Scientific.

ATOMS.

We would be as gods, knowing all things; and the child is father to the man. The boy breaks up his most ingenious toys, to surprise the secrets hidden within; the man dissects, analyzes, probes all nature, to discover the ultimate qualities and causes of everything. It is quite an error to suppose that curiosity is a passion to which the fair sex is peculiarly propense. Tell either man or boy that there is a thing he cannot do, a place he cannot visit, a fact he cannot ascertain, and no rest is his until he has effected the thing, reached the spot, tested the circumstance. From what else should arise the strong attraction which the transmutation of metals, the top of Mount Cervin, the constitution of matter, exercises on multitudes?

Respecting the latter subject of inquiry, modern science has drawn up for itself a creed which is almost as precise as a treatise on arithmetic. Whether future philosophers will modify those notions it remains for a future period to show. There seems at present every probability that we have really hit upon the truth.

Matter is known to us under three forms—solid, liquid, and gaseous. The ethereal modification of matter (the attenuated ether which fills the interplanetary and intersidereal spaces) we do not *know*, but only infer, suppose, and guess at. But, as Professor Tyndall quietly observes, there is no more difficulty in conceiving this *ether*, as it is called, which fills space, than in imagining all space filled with jelly.

All matter, of whatever form, is believed to be made up of atoms. Gases we can easily conceive to consist of independent particles which repel each other; liquids to be made up of minute molecules, behaving, when poured out, like grains of wheat or sand, still held together by a slight attraction; but there is much greater difficulty in granting solid bodies to be collections, groups, or aggregates of atoms not in actual contact with each other.

Solid bodies especially, therefore, have long puzzled people who have considered them with careful attention. They expand, and they contract. How? It must be by the expansion and contraction of their constituent parts. But what are their constituent parts? They cannot be anything else than atoms of inconceivable littleness. According to many philosophers, group atoms together, and you have a molecule; but, in common parlance, atoms and molecules may be regarded as synonymous. Combine molecules in sufficient quantity, and you produce a particle—a portion of matter of form and size appreciable by the human eye.

Matter is similar in its nature, throughout the solar system at least. Spectral analysis has shown that minerals, found on earth, are also contained in the sun and the planets, not to mention diverse and sundry fixed stars. The same fact is proved by the examination of bolides, or shooting stars.

A bolide is a planet in miniature: a small mass of matter, revolving round the sun in a longer or shorter elliptical orbit, obeying the same laws and governed by the same forces as the greater planets. Now, suppose the orbit described by a bolide to cross the orbit of the earth, exactly as one road crosses another; and, moreover, that the two travellers reach the point of junction or crossing at the very same time: A collision is the inevitable consequence. The bolide, which, in respect to size, is no more than a pebble thrown against a railway train, will strike the earth without her inhabitants experiencing, generally, the slightest shock. If individuals happen to be hit, the case will be different. It the earth arrive there a little before or after the bolide, but at a relatively trifling distance, she will attract it, cause it to quit its own orbit, dragging it after her, an obedient slave, to revolve around her until it falls to her surface. Or it may happen that the bolide may pass too far away for the earth to drag it into her clutches, and yet near enough to make it swerve from its course. It may even enter our atmosphere, and yet make its escape. But, in the case of its entering the atmosphere, its friction against the air will cause it to become luminous and hot, perhaps determining an explosion. Such are the meteors whose appearance at enormous heights our newspapers record from time to time.

Be it remarked that bolides are true planets, and not projectiles shot from mountains in the moon, as has been conjectured. A projectile coming from the moon would reach the earth with a velocity of about seven miles per second. But the most sluggish bolide travels at the rate of nearly nineteen miles per second, fast-goers doing their six-and-thirty miles in the same short space of time. None of the inferior planets travel so rapidly as that: Mercury, the swiftest of them all gets over only thirty miles per second. Mr. Tyndall states that this enormous speed is certainly competent to produce the effects ascribed to it.

When a bolide, then, glances sufficiently close to our earth to pass through our atmosphere, the resulting friction makes its surface red hot, and so renders it visible to us. The sudden rise of temperature modifies its structure. The unequal expansion causes it to explode with a report which is audible. If the entire mass does not burst, it at least throws off splinters and fragments. The effect is the same as that produced by pouring boiling water upon glass. The fragments, falling to the ground, are aerolites. It is needless here to cite instances of their falling. They are of universal notoriety. Aerolites have no new substance to offer us. If the earth, therefore, be made up of atoms, we may conclude that the universe is made up of atoms.

In imagining the ultimate composition of a solid body, we have to reconcile two apparently contradictory conditions. It is an assemblage of atoms which do not touch each other—for we are obliged to admit intermolecular spaces—and yet those atoms are held together in clusters by so strong a force of cohesion as to give to the whole the qualities of a solid. This would be the case even with a solid undergoing no change of size or internal constitution. But solids *do* change, under pressure, impact, heat, and cold. Their constituent atoms are, consequently, *not* at rest. Mr. Grove tells us: "Of absolute rest, Nature gives us no evidence. All matter, as far as we can ascertain, is ever in movement, not merely in masses, as with the planetary spheres, but also molecularly, or throughout its most intimate structure. Thus, every alteration of temperature produces a molecular change throughout the whole substance heated or cooled. Slow chemical or electrical action, actions of light or invisible radiant forces, are always at play; so that, as a fact, we cannot predicate of any portion of matter, that it is absolutely at rest."

The atoms, therefore, of which solid bodies consist are supposed to vibrate, to oscillate, or, better, to revolve, like the planets, in more or less eccentric orbits. Suppose a solid body to be represented by a swarm of gnats dancing in the sunshine. Each gnat, or atom, dances up and down, at a certain distance from each other gnat, within a given limited space. The path of the dance is not a mere straight line, but a vertical oval—a true orbit. Suppose, then, that in consequence of greater sun heat, the gnats become more active, and extend each its respective sweep of flight. The swarm, or solid body, as a whole, expands. If, from a chill or the shadow of a cloud, the insect's individual range is less extensive, the crowd of gnats is necessarily denser, and the swarm, in its integrity, contracts.

Tyndall takes for his illustration a bullet revolving at the end of a spiral string. He had spoken of the *vibration* of the molecules of a solid as causing its expansion; but he remarks that, by some, the molecules have been thought to *revolve* round each other; and the communication of heat, by augmenting their centrifugal force, was supposed to push them more widely asunder. So he twirls the weight, at the end of the spring, in the open air. It tends to fly away; the spring stretches to a certain extent; and, as the speed of revolution is augmented, the spring stretches still more, the distance between his hand and the weight being thus increased. The spring rudely figures the force of cohesion, while the ball represents an atom under the influence of heat.

The intellect, he truly says, knows no difference between great and small. It is just as easy, as an intellectual act, to picture a vibrating or revolving atom as to picture a vibrating or revolving cannon ball. These motions, however, are executed within limits too minute, and the moving particles are too small, to be visible. Here the imagination must help us. In the case of solid bodies, you must conceive a power of vibration, within certain limits, to be possessed by the molecules. You must suppose them oscillating to and fro; the greater the amount of heat we impart to the body, the more rapid will be the molecular vibration, and the wider the amplitude of atomic oscillations.

It is held that all matter differs only in the grouping of its elements—in the juxtaposition of its molecules. That juxtaposition depends on the temperature, and the speed with which changes of temperature have taken place. The mode and manner of those changes are so many causes of the transformation of matter—so many origins of divers substances. It is maintained that, in the actual state of science, bodies differ only by the clustering of their atoms, exactly as the constellations of the sky differ through the arrangement of their stars.

Take a bird's-eye view, from the car of a balloon, of four or five towns, at a considerable altitude. They will differ but very slightly in aspect; they are simply towns. From a point of view nearer to the earth, their distinctive characters will be visible; showing themselves in the disposition of the houses, the topography of the streets, and the distribution of the public walks. Such is the case with a mineral or any other substance whatever. Accordingly, as natural forces have laid out, on this or that plan, the walks, streets, and houses of our little molecular cities, they strike you with a different impression. The one depends on the will of the architect, the other on the action of the predominant force.

Wax, for instance, is cited by our great lecturer as *expanding*, in passing from the solid to the liquid state. To assume the liquid form, its particles must be pushed more widely apart, a certain play between them being necessary to the condition of liquidity. Ice, on the contrary, on liquefying, *contracts*. In the arrangement of its atoms to form a solid, more room is required than those atoms need in the neighbourhood. No doubt this is due to crystalline arrangement. The attracting poles of the molecules are so situated, that, when the crystallizing force comes into play, the molecules unite, so as to leave larger interatomic spaces in the mass. We may suppose them to attach themselves by their corners; and, in turning corner to corner, to cause a recession of the atomic centres. At all events, their centres retreat from each other when solidification sets in.

The atoms of bodies must be regarded as all but infinitely small; the necessary consequence of which is, that they must be all but infinitely numerous. A learned Frenchman, Monsieur A. Gaudin, calculator at the Bureau des Longitudes, has lately estimated, by a very ingenious process, the distances which separate molecules and their component atoms, and their number. The result he obtains is, that, if you set about counting the atoms contained in a little cube of solid matter two millimetres high, that is, about the size of a pin's head, and that you counted *a billion of them per second*, it would take you about two hundred and fifty thousand years to complete the task! Consequently, although the increase of the diameter of a revolving atom's orbit by the communication of heat is insensible, the sum of an almost infinite number of increased orbits becomes perfectly sensible.

Comparing the infinitely small with the infinitely great, it is held that a body, of what kind soever, represents in miniature, and very exactly, an astronomical system, like those which, weather permitting, we behold every night in the firmament.

Astronomers are perfectly aware that the earth is only a molecule amidst the innumerable stars which constitute the Milky Way. But a body never mind what—take wood, gold, or diamond, to have a clear idea—is nothing more than a heap of molecular constellations diversely grouped. From the extreme of vastness to the extreme of minuteness, the analysis holds good throughout. Although our eye is not framed to perceive all their details, these infinitely small stars and systems of stars, other creatures, as for example insects, whose vision is differently constituted to ours, may possibly—although not probably—be able to see some of them.

One thing, however, appears certain; if we could construct a microscope of sufficient power, we should be able, by the help of such an instrument, to resolve the molecular constellations of every little terrestrial milky way, exactly as our first-rate telescopes resolve the celestial nebulæ and separate double and triple stars. It is a mere question of visual power. Were our sight sufficiently penetrating, we should behold what now appear mere confused heaps of matter, arranged in groups of admirable symmetry. Bodies would appear honeycombed in all directions. Daylight would stream through vast interstices, as it does between the columns of a temple or the tree-trunks of a forest. Nay, we should see immense empty spaces, like those which intervene between the planets.

From distance to distance, too, we should perceive clusters of stars in harmonious order, each surrounded by its own proper atmosphere; and—still more astounding spectacle!—every one of these little molecular stars would be found revolving with giddy rapidity, in more or less elongated ovals, exactly like the great stars of heaven; while by increasing the power of our instrument, we should discover around each principal star, minor stars—satellites resembling our moon—accomplishing their revolutions swiftly and regularly. This view of the constitution of matter is aptly described by M. de Parville as molecular astronomy, maintaining even that astronomy, without our suspecting it, is dependent on mineralogy; and that whenever we shall have discovered the laws which govern the groupings and the movements of the infinitely small, astronomers will have only to follow in our track. But who, a hundred years ago, could dare to imagine that the infinitely small was so infinitely great? What is now believed to be the nearest guess at the truth, appears, at first sight, to be the dream of a madman.

Those who love to indulge in paradox now state that their theory is very simple. For them, the solar system is a solid particle, homogeneous. The planets composing it are molecules which virtually crowd each other, touch, and adhere. The space between them is no more than the interval which separates the atoms of the compactest metal—silver, iron, or platina! Distance, therefore, it is argued, is an empty word; distance, in fact, does not exist. Nevertheless, a man may convince himself that distance, for him, is *not* an empty word, by jumping out of a first-floor window.

The wonder is, that these molecular motions, so rapid as to escape human observation, are yet able to impress human senses, to give us pain or pleasure, to help us to live or to cause us to die. And unseizable as atoms are, they can, nevertheless, be counted and weighed. Chemists have determined the relative weights of the atoms of different substances. Calling the weight of a hydrogen atom one, the weight of an oxygen atom is sixteen. Hence, to make up a pound weight of hydrogen, sixteen times the number of atoms contained in a pound of oxygen would be necessary.

What a strange result of the study of atoms! Heat and light, whose origin was inscrutable, or attributed to some mysterious hypothetical fluid, are now traced to their causes. The reader has already been informed that the heat of the sun is attributed to the collision he sustains from a never-ceasing shower of meteors. The heat of terrestrial fire is similarly produced. All cases of combustion, Tyndall tells us, are to be ascribed to the collision of atoms which have been urged together by their mutual attractions. It is to the clashing together of the oxygen of the air and the constituents of our gas and candles that the light and heat of our flames are due. It is the impact of the atoms of oxygen against the atoms of sulphur, which produces the heat and flame observed when sulphur is burned in oxygen or in air. To the collision of the same atoms against phosphorus are due the intense heat and dazzling light which result from the combustion of phosphorus in oxygen gas. Whether atoms are concerned, or suns and planets, the theory is equally applicable and true.

When interatomic movements occur under given conditions of mass and velocity, they make an impression on the eye. Their undulations, communicated from one to the other, strike the retina, and in turn set vibrating the atoms of which it is composed. We see; we receive the impression of light. And accordingly as the vibrations occur with certain proportional rapidities, they give us the sense of blue, yellow, red, and the other *visible* tints of the rainbow, because there are certainly other tints which are not visible to the human eye, exactly as there are sounds not audible to the human ear. Atoms and their motions are therefore the physical cause of color. Wonderful as it must appear, the length of the waves both of sound and light, and the number of shocks which they respectively impart to the ear and eye, have been strictly determined. The number of waves of red light *which enter the eye in a single second* is 474,439,680,000,000. To produce the impression of red in the brain, the retina must be hit at this almost incredible rate. To produce the impression of violet, a still greater number of impulses is necessary, amounting to six hundred and ninety-one millions of millions per second.

Thus a thing, an entity, several billions of which can be contained within the point of a needle, is able to give the cattle disease, hydrophobia, or the plague; or to gratify you with the perfume of a rose, the flavor of a peach, the warmth of sunshine, the delights of music. Are atoms, then, to be despised and disregarded, being components of ourselves and of everything around us?

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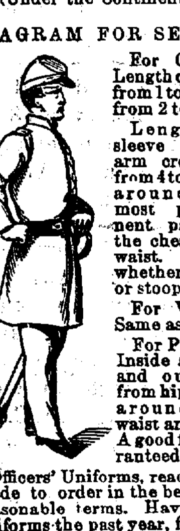

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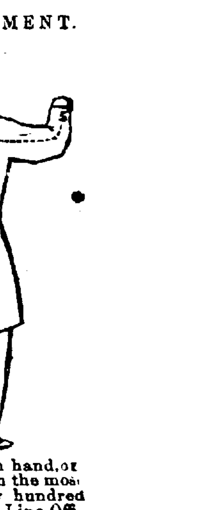

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