little light upon the original charging of clouds, and of their discharge, whether between each other, or between one or more and the earth. The sky, which was not only cloudless previous to this phenomenon, but which had been so for some time, without dew, or any other sign of even local saturation with humidity, must be supposed to have been in the condition of a non-conductor; and we may suppose that the whirling motion of the nucleus, by means of its friction against the air, may have excited electric action, and become charged, after which it would naturally attract the succeeding portions of the rising column towards it, in the same manner as a large thunder-cloud may be observed drawing towards it all the small clouds in its vicinity, and incorporating them in its mass. The violence with which the water descended in this case, and the short time required to clear the air of a mass of cloud, —which, both from its darkness, and from the great quantity of water which it left upon the ground, must have been great, give us a little insight into the use of thunder-storms. It is a common saying, that "Thunder-storms clear the air;" and as those common sayings are the results of experience, and must be in accordance with general observation before they are received into general use, it is worth while to attend to the manner in which this is done. It should seem that for the charging of one cloud, some considerable degree of disturbance—of motion of the air against the cloud, or of the cloud against the air—is necessary. At least this is the only means of performing the operation that resembles any thing which we know to be fact with regard to the charging of a conducting substance with electricity; and if we have something in nature analogous to what we ourselves can perform by direct experiment, we do not act very wisely if we leave this, the plain and obvious path—the only path of truth, in short—to wander upon the mountains of vanity, or lose ourselves in the mazes of conjecture.

From all that we can observe in nature, this seems the rational view of the case. Thunder-storms are most common, and most violent, in those parts of the world, and at those seasons of the year, where and when evaporation is at its maximum, the lower atmosphere at its greatest heat, and when, by necessary consequence, the moisture which it contains is at its greatest degree of tension, or most completely assimilated in its state to the non-conducting air with which it is mingled. In proportion as the heat and drought are of long continuance, we can readily understand that this heat and dryness will extend upward in the atmosphere, and, by the expansion or elasticity which they produce, raise the entire atmospheric mass to a greater elevation above the earth's surface. This increased elasticity and elevation will not affect the height of the column of mercury in the barometer, because the same volume of air is still over the surface, and of course the gravitation will hardly be different. It must, however, raise the line, or curve, at which clouds are most readily formed, to a greater elevation above the surface of the earth, and also prevent the formation of clouds in any region lower down; so that, under this influence, the atmosphere for a great way up must be rendered steady, or obedient only to the general current, dependant on those causes affecting the whole globe, to which we have had so frequent occasion to allude.

This is the reason why, in tropical countries especially, during the dry season, the winds are so moderate, and the variations of the barometer so small; though, of course, when the turn of the season comes, and the resistance of this mass of dry and uniform atmosphere is subdued, the subduing of it must be attended with circumstances proportional to, and demonstrative of, the violence of the struggle. Nor need we wonder that it should require the utmost intensity of the lightning's flame, and the loudest voice of the thunder, before the seasonal rains are able to descend upon the parched plains of India, of Africa, or of South America. Throughout all nature we find the balance kept up; the weak yields to a weakly conqueror, and the victory is obtained in comparative peace; but the strong submits not, save to greater strength, and the accompaniments are in a style of corresponding magnificence. Let us take an instance:—The *Llanos*, or plains, of tropical America, say in the valley of the Orinoco, are, during the dry season, parched and denuded of their vegetation; and, though the power of evaporation continues to draw moisture from the ground from depths far beyond what we would suppose, the air continues so thirsty, in consequence of its great heat, that not a particle of moisture, be it hid where it will, can escape its scrutiny. And even when the current is brought from the south, and the cold and the warm strata are grinding each other into copious moisture, it is long before their action can produce any thing like a cloud; and it is not till the struggling vapour, or rather the incipient drops of water, which are still of extreme minuteness, have acquired such an assemblage that all the more refrangible rays of the sun, when it beams from the meridian, are thrown above the nascent cloud, and only the red find their way through, covering the horizon with crimson, that the upper air is able to make the slightest impression on that which is below. This lurid appearance of the atmosphere deepens till the sun is almost obscured, and the skies, ere while so bright and sparkling during the nights, display the stars surrounded with a fringe, so that what is going on above this gorgeous appearance is concealed from observers on the earth. There is no doubt, however, that the young clouds are busily at work there, that they are reeling to and fro, until some shall have been so charged with electric action as that they can gather the others into their mass; and, as drop is attracted by drop, as well as cloud by cloud, the power of gravitation comes in to assist in the descent. But even when the mass of accumulated clouds has acquired that density, and the individual drops that magnitude, which would send them downward through the utmost resistance of our skies after the longest period of drought, the lower atmosphere of the tropical country continues to battle inch by inch, as it were; nor is it till the volume of cloud has forced its way so far downward as that it can aim its lightning-stroke against some projecting point, that the coming rain triumphs over the dry air. In this case it is no single flash, and unrepeated peal;

for, during the early part of the night, the blazing and the din are incessant, so that, to one not accustomed to such occurrences, the action of nature is terrific. To increase the grandeur of the display, it is generally during the night that the final struggle takes place. We can see the reason of this :—as long as even the red rays of the solar beam can reach the surface of the earth, the beams of heat are sure to reach it, for they are the least refrangible of the whole, and thus it seems as though the sun were struggling to maintain his dominion of parching over the earth. The heat, too, under the murky sky, is intolerable, far more intense and fatiguing than while the air was clear. This will readily be understood, for it is the same in principle as the preventing of the formation of dew by a canopy of clouds in our own country. As long as the nocturnal sky is clear, the radiation of heat from the earth finds its way upward to a great height in the air; but after the canopy of cloud has thickened to the extent which it there acquires, and descended to nearly the point of its rupture and discharge, it returns the whole of the radiated action of heat back again. This tends to prolong the struggle, and to make it more severe, and it makes the nights hotter up to the very one on which the rain is to fall. But no sooner have the lightning and the thunder given their warning, than down it comes, one continuous mass, and, before the morning sun, a river rolls in every ravine, and a lake is formed in every hollow. It is in consequence of the violence with which these seasonal rains burst, that the watercourses in the hilly parts of those countries are torn so deep, and this is also the reason why the lower valleys of those rivers are so exuberant in their fertility. The accumulated flood, as it gets to the lower valley, has another struggle to make. Former floods have carried down a vast mass of the ruins of the land into the sea; the re-action of the sea returns this in great part during the dry season, throwing up a sort of barrier, as it were; and it is not till the pressure of water, in the highest swollen river, is able, in whole or in part, to remove this barrier, that its flood begins to ebb away. While the flood remains, those lower valleys present a curious appearance: for a wide extent the water covers the land to the depth of many feet, and the inhabitants of the land and of the waters are living together in the same forest, the former in the trees, and the latter sporting between them. Some tribes of the Indians that inhabit those places contrive at this time to make themselves tents in the tops of the palm trees, by tying the leaves together, and they are completely cut off from the earth until the waters subside. This may be regarded as the extreme case; but in all countries where the air is sufficiently dry and warm for offering a powerful resistance, the setting in of the rains is, generally speaking, accompanied by thunder, violent in proportion to the resistance of dry air, which has to be overcome before the rain can reach the ground. But we must briefly notice the characters of the several clouds.

Cirrus, we have said, is the most elevated of the whole, and, in temperate climates, it is the first to be formed after long drought. It is easily known by its light and fibrous structure, and the perpetual changes which it undergoes. Generally speaking, it may be considered as an indication of the breaking of the weather; but it not unfrequently fails for several days, and even weeks. In Britain, the first, lightest, and most lofty formations of it, generally have their fibres extending in the direction of south-west and north-east. In these cases, the broadest part of the cloud is generally to the south-west, and the opposite extremity is divided into wavy points, on account of which it is called "curl-cloud," "mare's-tail cloud," and a variety of other names. It appears to have little motion, but much change in its appearance, and its colour is invariably white. The want of apparent motion is in part owing to its great height, and in part also to its situation, being in the comparatively stagnant air between the two contrary currents. One of the simplest, and indeed the first, formations of this cloud, is in long and slender threads, which frequently cross the whole visible portion of the sky. This is among the most elevated, and it gets the name linear cirrus. Sometimes the lines cross each other, exhibiting a sort of net work, which shows that part of them are affected by one current of air and part by another. In both of these, the lines, whether they cross each other or not, are nearly straight, and indicate that the currents are tolerably steady; but when the proper curl-cloud, in which the lines are wavy, makes its appearance, it is a sign that the atmosphere is more disturbed, and variable weather may generally be expected. Cirri often appear in the upper part of the sky, not only when the weather is clear, but when there are several other strata of clouds lower down; they are not unfrequently seen through the openings of the clouds in broken and showery weather; and, as they appear to be the lightest and most moveable, or, as one might almost say, restless, of all clouds, they are not unfrequently observed performing the office of messengers between cloud and cloud,—for two clouds, at a considerable distance from each other, may be observed linked by a band of cirrus, which gradually draws them together, and loses itself in their united mass. In these cases, broken weather may in general be expected; and, indeed, this is the case whenever the cloud under consideration appears lower down in the sky than usual.

Cirrocumulus is perhaps the next cloud. It consists of round masses, situated near to each other, but still with openings of the sky between them. In settled weather, this kind of cloud may appear and disappear many times without any change following; and the chance of rainy weather is small, in proportion as the different masses of cloud are light in their structure. Still, however, this is a more solid kind of cloud, and, consequently, more apt to descend into the lower sky, to be condensed by so descending, and to change into rain cloud, than the fleecy cirri, which appear at a greater elevation. If the masses are compact and dark, and in very close juxta-position with each other, it is generally an accompaniment, or an indication, of thundery weather, and of course, in our climate, is most prevalent during the summer. In rainy weather, a particular modification of this cloud may be often seen careering about among the other clouds, very generally in a different direction, and often of a very light and flimsy texture. The individual pieces of this are often exceedingly small; but they are always to be considered as indications of continued rain, for they do not appear until the resistance of the lower atmosphere has been overcome; and they show that there is a very great disposition in the atmosphere to form clouds in those intervals which no cloud occupies. In fact, they show that the whole atmosphere is in a complete state of saturation; and the necessary consequence of this is, a continued fall of rain, until the whole has been exhausted. When, in fair weather, this cloud appears in lighter masses, they usually accompany light gales, and are formed and dissolved with great rapidity, and often for many days, without any rain following. These generally form without any cirrus previously appearing in the upper air; but when the formation of cirrocumulus follows that of cirrus, we may expect bad weather. There are often different strata of these clouds at various elevations; and if they so appear, with a moderate wind, on moonlight nights, the sky presents a very beautiful appearance. The abundance of this cloud is, at almost all seasons, an indication that the weather will soon be warmer. In early summer, it appears most frequently after a prevalence of cold easterly winds; and the breaking of the weather, which ensues, is accompanied by thunder storms and great heat; and in the latter part of spring, and sometimes in the early part of summer, the thunder is followed by violent hail showers, immediately after which the wind shifts to the west, the temperature rises considerably, and vegetation looks perhaps more fresh than under any other circumstances. In winter, cirri do not so often form in the upper air; but, after long-continued frost, with a clear sky, the appearance of cirrocumulus is not unfrequently the first indication of a thaw.

Cirrostratus is, perhaps, the thinnest of all clouds, in proportion to its horizontal extent. It is generally lower in the atmosphere than any of the two former ones; and it is seen at very variable heights, and sometimes it is very elevated, and has partially the character of cirrocumulus, only the masses consist of portions more elongated, and closer together. This cloud has been called wane-cloud, because it often fades away. At other times it appears in extended bars, a great way down the sky; and when it does this, it is generally a sign of stormy weather. This is the cloud in which those peculiar reflections of the sun and moon, to which the names of halos, mock-rains, false-moons, and many others, are given; and when it is of sufficient density to produce these results, rain or snow may pretty confidently be expected. This species of cloud appears, however, in so many forms, and is found in so many stages of passage, from the most elevated cirrus down to cumulus, cumulostratus, and even rain-cloud itself, that it is very difficult to give any description which can meet all its varieties. In that form in which it most nearly resembles cirrus, and forms a mackerel sky, it is usually at a great elevation,—perhaps not less than between two and three miles; and if it keep at this elevation, however it may shift and show disturbance in the region which it occupies, no general disturbance of the atmospheric mass may ensue, until brought about by some other cause. In mountainous countries, indeed, it often happens that this cloud remains, or rather alternately appears and disappears, in the upper sky, without any disturbance there, while showers are produced nearer the surface. In these cases, it should seem that there is a volume of the middle air, in a sufficient state of dryness for keeping up the clouds which are above it, and keeping down those which are below, so that they shall not unite their forces; but if a streak of this cloud can once get downward, to lie along the tops of the cumuli below, it is a pretty sure sign that the whole atmosphere has given way, and that a general rain will be the result; whereas, so long as the middle air can keep the upper and the under separate, the showers, however violent or accompanied by lightning and thunder, are generally very local; and, during their fall, there are winds alternately from all points of the compass. In Britain—at least on the east side of the island, for the west is generally watery at all times—it is the east wind which maintains the general drought; and, below this, the partial showers may be considered as resulting from causes more immediately connected with the earth's surface; and the showers which take place in such weather,—which is of course during the summer,—often extend only over a very little surface, but they are very violent. Mountainous countries, from the diversity of their surface, are much more subject to those summer showers than flat plains; and it not unfrequently happens, that if one has to pass two rivers, which overlap one another near their sources, one may have been walking in sunshine during the whole day, and yet find the larger river so low as to be passed dry-shod, while the smaller river shall be red with gravel, foaming over its banks, and presenting an insuperable barrier, except to those who know the fords, and do not mind wading up to the neck, and encountering the cannonade of pebbles, sometimes of pretty large size, with which the feet and legs are assailed.

Cumulus very frequently forms without the previous appearance of any of the varieties of cloud already mentioned; but it is always lower in the atmosphere. This cloud is called cumulus because it is a "gathering;" and it may gather its materials either from the atmosphere or the earth. When it collects them from the atmosphere, it is a pretty decisive sign that the whole atmosphere is inclined to rain; which is far from being the case if it collects them from the earth. In the latter case, the materials which are collected into cumulus are very generally fragments of stratus, or the ground fog which forms during the night, in many situations and states of the weather. If this be the origin of cumulus it is not immediately accompanied by rain; for stratus is often a fine-weather cloud. In such cases, it makes its appearance about sunrise, in larger or smaller masses according to the materials; and those masses are generally rounded in their outlines, and may keep sailing about through the day, but they generally disappear in the evening, and stratus again presents itself. These may appear and disappear for many days, or even for several weeks, without any breaking of the weather, or even without a shower; and there is something worthy of remark about them, as differing from almost all other clouds, excepting stratus, which is, properly speaking, not a cloud, but a ground-fog. All other clouds, from cirrus down to nimbus, including cumulus among the rest when it gets its materials from above, are clouds in progress toward the formation of rain, and would ultimately be followed by the fall of rain, if not prevented by some counteracting circumstances; and of these there is no doubt that the very lightest in appearance would wet one, if one came within its mass, in the same way that the cirrostratus,—which trails across the mountain tops, forming that hat or cap on the mountain which is so well known in many places as a certain presage of rain,—very speedily wets one to the skin, although at a distance it appears as light and as fleecy as wool. Stratus, on the other hand, though it presents pretty nearly the same appearance, has almost exactly the same colour, and seems even more dense than the trailing mist of the mountain, is quite a dry mist; and one may pass through it with very little perception of moisture. In like manner, the species of cumulus which is formed, as one would say, of the fragments of this stratus, is a cloud which probably never, unless mixed with other clouds, produces rain. This agreement of the two is not a little remarkable, and it has been regarded as owing to those clouds being in the same electric state with the earth and all upon it, so that there is a repulsion between them, in the same manner as there is between equally charged bodies in our common electric experiments. It is difficult, however, to come to any positive decision on this point; but it is worthy of farther investigation. It should seem that the moisture, which forms stratus during the night, and cumulus during the day, is in a state of alienation, both from the earth and the great mass of the atmosphere; but it very often happens that wandering portions of cirrostratus find their way to the one or the other of these; and though we are not warranted in saying that this contact changes the electric state of either the one or the other, yet it is exceedingly probable that, after the mixture of these earth clouds—for they are both so, in reality—with a sky cloud, they cease to have their dry nature; and the fog wets, while the cumulus often descends in showers. This appears to be most frequently the case in mountainous countries, where there is very generally stratus in the bottom of the valley, and cirrostratus on the mountain; and it is natural to suppose that, as the mountain itself affords some means of communication, the upper cloud should always be, to a certain extent, blended with the under one. It seems, too, that the lower stratus, or ground-fog of mountain valleys, is never of the same dry character as that on places where there are no mountains; and though cumulus is as often formed in the mountainous country without the immediate fall of rain at any one place, yet there is seldom a day, in a country of this kind, if it is of any extent,—and especially if near the sea,—during which there is not a shower at one place or another.

Nimbus, or rain cloud, is the lowest, and, in a succession, the last formed of all the air-produced clouds. It is not the actual fact of the descent of rain,—for the name given to that by the ancients was, *Imber*, or a shower,—whereas the *Nimbus*, or rain-cloud, merely means water collected in such drops in the atmosphere, as that, unless some strong counteracting circumstances prevent it, it must fall to the ground.

It does not follow that nimbus shall be, in all cases, or even in any particular case, preceded by the other formations; though such is the fact generally, when the weather changes from dry to wet. But nimbus is always known by the size of its drops, even though, from the position of the light upon it, it should have, at a distance, the appearance of cumulostratus; indeed, the clouds which cap the mountains, and indicate the first victory of the coming rain over the warmer and drier air on the surface, are not unfrequently nimbus; and those who have occasion to enter them soon find out that they ar so. They do not dew, or settle upon one in small drops,—as is the case with cumulostratus,—and so wet one to the skin without any of the ordinary appearances of falling rain; they pelt, and that heartily, even although the whole mass of cloud is too small, and apparently filmy, for very much obscuring the light of the sun. We remember once ascending Mam Suil, one of the highest mountains in Scotland, though one of easy ascent, and grassy on the top,—in all probability in consequence of the incessant rains upon it in summer. One may infer this from the fact, that the horse-shoe precipice on its north-eastern side is never without snow and *Loch-na-nuan*, the little lake which occupies the curve of the horse-shoe at the bottom, is never thawed. As we ascended the valley of the little rivulet which flows from this frozen lake, the heat of the day was intolerable, and the sky overhead was without a cloud; but when we came within sight of the summit and the precipice, they were blotched over with little white patches, something in the same way as Constable spatters his landscapes; and we heartily wish that we had had the resource of that most talented and much lamented artist Fuseli, when he went to view a chef-d'-œuvre of this delightful, though dripping artist. "Boy," said the veteran, "fetch me my great coat and umbrella, for now I am going to see Mr. Constable's picture;" and heartily do we wish that we had had our great coat and umbrella when we visited the treacherous nimbus of Mam Suil. The continuance might probably not exceed a minute; but, at the end of that minute, it would have puzzled a conjurer to find a dry thread upon either of us.

Nimbus is the only cloud in which a decided rainbow appears, although slight traces of prismatic colours may be seen in clouds of lighter texture; and, by skilful observation at early morn, one may have the most beautiful rainbows imaginable from the dew drops on the grass. This phenomenon of the rainbow we have no room to explain, on optical principles; but the explanation is easy, and may be seen in any of the common books on the delightful science of light. The colours of the bow are produced by the different refrangibility of the several rays of coloured light; and when a cloud, or a falling shower, (for when the drops are large enough to form a distinct bow, they, generally speaking, fall,) is in a favourable situation, there are two bows, one formed by single refraction, and the other by double. It would give us great pleasure to enter into a full explanation of this lovely phenomenon, but our limits will not permit.

In proportion to the height from which the imber, or fall of the nimbus, descends, the drops are usually large; but it not unfrequently happens, that in this case great part is evaporated before the mean level of the earth's surface is reached, in consequence of the dry and warm character of the lower air. This is especially the case in summer showers; and, in consequence of it, it very often happens that when the summit of a hill, only 500 or 600 feet in height, receives an inch or two of rain, the low ground, within a few hundred yards of its base, may not receive above a tenth of an inch.

SECTION VIII.

CONCLUSION.

We have endeavoured, in the previous sections, to cast a hasty glance at the leading causes and phenomena of the general actions of the atmospheric fluid; and it would now remain to examine the influences which it has on the phenomena of the living and growing world.

Of these, the most important, beyond all question, is, respiration in animals—a function without which life cannot exist, and the intensity and necessity of which are always in proportion to the energy of life and of living action. This holds true, whatever may be the habit or element of the animal; whether it dwells in and surrounded by the atmosphere, creeps on the earth, or burrows under it, or tenants any portion, salt or fresh, of those waters which cover so vast a proportion of the surface of our globe; and it should seem, that, however living creatures may differ from each other in their structure and economy, this operation of respiration is, both in its nature and its effects, one and the same.

The vertebrated animals—that is, the animals with a spine, or back-bone,—which forms, as it were, the foundation upon which all the members of the body are articulated, and by which they are all supported,—the animals of this description which inhabit the land, and also the warm-blooded animals which inhabit the waters, whatever may be their form, their size, the kind of their food, or the other parts of their economy, all breathe air by that kind of apparatus to which we give the name of "lungs," or, in the more vulgar, but probably the more expressive wording, "lights." These words, and all words which are descriptive of this part of the animal organization, allude to the office of the organ, rather than of its structure. They mean, that which extends to receive air, and contracts to expel it again.

These lungs consist of a vast number of little cells, or chambers, the minute ones of which open into little galleries, or pipes, in the body of the organ, and there again unite into one principal trunk, which is made up of a series of rings of gristly, or cartilaginous, substance, so that it can admit of being bent in all directions, without having its cavity very materially lessened. Besides being the common passage for air to and from the lungs, this pipe,—which is called the *trachea*, or wind-pipe,—is directly connected with the voice of animals. In the mammalia,—or animals which suckle their young, and which are, generally speaking, ground animals, though a few inhabit the waters, and a few others are capable of a fluttering sort of flight, not by wings, but by membrane, or leather-looking substance, extended by means of their feet,—the peculiar organs of voice are situated at the upper, or mouth end of the wind-pipe; and the sounds which they utter are variously modified by the tongue, the mouth, and the teeth. In birds, again, which have, in general, much more varied motion of the neck than the last mentioned animals, the peculiar organs of voice are placed at the under, or pulmonary, or lung end of the windpipe; and thus the whole length of that canal has some influence in modulating the sound; and the sound is generally hollow, in proportion as this canal is lengthened, or convoluted into folds. This, by the way, is the reason why all very long-necked birds have the voice dull and husky; and why those that utter sharp notes have the neck comparatively short. No animals, however, have voice but those that breathe air, by means of lungs, through a trachea, or windpipe, terminating in the mouth and nostrils; and any sounds which are uttered by animals which do not breathe in this manner, are produced by other parts of their bodies, generally by means of the external air, and not of that air which they breathe; although they all do breathe air, each in its peculiar manner.

The walls, or partitions of the cells of the lungs are ramified over with a network of very fine, and, in the healthy state, almost invisible, blood vessels. The arteries which send the blood to the lungs originate in the pulmonic *ventricle*, or cavity of the heart, which, as situated in the human subject, is the right one; and this blood is received into the ventricle from the right *auricle*, ear, or appendage of the heart. The veins which are united to those arteries at their capillary hair-like, very small, and, indeed, invisible extremities, carry the blood back again to the left auricle; from this it goes to the left, or systematic ventricle; and, by the collapsing of that ventricle, it is propelled into the systematic arteries, and, by their action, over the whole body of the animal. Thus, in man, and in all the warm-blooded animals which we are accustomed (though perhaps not very properly) to call the more perfect, there is a double pulsation of the heart,—one which sends the blood to the lungs, or aerating apparatus; and another which sends the blood which has been in the lungs, and has undergone the necessary action of the air there, all over the body of the animal, to stimulate and nourish the whole of its system.

The terminations of the arteries, and commencements of the veins in the lungs, are so exceedingly minute, that microscopic observation cannot perfectly trace them; and the globules of the blood, when they come to this most singular part of the animal system, are so small, that 8,000,000,000 of them would only make about one solid inch. This is an extremely fine division, but it is by no means an ultimate division, such as that which we speak of when we refer to the atom, or even to the first formation of a cloud in the atmosphere; for these globules of blood not only contain all the elementary principles necessary for repairing the animal structure, but, in addition to this, they contain that refuse of life, to clean the system of which is the purpose of breathing. It is right, however, that we should see how excessively delicate this operation is, and it is an operation without which no animal can live, no, not so much as a single moment; for unless the blood passes through this exquisite apparatus, it would be the tide of death instead of that of life. The blood which arrives through the *venæ cavæ*, or great returning veins of the system, has not only taken up the matter of every part which is no longer fit for the purpose of life—and which, if not so taken up, would instantly cause putridity in the system, as speedily fatal as the most deadly plague—but, a little before it reaches the heart, it receives into its mass the chyle or new matter which has been prepared by the various operations of digestion, for the nourishment of the animal. This blood is, therefore, in what we may consider a rude state; so much of it is, no doubt, healthy blood, but with this healthy blood there are mingled, first the refuse of life, which is no longer fit for its functions; and, secondly, the new supply derived from the food, which has not yet undergone preparation. These three come to the lungs in a dark tide, and it is not until the life-giving air has done its office upon them in this singular apparatus, that they put on that hue of lively red which blossoms on the cheek, and blooms on the lip, when the human body is in the freshness of vigour and the glow of health.

Here there is marvel, more than tongue can tell; and at every pulse of the heart, and every breath of the nostril, we, as it were, trench upon the borne of absolute nothingness. There is not a pore in those delicate vessels which would admit the millionth part of the thinnest hair. They themselves have their coats fine beyond all expression, so that, perhaps, ten thousand of them would not probably amount to nearly the thickness of the finest tissue paper, but they are as impervious, as free from any opening, as if they were gateless walls of brass. And in this marvellous structure is the life of man, and of every breathing creature, kept and maintained throughout every moment of its existence, and not only kept, but kept in such safety and such power as that it is capable of performing the most energetic operations; and, by means of this inexpressible fine tissue the horse and the hound course, the eagle drives through the sky, the lion and the tiger bound upon their prey, and man performs all those operations, and exercises that connection between the sensation of the body and the intellectual perception of the mind which makes him the lord of the creation. When we contemplate this portion of the animal system, and it is common to every animal, how can we—how dare we refrain from thinking of the Maker? Here, on the very verge of nothing, as it were, and delicate, and, as we may say, tender, beyond the very dreamings of our philosophy, life stands—secure, stands as secure as if it were encased in walls of adamant, and the all but infinitisemal globules which we have mentioned are here as safe, in the keeping of the Almighty, as are those voluminous masses which revolve in the sky, and constitute the glory and the wonder of material magnitude.

But, delicate, beyond all conception, as this structure is, the blood is unfit for the purposes of life unless every particle of it passes through this most extraordinary filter, —a filter so singular, that it is impossible for us to say whether the connection of artery and vein in the lungs be a continuation of the opening of the one little tube with that of the other, or whether there may not be some mysterious diaphragm, or partition, at the one side of which the blood is decomposed, so as to pass through in the state of gas, or gases, leaving its impurities behind, and being again reproduced as pure and wholesome blood at the other side of the partition. This we shall never be able to ascertain: for, though close observers have been enabled to watch the circulation passing from artery to vein, in some animals which have a sluggish circulation, such, for instance, as the common frog; yet the animals upon which those observations have been made are comparatively imperfect breathers, and their system can lie, and, generally speaking, does lie, quiescent for several months of the year, without pulse and without respiration. In animals of more energetic life, this apparatus is much too delicate for our being able to approach it with the eye of science when it is in the working state; and, after death has passed upon it, one of the acts of this death may, for aught we know, be the dissolution of this mysterious connection between artery and vein, upon which life so immediately depends.

Although, however, it is not given to us to look with mortal eyes upon the immediate action of this wonderful part of our frame, yet we can judge of the result; we can know in what state the atmospheric air is taken into the lungs, and in what state it is when it is returned from those organs. And there is a very simple experiment which may in so far convince any one of this. Every one knows the two operations of "blowing hot" and "blowing cold," by means of air from the mouth. Now, in blowing cold, the air has never entered the windpipe, and, if the blowing is continued, the supply is chiefly by the nostrils. In blowing hot, again, the air is from the lungs, and is of course the product given out after the lungs have performed their office upon it. Now, let any one take a candle, or taper, and blow cold upon it, but not with so much violence as to blow it out, and then let them blow hot with as nearly the same force and continuance, and let them mark the result. It will be found, that the cold blowing, though it agitates the flame, increases its size, and makes it brighter, but that the hot blowing diminishes the flame, and makes it more dingy in the colour. Thus it is evident that there is something in the cold blast which is favourable to the action of burning, and something in the warm blast which is unfavourable to the same; for, as we have supposed the operation to be of the same intensity and continuity in both cases, the different effects must be produced by a difference in the substance applied to the flame. We know, from many natural occurrences, as well as from direct experiment, that the air which is produced by burning, and which is known to be carbonic acid gas, or a mixture of oxygen with carbon or charcoal, is, of all applications, the most destructive or detrimental to the act of burning. This is so obviously the case, that if one were to continue burning paper in the ash pit for some time, it would extinguish the fire in the grate; and every one knows that the partial combustion occasioned by the direct beams of the sun, or even by a strong light of any kind, weakens or extinguishes the fire.

Thus we have a connection established between the process of burning and the process of breathing, and the general supporter, as well as the general product, of both is the same,—the supporter, oxygen—the product, carbonic acid. In what state the carbon is, which is thus shown to be the general waste of the living system,—that is, of the action of life itself,—when it arrives at the lungs of the animal, and is there subjected to the operation of the air, we have no means of ascertaining; though, as the supporter and the product are exactly the same in both cases, we have reason to believe that it is identical with common combustion, or burning, as we observe it in a fire. In the animal, however, it is a fire of atoms; for the small vessels, or tissues, in which it takes place, are, in all probability, impervious to the least aggregation of atoms that we can imagine. Still the oxygen of the atmosphere does continue to unite with just as much carbon as shall form a volume of carbonic acid equal to that of the oxygen; and in the healthy state of every animal, the power and size of the lungs are adapted to this with such perfect nicety, that, delicate as those organs are, and incessant as is their acting, they are never fatigued; and, though the really acting structure here is delicate down to the very verge of nothing, its power of endurance is greater than that of the feet of lions or the wings of eagles.

Animals of various classes have this apparatus different from each other, but in all classes its perfection is in proportion to the acting energy of the animal. If the animal lives on land, the air is taken into cells of some kind or other, and given out loaded with charcoal. If the animal lives in water,—that is, if it breathes under the surface,—it has apparatus of a different kind. These are called gills, and consist of fringe-like appendages, generally attached to little arches of bone at their one extremity, and free at their other. As may be seen in any common fish, the fibres of those gills are directed backward: and, in breathing, the fish receives a current of water by the mouth, and discharges it through the gill openings, so that the fibres of the gills are everywhere surrounded by this current. It is not the water, however, which sustains life in the fish, it is the air which the water contains; for a fish cannot live in water which has been entirely deprived of air, neither can it live in water which contains beyond a certain portion of carbonic acid gas; and one reason why the fishes are killed when submarine volcanoes discharge themselves into the waters of the ocean is, that they are poisoned by the carbonic acid thus given out, and not, as is generally supposed, destroyed either by the heat of the water or by sulphurous vapour: for the heat would give warning of its approach, and they could escape from it, and sulphurous vapours would ascend, because of their inferior specific gravity; but the carbonic acid is a "pestilence which walketh in darkness," and gives no sign of its coming. The subject is, however, interminable; and, we regret to say, our measure is full: but should the reader feel his attention drawn to any of the many subjects which we have been able only to name, he will find no difficulty in procuring the necessary information to put him on his way; and, if he can once get in full career, knowledge and pleasure will come to him, unbidden, upon all the winds of heaven.

SAVILL, PRINTER, (LATE HARJETTE AND SAVILL,)
CVII, ST. MARTIN'S LANE.