of a repulsive force in common matter has a great advantage in point of simplicity, and may perhaps hereafter be capable of proof, though at present it can only be regarded, and was at first only offered, as an hypothesis.

M. la Place, equally dissatisfied as Sir Isaac Newton with the idea of gravitation being an essential property of matter, passes away from the inquiry with suitable modesty, to practical subjects of far higher importance, and which equally grow out of it, in whatever light it is contemplated. "Is this principle," says he, "a primordial law of nature? or is it a general effect of an unknown cause? Here we are arrested by our ignorance of the nature of the essential properties of matter, and deprived of all hope of answering the question in a satisfactory manner. Instead, then, of forming hypotheses on the subject, let us content ourselves with examining more particularly the manner in which philosophers have made use of this most extraordinary power."*

There is, indeed, one very striking objection to Sir Isaac Newton's suggestion, and which it seems very difficult to repel. It is, that though it may account for the attraction of gravitation, as a phenomenon common to matter in general, it by no means accounts for a variety of particular attractions which are found to take place between particular bodies, or bodies particularly circumstanced; and which, excepting in one or two instances, ought, perhaps, to be contemplated as modifications of gravitation.

Upon these particular attractions, or modes of attraction, including homogeneous attraction, or the attraction of aggregation, heterogeneous attraction, or the attraction of capillary bodies, elective attraction, and those of magnetism and electricity, each of which is replete with phenomena of a most interesting and curious nature, I intended to have touched in the present lecture, but our limited hour is so nearly expired, that we must postpone the consideration of them as a study for our next meeting. Yet it is not possible to close the observations which have now been submitted, without testifying our gratitude to the memory of that transcendent genius whom the providence of the adorable Architect of the universe at length gave to mankind six thousand years after its creation, to unravel its regular confusion, and reduce the apparent intricacy of its laws to that sublime and comprehensive simplicity which is the peerless proof of its divine original.

It has been said, that the discovery of the universal law which binds the pebble to the earth, and the planets to the sun, which connects stars with stars, and operates through infinity, was the result of accident. Nothing can be more untrue, or derogatory to the great discoverer himself. The earliest studies of Newton were the harbinger of his future fame: his mighty mind, that comprehended every thing, was alive to every thing; the little and the great were equally the subjects of his restless researches: and his attention to the fall of the apple was a mere link in the boundless chain of thought, with which he had already been long labouring to measure the phenomena of the universe.

Grounded, beyond all his contemporaries, in the sure principles of mathematics, it was at the age of twenty-two that he first applied the sterling treasure he had collected to a solution of the system of the world. The descent of heavy bodies, which he perceived nearly the same on the summit of the loftiest mountains and on the loweſt surface of the earth, suggested to him the idea that gravity might possibly extend to the moon; and that, combined with some projectile motion, it might be the cause of the moon's elliptic orbit round the earth: a suggestion in which he was instantly confirmed by observing that all bodies in their fall describe curves of some modification or other. And he further conceived, that if the moon were retained in her orbit by her gravity towards the earth, the planets must also in all probability be retained in their several orbits by their gravity towards the sun.

To verify this sublime conjecture, it was necessary to ascertain two new and elaborate positions: to determine the law of the progressive diminution

* Exposition du Système du Monde, liv. iv. ch. xv.

of gravity, and to develope the cause of the curves or ellipses of falling bodies. Both these desiderata he accomplished by a series of reasonings and calculations equally ingenious in their origin and demonstrative in their result; and ascertained the truth of his principles by applying them, practically and alternately, to the phenomena of the heavens, and to a variety of terrestrial bodies.

The bold and beautiful theorem being at length arrived at, and unequivocally established—a theorem equally applicable to the minutest corpuscles, and the hugest aggregations of matter—that all the particles of matter attract each other directly as their mass, and inversely as the square of their distance, he at once beheld the cause of those perturbations of motion to which the heavenly bodies are necessarily and so perpetually subject: it became manifest, that the planets and comets, reciprocally acting and acted upon, must deviate a little from the laws of that perfect ellipse which they would precisely follow if they had only to obey the action of the sun: it was manifest, that the satellites of the different planets, exposed to the complicated action of the sun, and of each other, must evince a similar disturbance: that the corpuscles which composed the different heavenly bodies in their formation, perpetually pressing towards one common centre, must necessarily have produced, in every instance, a spherical mass: that their rotatory motion must at the same time have rendered this spherical figure in some degree imperfect, and have flattened these masses at their poles; and, finally, that the particles of immense beds of water, as the ocean, easily separable as they are from each other, and unequally operated upon by the sun and the moon, must evince such oscillations as the ebbing and flowing of the tides. The origin, progress, and perfection of these splendid conjectures, verifications, and established principles, were communicated in two distinct books, known to every one under the titles of his "Principia" and his "Optics;"—books which, though not actually inspired, fall but little short of inspiration, and have more contributed to exalt the intellect of man, and to display the perfections of the Diety, than any thing upon which inspiration has not placed its direct and awful stamp.

LECTURE V.

ON THE PROPERTIES OF MATTER, ESSENTIAL AND PECULIAR.

(The subject continued.)

We closed our last lecture with remarks on the universal operation of the common principle of gravity over matter in all its visible forms, from the minutest shapes developed by the microscope, to the mightiest suns and constellations in the heavens. But we observed, also, that, independently of this universal and essential power of attraction, matter possesses a variety of peculiar attractions dependent upon circumstances of limited influence, and which consequently render such attractions themselves of local extent.

These I will now proceed to notice to you in the following order:—1st, The attraction of *homogeneous* bodies towards each other, which is denominated, in chemical technology, the attraction of aggregation: 2dly, The attraction of *heterogeneous* bodies towards each other, under particular circumstances, which in its more obvious cases is denominated capillary attraction: 3dly, The attraction of bodies exhibiting a peculiar degree of affinity to each other, and which is denominated electrive attraction: 4thly, The attraction of the electric fluid; and, 5thly, That of the magnetic.

I. The law of physics, which has rendered every material substance capable of attracting and being attracted by every other material substance, seems at the same time to have produced this power in a much stronger degree between SUBSTANCES OF LIKE NATURES. Thus, drops of water placed upon a plate of dry glass have a tendency to unite, not only when they touch, but when in a state of vicinity to each other; and globules of quicksilver still more so: and it is this kind of attraction which is called the attraction of aggregation. And in both these cases the attraction in question evinces a considerable superiority of force to the general attraction of gravitation; since the particles of the drops or globules ascend from the surface of the glass, except those that form their narrow base, and are drawn towards their proper centres, instead of being drawn towards the centre of the earth.

If, however, the convex shape of the drop of water be destroyed by pressing it over the glass into a thin extended film, the general attraction of gravitation, acting with increased effect upon an increased space, will overpower the individual attraction of aggregation, and the particles of water will be restrained from attempting a spherical figure as before. In the quicksilver, nevertheless, the attraction of aggregation being much stronger than in the water, it will still continue to prevail; and it is only by a very minute and elaborate division of the particles of this material that we can give to the attraction of gravitation a predominancy.

The same result occurs in the homogeneous particles of oil. And hence, if we divide its particles by shaking a certain portion of it in water, we find, upon giving the mixture rest, that the water will first sink to the bottom, or, which is the same thing, the particles of the oil will rise to the surface; and then that these particles, as soon as they have reached the range of each other's attraction, will unite into one common body.

Now, in all these cases it is obvious that the particles of matter thus obeying the law of homogeneous attraction assume or attempt to assume a spherical figure; and we not unfrequently perceive a similar attempt, even where the breadth of the surface, and the consequent potency of the attraction of gravitation, would hardly induce us to expect that there could be the least effort towards it: as, for example, in a glass brim-full, or somewhat more than brim-full of wine, or any other liquid.

We behold the same figure in the drops of rain as they descend from the clouds; a figure which, in fact, is the sole cause of the vaulted form of the rainbow, as I may possibly take leave to explain more particularly on some future occasion. We behold it in reality throughout all nature, in every substance whose particles are capable of uniting and separating with ease; and, consequently, of readily obeying the laws of cohesibility and divisibility, as those of liquids; and we should see it equally in solids, but that the particles of these last are incapable of doing readily either the one or the other.

What, then, is the general cause that produces so general an effect? Clearly this: a cause to which I have already in some degree adverted, in speaking of the general attraction of gravitation: that, there being an equal tendency in every particle of homogeneous bodies to press together, they must press equally towards one common centre, and strive to be as little remote from that centre as possible. Such a strife, however, must necessarily produce a globular or spherical form; for it is in such a form only that the extreme particles, or those constituting its surface, and which are prevented from a closer approach by those that lie within, are equally near and equally remote in every direction.

Hence, then, the cause of the globular figure of drops of quicksilver, drops of water, drops of rain, and drops of dew, collected and suspended from the fresh leaves of plants in the balmy air of the morning: and hence one reason, though there is also another that concurs with it, and which I shall explain presently, for the convex shape assumed by a wine-glass of liquid of any kind, on its surface, when brim-full, or somewhat more.

The same reasoning may be applied to account for the spherical figure of the heavenly bodies; each of which, though probably composed of many different or heterogenous substances in itself, may be fairly contemplated as a homogeneous mass when compared with those by which it is surrounded: and hence, too, we see the necessity for their having at first existed, from some cause or other, in a fluid state; since, otherwise, the different corpuscles which enter into their make could not have assumed that symmetrical arrangement which alone gives sphericity to the total bulk.

We have equal proofs of the same peculiar attraction existing between

solid bodies, though the proofs are not so common; since, as I have just observed, the particles of solid bodies have less power of movement, and, consequently, of adaptation to each other, than those of liquids. Thus, two plates of lead, whose opposite surfaces correspond so exactly that every particle of each surface shall have a bearing upon the particle opposed to it, when once united by pressure, assisted by a little friction, cohere so powerfully as to require a very considerable force to separate them. And it may be shown, either by measuring this force, or by suspending the lead in the vacuum of an air-pump, that the pressure of the atmosphere is not materially concerned in producing this effect. A cohesion of this kind is sometimes of practical utility in the arts; little ornaments of laminated silver remaining attached to iron or steel, with which they have been made to connect themselves by the powerful pressure of a blow, so as to form one mass with it. And it is now a well-known fact, and of a most curious nature, that one of the causes by which eight-day clocks go at times irregularly, and monthly clocks, whose weights are much larger and heavier, often amounting to not less than thirty pounds, stop suddenly, proceeds from the attraction which takes place between their leaden weights and the leaden ball of the pendulum, when the weights have descended just so low as to be on a level, and, consequently, very nearly in a state of contact, with the pendulum-ball. And hence the reason why both these kinds of clocks, if the pendulum have not actually stopped, seem gradually, a few days afterward, to recover their former accuracy; the attraction diminishing as the distance once more increases.* In like manner, Studor remarks that beams of steel become sometimes erroneous by acquiring magnetic polarity.†

It is by the same means that the greater number of rocks seem to be produced that enter into the substance of the earth's solid crust. The lowermost of these, as I shall have occasion to observe in an ensuing lecture, are united by an intimate crystallization, which is the most perfect form of aggregate or homogeneous attraction that can exist between solid bodies, and which must have commenced while such bodies were in a fluid state. Some of the upper kinds or families are united by a particular cement, which is nothing more than a substance possessing a peculiar attraction, or, if I may be allowed the expression, physical partiality to the rudimental corpuscles of which the rock consists; and others by nothing more than the law of aggregation or homogeneous attraction in its simplest state; whence earths unite to earths in consequence of mutual approximation, assisted by their own or a superincumbent pressure, in the same manner as I have just stated that plates of lead or other metals unite to metals.

II. But there are substances that are UNLIKE IN THEIR NATURE, as solids and fluids, for instance, that under particular circumstances are often found to exhibit a mutual attraction; whence this mode of union is called HETEROGENEOUS ATTRACTION, and from its occurring most palpably between liquids and solid substances possessing small capillary or hair-tubes, CAPILLARY ATTRACTION.

The cause of this attraction is obvious; and it is still more clearly a mere modification of the general attraction of gravitation, than the preceding power of homogeneous attraction. It is the common attractive property of material substance for material substance; the liquid, or that whose particles are easily separable, pressing toward the solid, whose parts are by any action of their own altogether inseparable. Hence the reason why water or any other liquid hangs about the sides of a wine-glass: hence, partly, the reason why a wine-glass, when somewhat more than brim-full of a liquid, does not overflow; the co-operative reason being, as I have already stated, the homogeneous attraction of the corpuscles of the fluid for each other, which prevents them from separating readily: and hence also the reason why a liquid contained in a narrow-necked and inverted phial does not obey the common attraction of gravitation, and fall to the earth, although the stopper be removed to allow it, till we

* Reid, in Nicholson's Journal, vol. xxxiii. p. 92.

† Gilb. xiii. 124. Young's Nat. Phil. ii. 150.

aid the power of gravitation, or rather loosen the power of the peculiar attraction, by shaking the phial.

In this last case it is manifest that the heterogeneous attraction, or that between the two different substances, is stronger than the common force of gravity. In minute capillary tubes or pores this is still more obvious. Such are the pores of a piece of sponge, when pressed or softened, so as to become more pliable to the action of water or of any other liquid within its reach. For, in this case, the water being minutely divided by the pores of the sponge into very small portions, and still surrounded by the pores in every direction after such division, has its common force of gravitation and its peculiar force of homogeneous attraction equally overpowered; and ascends from the surface of the earth, instead of descending to it, or uniting into a spherical form; and the same kind of pores, and, consequently, the same kind of power, being continued to the utmost height of the sponge, it will rise to the full extent of its column. The tubes of various imperfect crystals, as those of sugar, for example, are still smaller; and hence the lateral attraction must be still stronger; and any liquid within its reach will rise both higher and more freely, till the sugar at length becomes dissolved, and, consequently, its pores are totally destroyed. The cause of capillary attraction is therefore obvious: and the reasoning and phenomena now submitted may be applied to an explanation of every other species of the same kind that may occur to us.

III. The third particular attraction I have noticed, is that of PECULIAR BODIES FOR PECULIAR BODIES, and which has hence been denominated ELECTIVE OR CHEMICAL ATTRACTION; as the tendencies they have to each other have been denominated AFFINITIES. Thus lime has a strong affinity for carbonic acid, and greedily attracts it from the atmosphere, which hence becomes purified by being deprived of it. But the same substance has a still stronger affinity for sulphuric acid, and hence parts with its carbonic acid, which flies off in the form of gas, in order to unite with the sulphuric whenever it has a possibility of doing so. It is highly probable that this kind of attraction is also nothing more than a peculiar modification of that of gravitation, more select in its range, but more active in its power. To trace out the various substances that are possessed of this peculiar property, and to measure the degrees of their affinities, is one of the chief branches of chemistry, but of too voluminous a nature to touch farther upon at present.

IV. V. The two remaining kinds of attraction to which I have adverted, those of ELECTRICITY and of MAGNETISM, are still more select, and perhaps still more powerful than even the preceding: but the phenomena to which they give rise cannot, I think, be attributed to any modification of a gravitating ethereal medium. We call the medium in both these cases a fluid, but we know little or nothing of the laws by which they are regulated; whether they be different substances, or, according to M. Ampere, the same substance under different modifications, or whether, in reality, they be material substances at all. They are certainly deficient in the most obvious properties of common matter, and may be another substrate of being united to it.

There are also two other substances, or which are generally conceived to be substances, in nature, of a very attenuate texture, which largely contribute to the changes of material bodies. I mean LIGHT and HEAT, of the general nature of which we are still also in a considerable degree of ignorance. Like the powers of magnetism and electricity, we only know them, and can only reason concerning them, by their effects. These effects, indeed, are of a most curious and interesting character, but spread too widely to be followed up in the course of the present lecture, though we may endeavour to pursue them, and, as far as we are able, to develope them, hereafter.

All these four powers or essences, for we know not which to call them, concur in exhibiting none of the common properties of matter; their respective particles repel each other at least as powerfully as they attract, and in the cases of light and heat repel alone, and without attracting. They may, possibly, be ponderable; but if so, we have no instruments fine enough to detect their

relative weights; and we are hence incapable of determining, as I took leave to observe on a former occasion, whether they be matter at all, whether mere properties of matter, or whether modifications of some etherealised and incorporeal substrate, combining itself with the material mass, and exciting many of its most extraordinary phenomena. It is at present, however, very much the habit to generalise them into one common origin; and to conceive the whole as modified results of matter, or of the gravitating property of matter. Thus, the attractive powers of chemical affinity and of electricity are identified in the following passage of Sir Humphry Davy's valuable "Elements of Chemical Philosophy:"—"Electrical effects are exhibited by the same bodies when acting *as masses*, which produce chemical phenomena when acting by their *particles*; it is not improbable, therefore, that the primary cause of both may be the same."* And in like manner, in an adjoining passage, he suggests that all the various properties or essences that have thus far passed in survey before us, may be nothing more than the general attractive power of matter, though he admits that at present we are incompetent to determine upon the subject. "With regard to the great speculative questions, whether the electrical phenomena depend upon one fluid *in excess* in the bodies positively electrified, and *in deficiency* in the bodies negatively electrified, or upon two different fluids capable by their combination of producing heat and light, or whether they may be *particular exertions of the general attractive power of matter*, it is, perhaps, impossible to decide, in the present imperfect state of our knowledge."†

And hence, heat, in the view of Sir Humphry Davy, Count Rumford, and various other justly celebrated chemists and philosophers of the present day, coincidently with the doctrine of the Peripatetic school, is a mere property of matter, and not a substance sui generis, as was contended for by the Epicureans, in opposition to the disciples of Aristotle, and is contended for by the disciples of Boerhaave, Black, Crawford, and most of the chemists of our own times. The cause of heat, among those who deny it a substantive existence, consists in a vibrating motion of the constituent particles of the heated body, too rapid to be traced by the eye. And as it is known to every one that bodies in general, as they become heated, occupy a larger space, and have their particles more widely repelled and separated from each other than in a colder temperature, it has of late become a favourite doctrine that the repulsive power, which in our last lecture we noticed to exist throughout matter, depends altogether upon the property of heat; in consequence of which Sir Humphry Davy uses heat and calorific repulsion as synonymous terms, and hence regards heat and gravitation, or general attraction, as antagonist powers.

There is much plausible reasoning to be urged in favour of this hypothesis. It will as readily account for many, perhaps most, of the phenomena which accompany bodies in their change from one temperature to another, as the position of the substantive form of heat, and has some advantage in point of simplicity; but it is opposed by a variety of facts of so stubborn and intractable a nature, that no efforts of ingenuity have hitherto been capable of bending them into the service of the new doctrine. I observed, for instance, in our last lecture, that when two plates of glass are within a ten thousandth part of an inch of each other, they cannot be made to approach nearer without a strong additional pressure. I observed, farther, that Professor Robison has calculated the extent of this pressure from actual experiment, and finds it amount to not less than a thousand pounds weight for every square inch of the glass. Now this resistance or repulsive power between the two plates of glass takes place equally under an air-pump and in the fullest exposure to the air of the atmosphere, but it appears to cease under water. By what cause the repulsion is excited in the two former instances, or disappears in the latter, we know not; but it does not seem possible for any ingenuity of argument to connect this repulsive power with heat, whether regarded as a substance or a mere property.

* Elm. p. 164, 165

† Id. p. 176.

Heat, again, which undoubtedly makes the particles of iron repel each other, so that given weights of them occupy a larger space—makes the particles of a ball of clay, on the contrary, attract each other into a closer approximation, so as very considerably to lessen its dimensions; and it was on account of this peculiar property that Mr. Wedgewood selected this last material for the purpose of forming his celebrated pyrometer, or instrument for measuring intense heats, the increase of the heat being indicated by the decrease of the mass of clay.

So water at about 42° of Fahrenheit, which forms its medium of density, begins to expand upon exposure to heat, and continues to expand in proportion as additional heat is applied; but below 42° it begins to expand also upon exposure to cold, and continues to expand in the very same ratio upon the application of additional cold, till at 32° it freezes and becomes fixed. This curious phenomenon has never been accounted for. If calorific repulsion produce the expansion above 42°, what is it that produces the same effect below? We can, perhaps, explain the cause of the expansion during the act of freezing, from the peculiar shape of the crystals which the water assumes in the act of consolidating; but this explanation will in no respect apply to the expansion of the water when it reaches the freezing point. In this curious and unillustrated fact cold appears to be as much entitled to the character of a repulsive power as heat.

For these and numerous other reasons, therefore, heat is even at the present moment usually regarded, not as a mere quality of body produced by internal vibration, and forming an antagonist power to the attraction of cohesion, but as a distinct and independent substance. The sources of heat are various, though by far the principal reservoir throughout the whole solar system is the sun himself, which Dr. Herschel believes to be perpetually secreting the matter of heat from those dark and discoloured parts on its surface which we call spots, by many astronomers regarded as volcanoes, and many of which are larger than, and some of them five or six times as large as the diameter of the earth! This material Dr. Herschel supposes to be first thrown off in the form of an atmosphere, and afterward this atmosphere to be diffused in every direction through the whole range of the solar empire; and, in the Philosophical Transactions for 1801, he has endeavoured to show that the variation in the heat of different years is owing to the more or less copious supply of fuel which such spots communicate.

This opinion I at present merely glance at; as it is my intention on a future occasion to examine its validity, as well as to trace out the other sources from which heat is derived, and to take a survey of the laws by which it is regulated. It will form a progressive part of that investigation to follow up the general nature of light; to try the question whether it be a substance or a property; and if a substance, whether distinct from or a mere modification of heat. I shall at present only observe, that, in one of the latest opinions of the philosopher to whom I have just adverted, it is not only a substance, but the source of all visible substances, and the basis of all worlds.

Dr. Herschel has recently taken great pains to prove, but with no small degree of repugnancy to a former hypothesis of his, that the luminous fluid which so often appears in the heavens on a bright night, and shoots streaks athwart them, is diffused light, existing independently of suns or stars, though perhaps originally thrown forth from them; another kind of ethereal matter being sometimes united with that of light, and hence rendering it at times capable of opacity. In this diffused state he calls every distinct mass a nebulosity; he conceives all its particles to be subject to the common laws of gravitation, or the centripetal force; and that certain circumstances, unknown to us, may have occasionally produced a nearer approximation between some particles than between others; whence the diffused nebulosity is, in such part, converted into a denser nucleus, which by its comparative preponderancy, must lay a foundation for a rotatory motion, and attract and determine the circumjacent matter still more closely to itself, and consequently, diminish the extent of the nebulous range.

The nuclei thus arising may sometimes be double or triple, or still more complicated; and whenever this occurs, the nebulosity will be broken into different nebulæ, or smaller nebulous clouds; and if some of them be much minuter than others, the minuter may at length attend upon the larger, as satellites upon a planet: and Dr. Herschel gives instances of all these phenomena actually completed, or in a train of completion, in different parts of the visible heavens.

Such he submits as his latest opinion of the general construction of the heavens; believing stars, planets, and comets to have originated, and to be still originating, from such a source; the nebulous matter contained in a cubical space seen under an angle of ten degrees demanding a condensation of two trillion and two hundred and eight thousand billion times before it can be so concentrated as to constitute a globe of the diameter and density of our sun.

Some of these masses of light are indistinct and barely visible even by Dr. Herschel's forty feet telescope; and he hence calculates, that if a mass thus traced out contain a cluster of five thousand stars, they must be eleven millions of millions of millions of miles off. M. Huygens entertained an analogous idea: and conceived that there are stars so immensely remote, that their light, although travelling at the rate of eleven millions of miles in a minute, and having thus continued to travel from the formation of the earth, or for nearly six thousand years, has not yet reached us.

But this sublime conception is of much earlier origin; and it is due to the magnificence of the Epicurean scheme to state that it is to be found completely developed among its principles. Lucretius has beautifully alluded to it in lines of which I must beg your acceptance of the following feeble translation, the only difference being, that lightning or the electric fluid, is here employed instead of light, at least by Havercamp; for Vossius, in the Leyden edition, gives us *light* for *lightning*, reading *lumina* instead of *fulmina*.

The poet is speaking of the immensity of space:—

The vast whole
What fancied scene can bound? O'er its broad realm,
Immeasur'd, and immeasurably spread,
From age to age resplendent lightnings urge,
In vain, their flight perpetual; distant, still,
And ever distant from the verge of things,
So vast the space or opening space that swells,
Through every part so infinite alike.*

From this immense range of nebulous light Dr. Herschel derives comets, as well as stars and planets, believing them, indeed, to be the rudiments of the two latter; and he has especially noticed, as originating from this source, the well-remembered comet that so brilliantly, and for so long a period of time, visited our horizon during the close of the year 1811; which he conceives will be converted into a stellar or planetary orb as soon as its luminous matter, and especially that of its enormous tail, shall be sufficiently concentrated for this purpose. This tail he calculated, when at its greatest apparent stretch in October of the same year, at something more than a hundred millions of miles long, and nearly fifteen millions broad, though its bright or solid nucleus or planetary body was not supposed to measure more than four hundred and twenty-eight miles. Its perihelion path, or nearest approach to the sun, is stated at a distance of ninety-seven millions of miles, its distance from the earth at ninety-three millions. The comet of 1807 approached the earth within sixty-one millions of miles, or about a third nearer the earth, and that

* Omne quidem vero nihil est quod finiat extra.
Est igitur natura loci, spatiumque profundi,
Quod neque clara suo percurrere fulmina cursu
Perpetuo possint ævi labentia tractu;
Nec prorsum facere, ut restet minus ire, meando
Usque adeo passim patet ingens copia rebus,
Finibus exemptis, in cunctas undique parteis

† De Rer. Nat. i. 1000.

of 1680 within a sixth of its diameter, or as near as 147,000 miles, its tail being of a like length.

There is one comet, however, that we seem to be somewhat better acquainted with than with this that paid us so near a visit, or indeed than with any other, from its having approached us visibly for four times in succession, if not oftener. It was towards the beginning of last century that Mr. Halley was struck with the remark, that the general elements and character of the comets observed in 1531, 1607, and 1682, were nearly the same; whence he concluded that the whole formed but one identical body, that took about seventy-six years to complete its eccentric orbit; and hence, although in consequence of this eccentricity, and its travelling amid a range of heavenly bodies that are altogether invisible to us, and whose influence seems to bid defiance to calculation, it is difficult to form an estimate of its progress, he ventured to suggest, that it would appear again, making due allowances for these incidents, towards the close of 1758, or the commencement of 1759: and he had the high satisfaction of seeing his prediction verified; the comet passing its perihelion March 12th, 1759, within the limits of the errors of which he thought his results susceptible. It is apparently this comet, which at this last period only excited the curiosity of astronomers and mathematicians, that in 1456, or four revolutions earlier, towards the close of what are called the dark ages, spread such consternation over all Europe, already, indeed, terrified by the rapid successes of the Turkish arms, that Pope Calixtus was induced to compose a prayer for the whole western church, in which both the Turks and the comet were included in one sweeping anathema.

Admitting the truth of Dr. Herschel's hypothesis, as we are now contemplating it, it is possible that some of the lately discovered planets, which are now attendant upon the sun, were formerly comets, whose orbits have for ages been growing progressively more regular, as well as their constitutional rudiments more dense; and such, indeed, is the opinion of M. Voigt, and of various other philosophers on the continent.

The object of the present and the preceding lecture has been to submit a sketch of the most obvious properties belonging to MATTER, so as to enable you to obtain a bird's-eye view of the general phenomena it is capable of assuming, and the general changes it is necessarily sustaining. From the qualities I have placed before you, of passivity, cohesibility, divisibility, and attractions of various kinds, must necessarily result, according to the intensity with which they are called into action, the phenomena of liquidity, viscidity, toughness, elasticity, symmetry of arrangement, solidity, strength, and resilience. But the powers which thus perpetually build up the inorganic world, and to this our survey has been entirely confined, perpetually also destroy it: for the whole, as I have had occasion to observe, is a continued circle of action; a circle most wise, most harmonious, most benevolent: and hence as one compound substance decays, another springs up in its place, and can only spring up in consequence of such decay.

There is, however, another lesson, if I mistake not, which we may readily learn from these lectures, however imperfectly delivered, and which is altogether of a moral character: I mean that of humility, in regard to our own opinions and attainments; and of complacency, in regard to those of others. After a revolution of six thousand years, during the whole of which period of time the restless ingenuity of man has been incessantly hunting in pursuit of knowledge, what is there in physical philosophy that is thoroughly and perfectly known even at the present moment? and of the little that is thus known, what is there which has been acquired without the clash of controversy and the warfare of opposing speculations? Truth, indeed,—for ever praised be the great Source of Truth, for so eternal and immutable a decree—has at all times issued, and at all times will issue, from the conflict; but while we behold philosophers of the highest reputation, philosophers equally balanced in the endowment of native genius, proved by the great teacher Time to have been alternately mistaken upon points to which they had hon-

estly directed the whole acumen of their intellect, how absurd, how contemptible is the fond confidence of common life! Yet what, indeed, when fairly estimated by the survey that has now been briefly taken of the sensible universe,—what is the aggregate opinion, or the aggregate importance of the whole human race! We call ourselves lords of the visible creation: nor ought we at any time, with affected abjection, to degrade or despise the high gift of a rational and immortal existence.—Yet, what is the visible creation? by whom peopled? and where are its entrances and outgoings? Turn wherever we will, we are equally confounded and overpowered: the little and the great are alike beyond our comprehension. If we take the microscope, it unfolds to us, as I observed in our last lecture, living beings, probably endowed with as complex and perfect a structure as the whale or the elephant, so minute that a million of millions of them do not occupy a bulk larger than a common grain of sand. If we exchange the microscope for the telescope, we behold man himself reduced to a comparative scale of almost infinitely smaller dimension, fixed to a minute planet that is scarcely perceptible throughout the vast extent of the solar system; while this system itself forms but an insensible point in the multitudinous marshallings of groups of worlds upon groups of worlds, above, below, and on every side of us, that spread through all the immensity of space, and in sublime, though silent harmony, declare the glory of God, and show forth his handy work.

LECTURE VI.

ON GEOLOGY.

THERE are some subjects on which the philosopher is obliged to exercise nearly as much imagination as the poet; for it is the only faculty by which he can expatiate upon them. Such is a great part of the magnificent study upon which we have touched in our preceding lectures. Space, immensity, infinity, pure incorporeal intelligence, matter created out of nothing, innumerable systems of worlds, and innumerable orders of beings;—where is the mind strong enough to grapple with such ideas as these? They at once entice and overwhelm us. Reason copes with them till she is exhausted, and then gives us over to conjecture. Hence, as we have already seen, invention at times takes the place of induction, and the man of wisdom has his dream as well as the man of fancy.

Let us descend from such magnificent flights: let us quit the possible for the actual; and equally incapable of following up the fugitive material of which the visible universe consists, into its elementary principles and collective mass, let us examine it as far as we are able, in the general laws, structure, and phenomena it exhibits in the solid substance of the globe on which we tread.

It is this inquiry that constitutes the science of GEOLOGY, a brief outline of which is intended as a study for the present lecture;—a science than which few are of more importance, but which is only at present in its infancy, and of course almost entirely indebted for its existence to the unwearied assiduity and discoveries of modern times.

The direct object of geology is, to unfold the solid substance of the earth—to discover by what causes its several parts have been either arranged or disorganized—and from what operations have originated the general stratification of its materials, the inequalities of its surface, and the vast variety of bodies that enter into its make.

In pursuing this investigation, many difficulties occur to us. The bare surface, or mere crust of the earth's structure, is the whole we are capable of boring into, or of acquiring a knowledge of, even by the deepest clefts of volcanoes, or the deepest bottoms of different seas. It is not often, however, that we have the power of examining either seas or volcanoes so low as to their bottom. The inhabitable part of the globe bears but a small proportion