CONSTITUENT MATERIALS OF THE EARTH

AND OF THE OTHER BODIES OF SPACE.

The nebular hypothesis almost necessarily supposes matter to have originally formed one mass. We have seen that the same physical laws preside over the whole. Are we also to presume that the constitution of the whole was uniform?—that is to say, that the whole consisted of similar elements. It seems difficult to avoid coming to this conclusion, at least under the qualification that, possibly, various bodies, under peculiar circumstances attending their formation, may contain elements which are wanting, and lack some which are present in others, or that some may entirely consist of elements in which others are entirely deficient.

What are elements? This is a term applied by the chemist to a certain limited number of substances, (fifty-four or fifty-five are ascertained,) which, in their combinations, form all the matters of every kind present in and about our globe. They are called elements, or simple substances, because it has hitherto been found impossible to reduce them into others, wherefore they are presumed to be the primary bases of all matters. It has, indeed, been surmised that these so-called elements are only modifications of a primordial form of matter, brought about under certain conditions; but if this should prove to be the case, it would little affect the view which we are taking of cosmical arrangements. Analogy would lead us to conclude that the combinations of the primordial matter, forming our so-called elements, are as universal or as liable to take place everywhere as are the laws of gravitation and centrifugal force. We must therefore presume that the gases, the metals, the earths, and other simple substances, (besides whatever more of which we have no acquaintance,) exist or are liable to come into existence under proper conditions, as well in the astral system, which is thirty-five thousand times more distant than Sirius, as within the bounds of our own solar system or our own globe.

Matter, whether it consist of about fifty-five ingredients, or only one, is liable to infinite varieties of condition under different circumstances, or, to speak more philosophically, under different laws. As a familiar illustration, water, when subjected to a temperature under 32° Fahrenheit, becomes ice; raise the temperature to 212°, and it becomes steam, occupying a vast deal more space than it formerly did. The gases, when subjected to pressure, become liquids; for example, carbonic acid gas, when subjected to a weight equal to a column of water 1230 feet high, at a temperature of 32°, takes this form: the other gases require various amounts of pressure for this transformation, but all appear to be liable to it when the pressure proper in each case is administered. Heat is a power greatly concerned in regulating the volume and other conditions of matter. A chemist can reckon with considerable precision what additional amount of heat would be required to vaporise all the water of our globe; how much more to disengage the oxygen which is diffused in nearly a proportion of one-half throughout its solids; and, finally, how much more would be required to cause the whole to become vaporiform, which we may consider as equivalent to its being restored to its original nebulous state. He can calculate with equal certainty what would be the effect of a considerable diminution of the earth's temperature — what changes would take place in each of its component substances, and how much the whole would shrink in bulk.

The earth and all its various substances have at present a certain volume in consequence of the temperature which actually exists. When, then, we find that its matter and that of the associate planets was at one time diffused throughout the whole space, now circumscribed by the orbit of Uranus, we cannot doubt, after what we know of the power of heat, that the nebulous form of matter was attended by the condition of a very high temperature. The nebulous matter of space, previously to the formation of stellar and planetary bodies, must have been a universal Fire Mist, an idea which we can scarcely comprehend, though the reasons for arriving at it seem irresistible. The formation of systems out of this matter implies a change of some kind with regard to the condition of the heat. Had this power continued to act with its full original repulsive energy, the process of agglomeration by attraction could not have gone on. We do not know enough of the laws of heat to enable us to surmise how the necessary change in this respect was brought about, but we can trace some of the steps and consequences of the process. Uranus would be formed at the time when the heat of our system's matter was at the greatest, Saturn at the next, and so on. Now this tallies perfectly with the exceeding diffuseness of the matter of those elder planets, Saturn being not more dense or heavy than the substance cork. It may be that a sufficiency of heat still remains in those planets to make up for their distance from the sun, and the consequent smallness of the heat which they derive from his rays. And it may equally be, since Mercury is twice the density of the earth, that its matter exists under a degree of cold for which that planet's large enjoyment of the sun's rays is no more than a compensation. Thus there may be upon the whole a nearly equal experience of heat amongst all these children of the sun. Where, meanwhile, is the heat once diffused through the system over and above what remains in the planets? May we not rationally presume it to have gone to constitute that luminous envelope of the sun, in which his warmth-giving power is now held to reside? It could not be destroyed—it cannot be supposed to have gone off into space—

it must have simply been reserved to constitute, at the last, a means of sustaining the many operations of which the planets were destined to be the theatre.

The tendency of the whole of the preceding considerations is to bring the conviction that our globe is a specimen of all the similarly-placed bodies of space, as respects its constituent matter and the physical and chemical laws governing it, with only this qualification, that there are *possibly* shades of variation with respect to the component materials, and *undoubtedly* with respect to the conditions under which the laws operate, and consequently the effects which they produce. Thus, there may be substances here which are not in some other bodies, and substances here solid may be elsewhere liquid or vaporiform. We are the more entitled to draw such conclusions, seeing that there is nothing at all singular or special in the astronomical situation of the earth. It takes its place third in a series of planets, which series is only one of numberless other systems forming one group. It is strikingly—if I may use such an expression—a member of a democracy. Hence, we cannot suppose that there is any peculiarity about it which does not probably attach to multitudes of other bodies — in fact, to all that are analogous to it in respect of cosmical arrangements.

It therefore becomes a point of great interest— *what are the materials of this specimen? What is* the constitutional character of this object, which may be said to be a sample, presented to our immediate observation, of those crowds of worlds which seem to us as the particles of the desert sand-cloud in number, and to whose profusion there are no conceivable local limits?

The solids, liquids, and aeriform fluids of our globe are all, as has been stated, reducible into fifty-five substances hitherto called elementary. Six are gases; oxygen, hydrogen, and nitrogen being the chief. Forty-two are metals, of which eleven are remarkable as composing, in combination with oxygen, certain earths, as magnesia, lime, alumin. The remaining six, including carbon, silicon, sulphur, have not any general appellation.

The gas oxygen is considered as by far the most abundant substance in our globe. It constitutes a fifth part of our atmosphere, a third part of water, and a large proportion of every kind of rock in the crust of the earth. Hydrogen, which forms two-thirds of water, and enters into some mineral substances, is perhaps next. Nitrogen, of which the atmosphere is four-fifths composed, must be considered as an abundant substance. The metal silicium, which unites with oxygen in nearly equal parts to form silica, the basis of nearly a half of the rocks in the earth's crust, is, of course, an important ingredient. Aluminium, the metallic basis of alumin, a large material in many rocks, is another abundant elementary substance. So, also, is carbon a small ingredient in the atmosphere, but the chief constituent of animal and vegetable substances, and of all fossils which ever were in the latter condition, amongst which coal takes a conspicuous place. The familiarly-known metals, as iron, tin, lead, silver, gold, are elements of comparatively small magnitude in that exterior part of the earth's body which we are able to investigate.

It is remarkable of the simple substances that they are generally in some compound form. Thus, oxygen and nitrogen, though in union they form the aerial envelope of the globe, are never found separate in nature. Carbon is pure only in the diamond. And the metallic bases of the earths, though the chemist can disengage them, may well be supposed unlikely to remain long uncombined, seeing that contact with moisture makes them burn. Combination and re-combination are principles largely pervading nature. There are few rocks, for example, that are not composed of at least two varieties of matter, each of which is again a compound of elementary substances. What is still more wonderful with respect to this principle of combination, all the elementary substances observe certain mathematical proportions in their unions. One volume of them unites with one, two, three, or more volumes of another, any extra quantity being sure to be left over, if such there should be. It is hence supposed that matter is composed of infinitely minute particles or atoms, each of which belonging to any one substance, can only (through the operation of some as yet hidden law) associate with a certain number of the atoms of any other. There are also strange predilections amongst substances for each other's company. One will remain combined in solution with another, till a third is added, when it will abandon the former and attach itself to the latter. A fourth being added, the third will perhaps leave the first, and join the new comer.

Such is an outline of the information which chemistry gives us regarding the constituent materials of our globe. How infinitely is the knowledge increased in interest, when we consider the probability of such being the materials of the whole of the bodies of space, and the laws under which these everywhere combine, subject only to local and accidental variations!

In considering the cosmogenic arrangements of our globe, our attention is called in a special degree to the moon.

In the nebular hypothesis, satellites are considered as masses thrown off from their primaries, exactly as the primaries had previously been from the sun. The orbit of any satellite is also to be regarded as marking the bounds of the mass of the primary at the time when that satellite was thrown off; its speed likewise denotes the rapidity of the rotatory motion of the primary at that particular juncture. For example, the outermost of the four satellites of Jupiter revolves round his body at the distance of 1,180,582 miles, shewing that the planet was once 3,675,501 miles in circumference, instead of being, as now, only 89,170 miles in diameter. This large mass took rather more than sixteen days six hours and a half (the present revolutionary period of the outermost satellite) to rotate on its axis. The innermost satellite must have been formed when the planet was reduced to a circumference of 309,075 miles, and rotated in about forty-two hours and a half.

From similar inferences, we find that the mass of the earth, at a certain point of time after it was thrown off from the sun, was no less than 482,000 miles in diameter, being sixty times what it has since shrunk to. At that time, the mass must have taken rather more than twenty-nine and a half days to rotate, (being the revolutionary period of the moon,) instead of as now, rather less than twenty-four hours.

The time intervening between the formation of the moon and the earth's diminution to its present size, was probably one of those vast sums in which astronomy deals so largely, but which the mind altogether fails to grasp.

The observations made upon the surface of the moon by telescopes, tend strongly to support the hypothesis as to all the bodies of space being composed of similar matters, subject to certain variations. It does not appear that our satellite is provided with that gaseous envelope which, on earth, performs so many important functions. Neither is there any appearance of water upon the surface; yet that surface is, like that of our globe, marked by inequalities and the appearance of volcanic operations. These inequalities and volcanic operations are upon a scale far greater than any which now exist upon the earth's surface. Although, from the greater force of gravitation upon its exterior, the mountains, other circumstances being equal, might have been expected to be much smaller than ours, they are, in many instances, equal in height to nearly the highest of our Andes. They are generally of extreme steepness, and sharp of outline, a peculiarity which might be looked for in a planet deficient in water and atmosphere, seeing that these are the agents which wear down ruggedness on the surface of our earth. The volcanic operations are on a stupendous scale. They are the cause of the bright spots of the moon, while the want of them is what distinguishes the duller portions, usually but erroneously called *seas*. In some parts, bright volcanic matter, besides covering one large patch, radiates out in long streams, which appear studded with subordinate *foci* of the same kind of energy. Other objects of a most remarkable character are ring mountains, mounts like those of the craters of earthly volcanoes, surrounded immediately by vast and profound circular pits, hollowed under the general surface, these again being surrounded by a circular wall of mountain, rising far above the central one, and in the inside of which are terraces about the same height as the inner eminence. The well-known bright spot in the south-east quarter, called by astronomers *Tycho,* and which can be readily distinguished by the naked eye, is one of these ring-mountains. There is one of 200 miles in diameter, with a pit 22,000 feet deep; that is, twice the height of Ætna. It is remarkable, that the maps given by Humboldt of a volcanic district in South America, and one illustrative of the formerly volcanic district of Auvergne, in France, present features strikingly like many parts of the moon's surface, as seen through a good glass.

These characteristics of the moon forbid the idea that it can be at present a theatre of life like the earth, and almost seem to declare that it never can become so. But we must not rashly draw any such conclusions. The moon may be only in an earlier stage of the progress through which the earth has already gone. The elements which seem wanting may be only in combinations different in those which exist here, and may yet be developed as we here find them. Seas may yet fill the profound hollows of the surface; an atmosphere may spread over the whole. Should these events take place, meteorological phenomena, and all the phenomena of organic life, will commence, and the moon, like the earth, will become a green and inhabited world.

It is unavoidably held as a strong proof in favour of any hypothesis, when all the relative phenomena are in harmony with it. This is eminently the case with the nebulous hypothesis, for here the associated facts cannot be explained on any other supposition. We have seen reason to *conclude that the primary condition of matter was* that of a diffused mass, in which the component molecules were probably kept apart through the efficacy of heat; that portions of this agglomerated into suns, which threw off planets; that these planets were at first very much diffused, but *gradually contracted by cooling to their present* dimensions. Now, as to our own globe, there is a remarkable proof of its having been in a fluid state at the time when it was finally solidifying, in the fact of its being bulged at the equator, the very form which a soft revolving body takes, and must *inevitably take, under the influence of centrifugal* force. This bulging makes the equatorial exceed the polar diameter as 230 to 229, which has been demonstrated to be precisely the departure from a correct sphere which might be predicated from a knowledge of the amount of the mass and the rate of rotation. There is an almost equally distinct memorial of the original high temperature of the materials, in the store of heat which still exists in the interior. The immediate surface of the earth, be it observed, exhibits only the temperature which might be expected to be imparted to such materials, by the heat of the sun. There is a point, very short way down, but varying in different climes, where all effect from the sun's rays ceases. Then, however, commences a temperature from an entirely different cause, one which evidently has its source in the interior of the earth, and which regularly increases as we descend to greater and greater depths, the rate of increment being about one degree Fahrenheit for every sixty feet; and of this high temperature there are other evidences, in the phenomena of volcanoes and thermal springs, as well as in what is ascertained with regard to the density of the entire mass of the earth. This, it will be remembered, is four and a half times the weight of water; but the actual weight of the principal solid substances composing the outer crust is as two and a half times the weight of water; and this, we know, if the globe were solid and cold, should increase vastly towards the centre, water acquiring the density of quicksilver at 362 miles below the surface, and other things in proportion, and these densities becoming much greater at greater depths; so that the entire mass of a cool globe should be of a gravity infinitely exceeding four and a half times the weight of water. The only alternative supposition is, that the central materials are greatly expanded or diffused by some means; and by what means could they be so expanded but by heat? Indeed, the existence of this central heat, a residuum of that which kept all matter in a vaporiform chaos at first, is amongst the most solid discoveries of modern science,* and the support which it gives to Herschel's explanation of the formation of worlds is most important. We shall hereafter see what appear to be traces of an operation of this heat upon the surface of the earth in very remote times; an effect, however, which has long passed entirely

* The researches on this subject were conducted chiefly by the late Baron Fourier, perpetual secretary to the Academy of Sciences of Paris. See his *Théorie Analytique de la Chaleur.* 1822.

away. The central heat has, for ages, reached a fixed point, at which it will probably remain for ever, as the non-conducting quality of the cool crust absolutely prevents it from suffering any diminution.